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PART ONE

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International Handbook of Information Technology in Primary and Secondary Education

Part One

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PREFACE

Since the introduction of the computer into education in the 1960s its potential for primary and secondary education has been recognized by many – researchers, policymakers and practitioners. In the International Handbook of Information Technology in Primary and Secondary Education we seek to provide researchers, policymakers and practitioners with an integrated overview of the field.

There is a vast amount of research on Information Technology (IT) in primary and secondary education. In this Handbook we aim to synthesize this research from a broad international perspective. The Handbook has 76 chapters to which 136 authors have contributed. The authors are from 23 different countries spanning five continents.

Consensus on the focus and structure of the Handbook was reached among 15 section editors and the external advisors during a joint meeting at the headquarters of the United Nations Educational Scientific and Cultural Organization (UNESCO) in Paris. The two main themes addressed in the Handbook were determined to be (1) the potential of IT to improve primary and secondary education, and (2) the support that is required to successfully implement IT in educational practice. These two themes are addressed in the 11 sections of the Handbook. Each section addresses the relevant theme(s) from a specific point-of-view.

For each section the editors summarize 5–6 chapters in a two-page overview and introduce their topic in an introductory chapter. In a parallel fashion, in the introductory chapter to this Handbook, the editors-in-chief discuss how the terminology used in the field evolved, explain the focus and structure of the Handbook and discuss intriguing trends that emerged across sections.

The editors-in-chief express their gratitude to the section editors and the authors for their valuable and interesting contributions to the Handbook. External advisors, Prof. Dr. Tjeerd Plomp (the Netherlands), Prof. Dr. Takashi Sakamoto (Japan) and Dr. Fred Litto (Brasil), contributed to the Handbook from the initial stages and helped strengthen the Handbook through critical, but constructive feedback. We particularly thank each of them for their wisdom and support throughout the process.

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IT IN PRIMARY AND SECONDARY EDUCATION: EMERGING ISSUES

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Introduction

This chapter introduces the main themes addressed in the International Handbook of Information Technology in Primary and Secondary Education. The challenges of information technology (IT) for education have been studied for about 40 years. Due to rapid technological developments the field is continuously changing in intriguing ways. There is a vast amount of research on IT in primary and secondary education, yet most of it is scattered, and a synthesis of the research from a broad international perspective has not yet been achieved. This Handbook aims to provide an overview of major directions of research in the field for researchers, policymakers and practitioners.

Since the beginning of research in this domain the implementation of the potential of IT in educational practice has been a recurring theme. In this Handbook the potential of IT, as well as its implementation in educational practice, is being examined from several perspectives. In this introductory chapter we first address the evolving terminology used in the field. Then we present the focus of the Handbook and finally we discuss common issues emerging across sections.

Evolving Terminology on Computer Use in Education

Since the introduction of the computer into education in the 1960s its potential for primary and secondary education has been recognized by many – researchers, policymakers and practitioners. The development of computer technology from processing information to also supporting communication augmented its potential for education. Owing to the enormous impact of these technologies, our society is in transition towards an information or knowledge society (e.g. Anderson, 2008). The term computer technology has been replaced by information and communication technology (ICT) (mostly used in Europe) or information technology (IT) or technology (in North America). Information and communication technology refers to all technologies used for processing information and communicating. Because of the integration of computers with communication systems, including audio and video technology, also terms such as multimedia or digital media are being used (Anderson, 2008).

It is generally accepted (Lai, 2008) that IT as such does not support learning. Only when IT is well integrated into a learning environment does the full potential of IT for learning become realized. In the early days of computer use in education these "learning environments" were narrowly defined and referred to the computer software that supports certain types of learning. The term computer-assisted instruction (CAI) was adopted, indicating either a type of software programme for education or a type of instructional process. Steinberg (1991), for example, emphasized CAI as computer-presented instruction that is individualized, interactive and guided.

CAI fits well in a behaviourist approach to education, where students have to learn facts, concepts and theories and be able to apply and illustrate concepts and acquire basic procedural skills (Dede, 2008). CAI was conceptualized as an assistant for teachers by taking over some of their tasks. CAI software has the capacity to provide feedback to the learners and to keep track of their performance. A major benefit of software for education in this category is that it became possible to individualize instruction. The first CAI programmes were introduced in education when large main frame computers were still in use. With the introduction of the personal computer (PC) in the early 1980s in schools (in North America and Western Europe) expectations of CAI to improve teaching and learning were high. The introduction of the PC in schools also triggered the development of a much broader use of IT in education. As a consequence, also other terms in addition to CAI evolved, such as computer-based instruction, computer-based education and computer-assisted learning. These terms were sometimes used in ways similar to CAI, but often also reflected a broader conceptualization of different kinds of computer use in education. Watson (1994), for instance, used the term computer-assisted learning for the whole variety of ways in which the computer is used in education.

The rather confusing terminology is partly due to rapid technological changes. By the twenty-first century, computer technology has become mobile, personal and networked; stand alone desktop PCs are being replaced by laptops, personal digital assistants or mobile phones. These developments also triggered the evolution of new terms, to indicate the use of computers – or more generally Information Technology (IT) – in education.

More recently, new terms evolved to indicate computer use in education, such as E-learning (electronic learning), M-learning (mobile learning), Web-based education or learning, multimedia learning and ubiquitous learning. The term E-learning is used for learning that is facilitated or delivered through the use of computer or communications technologies, Internet, CD-ROM and/or television. Similar to E-learning, the term M-learning emphasizes the facilitation of learning through the use of mobile computer technology, such as mobile phones, personal digital assistants and laptops. If the World Wide Web in particular is used to deliver instruction also the term Web-based instruction or Web-based education or learning is also used. The term multimedia learning is often used when a mix of audio and video technologies is integrated in the learning environment. The most recent term that is emerging for computer use in education is ubiquitous learning. Ubiquitous learning comes from ubiquitous computing, the ever-presence of computer technology in the environment. Ubiquitous learning refers to the potential of computer technology to make learning possible at any time and at any place. These more recent terms refer to broader conceptualizations of computer uses in education.

IT not only has the potential to enhance teaching and learning processes, it may also change the concept of education. Education is no longer limited to taking place in one physical environment at a certain time during the day. Rather, education can become available at any time and at any place. In this introductory chapter we will use the term information technology. However, based on the backgrounds of the scholars in this Handbook, as well as their perspectives on IT in education, the various terms, briefly introduced here, can be found throughout the Handbook.

Focus of the Handbook

Ten Brummelhuis and Kuiper (2008) in this Handbook distinguish four key elements that affect learning processes directly: the learner, the teacher, the curriculum and the infrastructure. Learners and teachers are the key players in the learning process. The curriculum determines the content and focus of the learning process, and the infrastructure deals with the physical (and/or virtual) learning environment, including the learning materials. Teaching and learning processes take place within an immediate social environment and simultaneously within a wider social context. The school, as the immediate environment, provides the organizational structure for the learning process. In the wider social context, the society, perspectives on education are discussed and educational policies are being developed and implemented, which affect how teaching and learning take place and are organized. Figure 1 presents a graphical representation

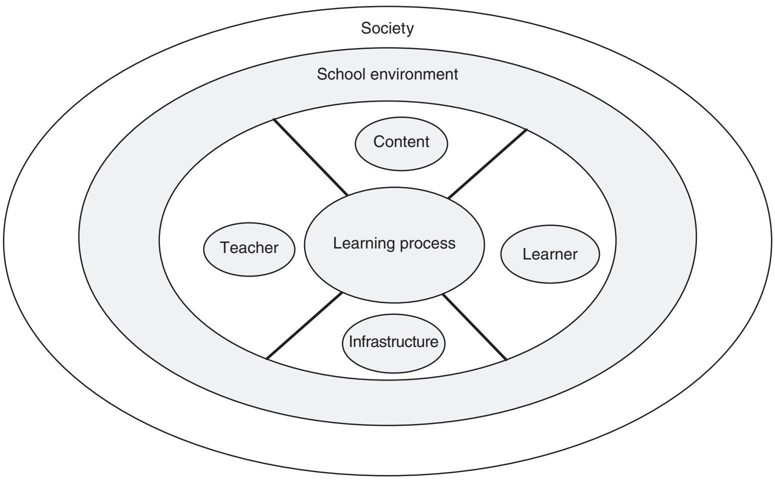

Fig. 1 The learning process: key elements and influencing factors (adapted from Plomp, Ten Brummelhuis and Rapmund, 1996; Voogt and Odenthal, 1997)

of the key elements, as well as the influencing factors affecting the learning process. This figure serves as a conceptual framework to discuss the focus of this Handbook.

The Potential of IT to Improve Education

The first theme of this Handbook addresses the *potential* of IT to improve education. Often two main perspectives are distinguished for IT in primary and secondary education: IT as an object in education, affecting learning content and goals, and IT as a medium to enhance teaching and learning processes (see also Voogt, 2008). The first view affects the curriculum, while the second role primarily affects the physical (and virtual) infrastructure for learning. From the perspective of IT as an object, improving primary and secondary education focuses on how learning content and goals should be attuned to the needs of society. From the perspective of IT as a medium, improving primary and secondary education concentrates on facilitating teaching and learning with IT. Although these perspectives can be distinguished separately, in research and policy debates they are often intertwined.

Within this first theme we aim to synthesize research on the design and impact of IT-based environments for student learning. Much research being carried out in this domain is especially focused on how to design IT-rich learning environments. These environments are based on up-to-date knowledge of fostering learning processes. In the Handbook we address this line of research in Section 3 (IT and the learning process), Section 7 (IT and distance learning in K-12 education) and Section 9 (Emerging technologies for education).

In Section 3 (IT and the learning process), research on some major educational software applications is presented and synthesized from the perspective of how these applications contribute to interactive learning, collaborative learning, inquiry learning and meta-cognitive learning.

Since the use of communication technologies became widespread, education has been attracted by the potential of IT to go beyond classroom walls. In Section 7 (IT and distance learning in K-12 education) the potential of IT for distance learning in primary and secondary education has been explored with particular attention paid to the virtual high school (or open school), the global classroom and the potential of distance learning for teachers.

Technology increasingly becomes part of our daily life. Section 9 (Emerging technologies for education) explores the potential of ubiquitous computing environments. Particularly, mobile technologies and Web 2.0 environments appear to have the potential to enhance education. Issues related to the design of learning environments using these emerging technologies are also addressed.

Infrastructure and Support Required to Implement IT in Education

The second theme addressed in this Handbook focuses on the *support* that needs to be in place to successfully *implement* IT into daily practices in primary and secondary education. This theme deals with the barriers and opportunities for IT implementation. As shown in Figure 1, factors at several levels may affect how IT is being used in learning processes. First, IT use is being influenced by the perceptions, attitudes and competencies of teachers and learners as the key players in the learning process. Curriculum content and goals may also affect how IT is used, and the available infrastructure either provides opportunities or restricts IT use in educational practice. In the immediate environment school leadership as well the way a school is organized may promote or hinder IT implementation. At the local, state or national level IT-in-education policies guide the way IT is used in teaching and learning.

In this Handbook research, on the implementation of IT in primary and secondary education is discussed from several perspectives. First the perspectives of the learner and the teacher are addressed in Section 4 (IT attitudes and competencies) and Section 5 (Pedagogical innovations, and teacher learning). The curriculum perspective is addressed in Section 2 (IT and curriculum processes), while in Section 6 (IT in schools) research on IT leadership in schools is presented. The influence of educational policy as the wider environment of teaching and learning processes is discussed in Section 8 (IT and the digital divide) and Section 11 (International and regional programmes and policies).

Since the early days of IT use in education, attitudes towards computers and IT competencies of learners (and later teachers and school leaders) have been in the domain of interest of researchers and practitioners, because they appeared to be an important factor in the decision to use IT in educational practice. Section 4 (IT attitudes and competencies) describes research in this domain. Utilizing the potential of IT in educational practice often implies that the role of the teacher has to change. The teacher not only has to learn IT basic knowledge and skills, but more importantly, has to learn appropriate pedagogical skills to be able to integrate IT in a sound way into educational practice. Section 5 (Pedagogical innovations, and teacher learning) addresses the implications of the use of IT in educational practice for the teacher and for teacher professional development.

The intentions for use of IT in the curriculum have not always been realized. Section 2 (IT and curriculum processes) discusses how IT might influence content, aims, organization and assessment of the curriculum. The section discusses these implications of IT in specific domains, and in cross-curricular settings.

An important condition for successful use of IT in schools is the support of school leadership in the implementation of IT. Section 6 (IT in schools) discusses IT leadership in schools and the activities that IT leaders could carry out to facilitate IT integration schoolwide.

Educational policy may also contribute to the implementation of IT in education. In Section 11 (International and regional programmes and policies) international and regional policies for IT in education are analysed, with the intention of identifying the contributions of particular policies to optimizing the impact of IT in education. From a global policy perspective the gap between those who have access to IT and those who have not, often referred to as the “digital divide”, is a growing concern. Strategies for realizing digital equity are addressed in Section 8 (IT and the digital divide).

A few additional topics are addressed in the Handbook. First of all the role of education in the information society is addressed (Section 1, Education in the information society). This section offers a rationale for the other sections. Particularly, attention is paid to new generic competencies that are needed for citizens to be prepared for the information and knowledge society, the role IT could play to acquire those competencies and how these new competencies affect curriculum and teaching and learning processes. Finally, in Section 10 (Researching IT in education) various aims for researching IT in education and the opportunities and limitations of several research approaches are discussed.

In the remaining part of this introduction chapter we briefly address major themes that emerged across the different sections of the Handbook.

Emerging Issues Across Sections

Different Views on the Role of IT in Education

The potential of IT to improve primary and secondary education can be discussed from several – sometimes competing – perspectives. In this Handbook two major rationales for the integration of IT can be found. First is the generally accepted belief that the society is changing from an industrial towards an information or knowledge society. This change implies that students need to be prepared for jobs that might not yet exist. Being able to use IT is seen as one of the core competencies for the twenty-first century. Anderson (2008) and Mioduser, Nachmias and Forkosh-Baruch (2008) elaborate on twenty-first century competencies. The second rationale is the belief that IT has the potential to enhance teaching and learning processes. Dede (2008) in this Handbook shows that IT applications have been developed on many different theories of learning. Although it is believed that IT applications particularly have great potential to facilitate the realization of constructivist approaches to teaching and learning, Dede argues that for some learning tasks simple CAI can be very effective.

Ten Brummelhuis and Kuiper (2008) offer a slightly different perspective. They distinguish between two instructional paradigms driving the integration of IT in education: the belief that IT has the potential to change education (see, for instance, Sections 7 and 9) vs. the belief that IT may contribute to addressing educational needs. Ten Brummelhuis and Kuiper position these two perspectives as opposing each other. For the belief that IT is considered a catalyst for educational change they use the term "technology push". For the belief that IT has to follow educational needs they introduce the term "educational pull". Table 1 is an effort to summarize what these different perspectives imply for the focus of technology use in education, as well as the kind of technology used.

Studying the Impact of IT on Student Learning

The ever-changing technology environment makes effective research into IT in education difficult, complex and challenging. This is particularly true for studying the impact for IT on student learning (Cox, 2008). The high expectations about the potential of IT for student learning could not easily be confirmed by convincing evidence

Table 1 Perspectives for technology use in education

	Information society	Enhancing teaching and learning processes
Technology push		
Focus	Creation of learning environments to encourage flexible learning	Enhancing existing (behaviourist/cognitivist) teaching and learning practices
Examples of IT applications	Content management systems, online learning environments, virtual high schools, mobile technologies	Commercially available IT-enhanced curriculum materials (e-books, websites added to textbooks)
Educational pull		
Focus	The use of technology to master twenty-first-century skills	Enhancing in-depth learning; in constructivist learning environments
Examples of IT applications	General application software; GPS systems, Internet; e-mail	Specific IT applications for education (simulations, games), knowledge-sharing environments, augmented reality

from research. Problems related to studying the impact of IT on student learning can be summarized as follows.

The kind of student outcomes. Initially it was expected that IT could enhance student achievement in traditional learning goals, as could be established by standardized tests. However, many IT applications also aimed at contributing to conceptual understanding of difficult concepts and the mastery of higher order cognitive skills such as problem-solving, which are different from traditional learning goals and could not easily be determined with standardized achievement tests. In addition, room was asked to pay attention in primary and secondary education to twenty-first century competencies next to traditional learning goals.

New indicators are needed. From the perspective of policymakers, higher scores on standardized tests attributed to the use of IT are a relatively easy and reliable way of determining the success of IT in education. However, more sophisticated IT applications contribute to other learning goals. From this perspective, standardized tests are not always a valid measure of the impact of IT on student learning. Small-scale studies about the impact of specific IT applications have developed their own tests and assessments for determining effects, but those findings could hardly be generalized. Increasingly, evidence about the impact of IT on student performance in the so-called twenty-first-century competencies becomes available in the form of self-report data. Although these data are considered an important source of information, they are not accepted as clear evidence of student performance. To be able to study the effect of IT on performance in more complex cognitive skills, efforts are needed in the development of "standardized" performance assessments.

Nature of research. To study the impact of IT on student learning is not an easy job. Experimental (or quasi-experimental) research designs are appropriate for studying the potential of specific IT applications under controlled conditions. However, it is not easy to transfer findings from experimental research designs to the reality of the classroom. Other research designs and methodologies are needed to take into account the complexity of the classroom, such as mixed methods approaches and design research. In addition, studies researching the impact of IT on student learning also require a careful specification of the IT application involved. In many large-scale studies IT is used as a container concept, which in reality consists of many different IT applications.

Despite the complex nature of studying the impact of IT in education, evidence on the impact of IT on student learning is slowly growing. Several contributions in the Handbook report about the major findings so far. Liao and Hao (2008) provide a comprehensive overview of findings from meta-analysis carried out between 1986 and 2006 in which they reviewed studies that compared IT-enhanced instruction and IT-enhanced distance education with traditional classroom instruction. The overall effect sizes on cognitive achievement, not taking into account specific IT application(s), domains or target groups, appeared small but in favor of computer use in education. A more detailed analysis of studies included in their review showed that IT-enhanced instruction has positive effects on achievement of language-disordered and cognitively disabled students. Liao and Hao also found that IT-enhanced instruction designed by research groups have greater effects on student achievement than commercial IT products.

Results on student achievement are reported for language arts, mathematics, science and twenty-first-century skills. Most convincing evidence for the effects of IT is related to student learning in Language arts (see also Voogt, 2008). The evidence with regard to student learning in math and science education seems less convincing (Voogt, 2008; Webb, 2008). Research focusing on student learning of twenty-first-century skills is scarce, and partly based on self-report measures. However, results so far indicate that more research is needed to be able to better understand how specific IT applications contribute to student achievement in these domains.

IT as Core or Complementary Technology

Collis and Moonen (2001) introduced the terms core and complementary technology. For IT to become a core technology the major activities of the teaching and learning process need to be based on it. To date, this particularly seemed to be realized in online learning contexts, but not in the dominant way of schooling in classrooms around the world. Complementary technologies in schools are often more specific than IT applications that offer a technology-based solution for a pedagogical problem. Collis and Moonen argue that IT can only become successfully integrated when IT has become a core technology for education, comparable to what the blackboard and the text book used to be. The use of complementary technologies in education is strongly connected to pedagogical approaches adopted (see also Dede, 2008); that is why, according to Moonen (2008), it is much easier to have policies for IT integration accepted for core technologies than for complementary technologies.

IT as Core Technology: The Success of the Virtual High School

Since the use of communication technologies has become widespread, education has been attracted by the potential of IT to go beyond classroom walls to provide learning opportunities at any time and at any place. A relatively new phenomenon in secondary education is the virtual high school or open school. Contrary to the relatively pessimistic views about the time needed to transform education and the role of IT in such transformation (e.g. Moonen, 2008; Voogt, 2008), the rapid increase of virtual high schools, particularly in the USA, is a success story in the history of IT in education (Roblyer, 2008). The goal of the virtual high school is to contribute to digital equity by providing learning possibilities for those in remote areas. Research has shown that the most successful students in the virtual high school in the USA are those who most capable of regulating their own learning. These students are successful in any learning environment. The discussion remains whether education in the virtual high school also will transform pedagogical practices. Some researchers (Nikolov and Nikolova, 2008; Butcher and Wilson-Strydom, 2008) argue that virtual schooling might consolidate behaviourist approaches to teaching and learning. Roblyer (2008), on the contrary, foresees a change because the virtual high school provides learning opportunities at any time and at any place.

IT as Complementary Technology: IT-Supported Learning Environments

To realize the potential of IT for learning, IT needs to be well embedded in a learning environment. The term "learning environment" is no longer narrowly defined, as in the early days of CAI, but covers a broader concept. It comprises people (teacher, students), technology, materials, classroom layout (or the virtual classroom) and the environment (Lai, 2008). In the domain of IT-supported learning environments, some environments have been well designed and studied for more than 15 years. Knowledge Forum (Scardamalia and Bereiter, 2003) is a well-known example of an IT-supported learning environment in which students are supported in knowledge creation in many domains. The work of Linn and colleagues (e.g. Linn, Clark and Slotta, 2003) in the domain of science education (e.g. The Web-Integrated Science Environment) focuses on concept learning through inquiry and collaboration. Both examples provide an infrastructure for collaboration between students and between students and their teacher and provide a variety of scaffolds to facilitate collaboration (Arvaja, Häkkinen and Kankarantaara, 2008), knowledge building (Chan and van Aalst, 2008) and meta-cognition (Lin and Sullivan, 2008). These are typical examples of complementary technology. The design and research of these "classics" demonstrate the added values of IT for enhancing teaching and learning processes, and also contributed to a better understanding of teaching and learning. It is unfortunate that despite their long history, they have only found their way to a very limited number of innovative teachers and did not become part of main stream education.

Core and Complementary Technology: Best Practices on IT Use

In comparison to the well-designed and researched IT-supported learning environments described earlier, schools and teachers themselves develop educational practices in which they make use of IT.

Increasingly, these educational practices are studied as innovative or best practices. Many best practice studies on IT use in primary and secondary education have been conducted with the aim of understanding the practice and its implementation conditions. In this Handbook several authors (see e.g. Voogt, 2008; Nachmias, Mioduser and Forkosh-Baruch, 2008) refer to the Second Information Technology in Education Studies (SITES) as a worldwide series of studies (Pelgrum and Anderson, 1999; Kozma, 2003; Law, Pelgrum and Plomp, 2008), paying attention to innovative pedagogical use of IT in education. The SITES studies indicate that increasingly schools and teachers use the basic possibilities of IT in innovative pedagogical contexts to be able to pay attention to the so-called twenty-first-century competencies. Compared to the classics described earlier, these examples do not exploit the full potential of IT. Instead they make particular use of the basic features of technology: communication and information handling. The use of IT in these best practices can often be typified as core (e.g. used as major information resource) and complementary (addressing pedagogical needs) educational resources.

Teacher Learning and IT Leadership

It is widely recognized that using IT for education also implies that teacher's pedagogical practices need to change. Teacher learning, in preservice and inservice settings, is needed to support teachers in changing their pedagogical approach and to learn how IT can be used to facilitate the new pedagogical approach. Research from Knezek and Christensen (2008) has shown that teachers' use of IT is affected by will (attitudes towards IT), skill (IT competencies) and access to IT tools. Teacher IT competency is not limited to basic IT knowledge and skills. A competent teacher is able to blend subject matter knowledge with appropriate pedagogy and IT knowledge and skills. The term technological pedagogical content knowledge (TPCK) (Hinostroza, Labbé, López and Post, 2008; Law, 2008) is used to emphasize the interaction between these three domains. To guide teacher learning in IT integration, standards for teachers (e.g. Thomas and Knezek, 2008), as well as benchmarks for teacher education programmes (Kirschner, Wubbels and Brekelmans, 2008), have been formulated. Law (2008) argues that TPCK is not enough for IT integration, but that teachers' disposition towards educational change is also important.

It is not only teachers who need to adopt IT and integrate it into a new pedagogical approach. Rather, organizational structures and contexts need to be in place to allow teachers to apply new pedagogical approaches. Davis (2008) argues that a shared school perspective on the integration of IT is needed in order to allow teachers to integrate IT in their educational practice. The importance of IT leadership is recognized by many. IT leadership needs to focus on vision building for IT integration, providing facilities for teachers to develop a vision on why and how to integrate IT into education, and in organizing support. According to Dexter (2008), a team approach is needed to arrange for IT leadership in schools. Riel and Becker (2008) argue that leadership should be a focus of attention in the preparation of every teacher. IT leadership from this perspective is not only an organizational issue, but also a challenge for the individual teacher. According to Riel and Becker, schools need to develop forms of distributed expertise of teacher leadership to be able to cope with the integration that technology requires.

Towards Digital Equity in IT for Education: The Potential of One-to-One Access

In less than a decade (between 1997 and 2006), the access to computers in schools has improved markedly (Law, Pelgrum and Plomp, 2008). The findings from PISA 2003 (Ainley, Enger and Searle, 2008) also show that the majority of students across countries participating in the PISA study have access to a computer at school, and a slightly smaller percentage of these students have access to computer at home. Hence, in developed countries access to IT does not seem to be an issue in discussions about computer uses in education. However, general figures about access to computers are only partially informative with respect to how computers are used in educational practice. As Ainley, Enger and Searle (2008) make clear, contexts for IT access and use differ among countries. Norris and Soloway (2008) argue that, despite the improved IT infrastructure, computers are still scarce resources. They show that even in many US classrooms teachers have limited access to computer laboratories or have only very few computers available in their classrooms. In such circumstances, one may not expect teachers to integrate IT into teaching and learning activities. Norris and Soloway (2008) argue that to make use of the full potential of technology in education, one-to-one access to technology is a condition sine qua non. The rapid development of low-cost mobile computing devices makes it possible that one-to-one access can indeed be realized in education.

The emergence of low-cost mobile computing devices also contributes to access to technology on a global scale. With the widespread use of cell phones throughout the world (Brown, 2008), as well as initiatives such as the One Laptop per Child Project (OLPC) from MIT, there is a real possibility that access will no longer be a problem for countries with fewer resources (Norris and Soloway, 2008). Although important, increased access to hardware and connectivity is only one of the strategies needed to increase digital equity. Resta and Laferrière (2008) propose five strategies that contribute to digital equity: (1) access to hardware, software and connectivity; (2) provision of content in local languages; (3) qualified educators; (4) quality research to enhance learning with IT and (5) access to content creation. Particularly, the availability of content in local languages and access to content creation seem to be of paramount importance to strengthen designated groups with technology. The importance of content is described by Roy Chen, Cherian and Tuiono (2008), who show how IT can be used to document cultural and historical artefacts of native Americans. In this way, IT may even strengthen minority groups in their struggle to survive within the majority society.

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Section 1

EDUCATION IN THE INFORMATION SOCIETY

1

EDUCATION IN THE INFORMATION SOCIETY

Ronald E. Anderson
Section Editor

For several decades, information society and knowledge society concepts have been discussed in the context of teaching and learning. Many official projects and policy documents from the school level up to the cross-national level have addressed the implications of these concepts for education. The principle implications relate to the changes wrought by harnessing information technology (IT) to improve and advance learning.

Information society concerns for education are discussed in other frameworks. For example, the many "twenty-first century skills" initiatives for the past 10 years have really been driven by what educators understand to be the implication of the information economy for curriculum, teaching and learning.

The field and practice of IT in education are moving very rapidly around the globe. Plomp et al. (2003) offer summaries of policies and practices of IT in education in well over 30 countries. And while each country has unique features, it is striking how similar the pattern of development of the field continues around the world. Globalized communication in the age of the information and knowledge economies works to bring common elements into otherwise diverse educational systems.

Information and knowledge processes are largely social (Brown and Duguid, 2000), which implies that education must consider this in effective harnessing IT in teaching. In fact, recent trends in K-12 education reveal a heavy emphasis upon collaborative problem solving and computer-supported cooperative learning (CSCL) more generally. Stahl (2006) has been exemplary in describing the theory and research in this direction.

Information (and knowledge) society notions are most importantly a set of perspectives for rethinking education in general. That potential is illustrated in this section, in which chapters are represented on theory as well as research and practice.

Chapter 1.1 defines key concepts and other background material, particularly as it relates to the role of information and knowledge in IT. The emphasis is on the relevance of these concepts to IT or ICT in education. The concepts include information, knowledge, knowledge societies, tacit knowledge, knowledge management,

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constructivism, twenty-first century skills, literacies, informatics, mindtools, collaborative learning, and communities of practice.

Mioduser and associates in Chapter 1.2 ask what it means to be literate in the age of knowledge and technology. They answer the question with a description and discussion of seven “literacies for the knowledge society.” The reader cannot help but come away with a more thorough appreciation of the many different ways that effective literacy demands effective technology.

Dede in Chapter 1.3 focuses on theory, but provides a unique perspective on how not only does IT shape education, but also forms of pedagogy shape technologies. He categorizes relevant theories as behaviorism, cognitivism, and constructivism, and then shows how these conceptual starting points both constrict and elucidate opportunities in teaching and learning.

Chapter 1.4 presents data from PISA 2003 and other sources to show how the typical, contemporary student already uses the Internet regularly to conduct research as well as engage in learning. For instance, students may be more likely to do technology-based information searches and knowledge building at home rather than at school because of limited access at school and because their teachers may lack the IT skills to help them in these endeavors. In addition to giving us data some 19 countries around the globe, the chapter makes a case for emphasizing advanced instructional methods such as simulations.

Chapter 1.5 contrasts traditional applications in IT and education such as computer-managed instruction (CMI) with emerging applications, such as inquiry learning, project-based learning, and modeling. Tool-oriented software such as word processors, spreadsheets, and databases can be used in a traditional sense in the spirit of computer-literacy instruction or in a more emergent way in that the emphasis is not upon teaching students how to use the tools but how to apply them to educational tasks, such as writing, modeling, and database design. The chapter describes many different computer applications from the standpoint of various dimensions of instructional philosophy, the type of application, and the instructional contexts.

Chapter 1.6 starts with a model of the instructional learning process and then shows how the key elements (goals, infrastructure, organization, environment, teacher, and learner) can fit together and yield effective outcomes in teaching and learning. Within this structure, alternative approaches are contrasted and discussed.

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1.1

IMPLICATIONS OF THE INFORMATION AND KNOWLEDGE SOCIETY FOR EDUCATION

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The Information Society

The metaphor of "information society" was first used in Japan by Kohyama (1968) and it was in Japan that this metaphor was first used as a rationale for national policy (Masuda, 1981). In the 1970s, the authors of computer-related texts were not likely to refer to an "information society" but instead used words like "information age" and a "computerized society" (cf. Martin and Norman, 1970; Rothman and Mosmann, 1972). However by the late 1970s and early 1980s, the information society was mentioned so often around the world that many forgot that it was only a metaphor.

In fact by the late 1980s, "information society" had become a phrase that captured the essence of a culture inundated by information and dominated by information technology (IT). Daniel Bell's "framework for the information society" spearheaded the movement to legitimize the information society concept (Bell, 1979). He confirmed that a majority of the jobs in the United States were information oriented in that they were structured to produce informational rather than material products. In subsequent years, as global networks became ubiquitous and a global information economy became more obvious, the information society metaphor became even more widely accepted (Webster, 2002).

The Knowledge Society

Ironically, the information society concept was undermined by the emergence of a new metaphor in the 1990s, the "knowledge society." While the information society metaphor was associated with an "explosion" of information and information systems, the knowledge society metaphor primarily referred to economic systems where ideas

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or knowledge functioned as commodities. Many, if not most, people could not differentiate the two concepts because they tended to largely equate information and knowledge (Allee, 1997).

Confusion about the nature of knowledge is still a problem, especially in the field of education. The educational community tends to define knowledge mostly in terms of facts or declarative knowledge, but the field of management defines it much more broadly encompassing insights, values, and other tacit cognitions (Tiwana, 2002). In this chapter, the broader definition of knowledge will be used.

Information vs. Knowledge

Increasingly, the definitional distinction of information from knowledge is that information consists of intentionally structured and formatted data, but knowledge consists of cognitive states needed to interpret and otherwise process information (cf. David and Foray, 2003). While information can generally be reproduced for minimal costs, knowledge reproduction requires training, apprenticeships, and other more costly forms of transmission. Knowledge that is difficult to codify and reproduce is called "tacit knowledge." Tacit knowledge includes judgment, experience, insights, rules of thumb, and intuition and its retrieval depends upon motivation, attitudes, values, and the social context (cf. Polanyi, 1996; Tiwana, 2002).

A knowledge economy necessarily depends upon information as well as the intellectual capital of economic communities. Thus, a knowledge society necessarily presumes an information society, but not the other way around. In this chapter's discussion of education, the rhetoric of the knowledge society will be used, but for the most part it will apply to the information society as well.

Knowledge Societies in Education

While economists tend to think of "knowledge society" as a global economy, other social scientists tend to think of it as a smaller level social collective. Thus, a knowledge society may exist on at least four levels: a global system, a national or cultural system, a social organization like a professional society, and a smaller community, e.g., the "Dead Poet's Society." A knowledge society is generally defined as an association of people with similar interests who try to make use of their combined knowledge.

Of course, knowledge societies are not new, but what is new is that there has been a sharp rise in them and they are much more visible. Their rise follows digital networks that make them possible without members coexisting (do you mean residing?) in the same region and the technology makes accessing and sharing knowledge so much more feasible. On top of that is the pressure to exchange knowledge that emerges from the knowledge economy.

Loosely speaking, any educational system is a knowledge society, and that would include schools and classrooms. However, unless the educational unit devotes particular attention to knowledge-related activities, it is not particularly useful to call it a knowledge society. When an educational group invests considerable effort toward sharing and producing new knowledge, then it should be called a *knowledge society*. Communities of practice, typically groups of teachers that work with each other to improve their teaching, are good examples of knowledge societies, especially those that use all the tools, electronic and otherwise, to facilitate their goals (cf. Hargreaves, 2003).

"Knowledge society" in the next section refers to *the* (global) knowledge society. Later sections of the chapter shift toward smaller scale knowledge societies.

Implications of the Knowledge Society for Learning Priorities

The contemporary currents of the knowledge society derive from two major forces: greater intercultural interaction made possible by global electronic networks and an economic system in which knowledge functions as a commodity. Underlying the new role of knowledge in society is, on the one hand, an explosion of information and knowledge, and on the other hand, a greatly increased value for knowledge that helps people get what they most want. Table 1 shows the major implications of the global knowledge economy for the skills and learning strategies of young people, particularly those entering the work force. For instance, making knowledge a commodity means that youth needs the skills to construct new knowledge, and project-based learning offers opportunities for learning such skills.

Another characteristic of the knowledge society is a much faster pace of change in what is known and what is institutionalized. The second row in the table suggests

Table 1 Implications of the demands of the global knowledge economy for youth in terms of required skills and learning strategies

Demands from society	Required skills	Learning strategies
Knowledge as commodity	Knowledge construction	Inquiry, project learning, constructivism
Rapid change, renewal	Adaptability	Learning to relearn, on-demand learning
Information explosion	Finding, organizing, retrieving information; ICT usage	Multidatabase browsing exercises
Poorly organized information	Information management, ICT utilization	Database design and implementation
Incompletely evaluated information	Critical thinking	Evaluation problem solving
Collectivization of knowledge	Teamwork	Collaborative learning

that young people need adaptation skills and access to on-demand information systems. They can expect that it may be necessary to be highly mobile occupationally, switching among jobs, if not careers. It is no longer possible to keep up with all the information and knowledge in a field, and employers are more preoccupied with how well a prospective worker is able to learn than how much he/she knows already.

The explosion of information implies using systems that require new skills for accessing, organizing, and retrieving information (Spitzer et al., 1998). Generally, our information resources are poorly organized and poorly evaluated, which means that there is a premium on the ability to manage information and critically evaluate it, and on information and communication technology (ICT) skills, including basic utilization as well as database design and application. Furthermore, since knowledge is increasingly collective, it is necessary to learn collaboration skills and spend more time working in teams (Brown and Duguid, 2000).

ICT and the rapidly evolving knowledge society pose a difficult challenge to educators and policy makers. Ideological interest groups have formed around different proposals for addressing the future, and each group develops its own rhetoric. Examples include lifelong learning, distance education, schools as learning organizations, constructivism, student-centered learning, high-performance learning, project learning, digital divides, and so forth.

ICT

As noted already, ICT stands for information and communication technology and refers in principle to all technologies used for processing information and communicating. In most educational circles, it means computer technology, multimedia, and networking, especially the Internet. Educators in the United States and a few other countries use the term "technology" or "information technology" instead; however, this appears to be changing to include ICT. In business and industry, the most common label is IT, but sometimes the terms "new media" or "digital media" are used. This semantic diversity derives from the rapidly evolving integration of computers with communications, video, and audio technologies, where the separate technologies become nearly indistinguishable. In this discussion, the acronym ICT is used, recognizing that it means the same as IT or technology to many.

The scope of ICT is dynamic and continuously changes with the creation of new technologies. At one time, technology referred only to hardware, now it includes software techniques as well. Daily invention of new technologies provides a major challenge to implementation of ICT-based educational strategies. Given the skyrocketing pace of new ICT in the past decade, it would not be surprising in the next 5 years to see whole new forms of e-commerce such as Internet auctions or radically new ways to do homework using personal software agents that roam the Internet. It is imperative to track such developments because not only do they change the skill requirements for students, but also they impact society and change research priorities for research on ICT and education internationally.

The Twenty-First Century Skills Movement

The 1990s witnessed heightened attention to globalization, rapid change, and information economies. Policy decision makers in many countries began adopting the rhetoric of the information society, the knowledge society, and twenty-first century skill requirements. The United Nations Educational, Scientific, and Cultural Organization (UNESCO, 1999) on "Task Force on Education for the Twenty-First Century," the European Union's project, i2010, on "A European Information Society for Growth and Employment" (i2010, 2007), and the "Okinawa Charter on the Global Information Society" of the G8 world leaders (G8, 2000) all reflect the movement at all levels of policy making.

Now, the twenty-first century skills movement in the United States is led primarily by an organization called the Partnership for 21st Century Skills (2007). Many other organizations have written similar frameworks and position papers defining and promoting reform that moves education toward goals that specify what are called "twenty-first century skills." They include the North Central Regional Educational Laboratory (NCREL, 2002), Edutopia (Pearlman, 2006), the 21st Century Literacy Conference (New Media Consortium, 2005), and the Australian Department of Education, Science, and Training (2005).

The content of the twenty-first century skills reports is summarized in Table 2 where key themes are listed.

Each report emphasizes different themes. The Partnership for 21st Century Skills stresses critical thinking and life skills, the Edutopia report emphasizes collaboration, the NCREL report puts heavy weight on high student productivity, and the Australian report emphasizes life skills, which it calls "enterprise skills." In general, the reports reveal considerable consensus and consistency.

While the next century skills rhetoric now is predominantly used in the United States, support for this framework can be found in many countries including Australia, Thailand, and Oman. The majority of the twenty-first century reports address education in general; however, a few, which are not described here, are primarily oriented toward vocational education. The most notable examples of vocationally oriented initiatives

Table 2 Presence of content themes in 21st century skills statements

Theme	Partnership for 21st Century Skills	Edutopia	NCREL and Metiri Group	Australian Department of Education
Communication	*	*	*	*
Creativity	*	*	*	
Collaboration	*	*	*	*
Critical Thinking	*	*	*	*
ICT Literacy	*	*	*	*
Information and Media Literacy	*		*	
High Productivity	*		*	
Life Long Learning	*			*
Life Skills	*	*	*	*

are the WorldSkills project (http://www.worldskills.org) and the e-Skills Certification Consortium (eSCC) (http://www.e-scc.org/default.aspx) organization.

As shown in Table 4, the twenty-first century reports consistently emphasize the following educational outcomes for students, and workers of the twenty-first century will have expanded needs for skills in the following areas:

– *Communication*. Constructing logical arguments, reasoning from diverse evidence and sensitivity to audiences are essential to the outcomes of most projects. Using ICT tools when effective is critical as well.
– *Creativity in knowledge generation*. It is claimed that innovation is a critical need for the knowledge society. Creative, new knowledge solutions yield bottom line results and help solve problems with organizations of all kinds.
– *Collaboration*. Knowledge-intensive organizations require teamwork as well as coordination. Networks and network-based tools have become prerequisites to cooperative work.
– *Critical thinking*. Despite attempts to teach information literacy in schools, students often have not learned to critically evaluate knowledge and knowledge claims.
– *ICT literacy*. New literacies in the digital age lie at the foundation of preparing students for the next century. Technology may become obsolete but contemporary work cannot be efficient without standard productivity software and tools to augment the human intellect.
– *Life skills*. Life skills for the next century consist of those of the last century (e.g., ethics, leadership, accountability, and self-direction) as well as those which have become more relevant (e.g., personal productivity and personal responsibility).

In reviewing educational outcomes that are recognized as high priority for the twenty-first century, it becomes clear that they coincide with requirements for knowledge societies. It would appear that the twenty-first century movement is predicated on knowledge and information society concepts and concerns.

Parallels in Education and Management

It is not accidental that the leading edge thinking about both education and organizational management tends to focus upon similar issues. Both attempt to anticipate the future where new forms of ICT are ubiquitous and knowledge is the dominant commodity. The contemporary reform rhetorics of education and management demonstrate some striking parallels as Table 3 illustrates.

Table 3 Parallel directions in education and management

Education	Management
Schools as learning organizations	Organizations as learning systems
Learning to learn	Renewal is integral
Knowledge constructing	Knowledge as product
Collaborative learning and teaching	Knowledge is collective

Table 4 Parallel definitions of knowledge in education and management

Education	Management
Factual knowledge: details, terminology	Data, statistics
Conceptual knowledge: principles, classes, theories	Managing principles, theories, best practices
Procedural knowledge: algorithms, application criteria	Procedural knowledge: rules and specifications
Metacognitive knowledge: strategies, self-monitoring, reflection	Integrative knowledge: strategic plans, philosophies; tacit knowledge

Similar parallels can be found in the way each institution defines knowledge (Table 4). The four types of knowledge defined in the first column under education are adapted from Lorin Anderson's taxonomy (Anderson and Krathwohl, 2000) and the categories of knowledge under management were extracted from Allee (1997). Tacit knowledge was added to the cell containing "integrative knowledge"; it might be found in any of the cells; however, it is most likely to occur with integrative or metacognitive knowledge.

Some Knowledge-Based Models in Education

Scardamalia and Bereiter (1996) pioneered various strategies linking educational needs with ICT and knowledge concepts. One strategy is to use software that helps students build new knowledge using scientifically guided experimentation and computer-based tools and resources. Another is to foster and guide knowledge-building communities (Bereiter, 2002). Learning tools are used that assist both with basic skills and with higher-level knowledge. The common element to these strategies is the goal of preparing learners for the knowledge society through exercises in ICT knowledge-based activities.

Using a very different rhetoric, Jonassen's (1999) "mindtools" paradigm also seeks to optimize learning using software to augment higher-level knowledge-based functions. Mindtools, which are guided activities utilizing software tools, put the student in the role of designer or partner, as most activities require construction of some type of product, usually knowledge. Other activities facilitate collaborative conversations, cognitive amplification, and reflection aimed to enhance critical thinking skills.

The influential "How People Learn" model argues that the last research in the cognitive processes of learning provides a guide for instruction (Bransford et al., 1999; National Research Council, 1999a). Taken as a whole, their synthesis of contemporary research identifies knowledge, assessment, and student-centeredness as major sources for optimizing learning.

These educational approaches also offer guidance in designing assessment strategies for measuring knowledge-based skills using ICT. A later section discusses how tasks using mindtools might be adapted for delivery as performance tests.

The Emerging Pedagogical Practices Paradigm

Out of this diversity and terminological confusion, the International Association for the Evaluation of Educational Achievement (IEA) SITES project developed a conceptualization called the "Emerging Pedagogical Practices Paradigm" (EPPP) (Pelgrum and Anderson, 1999; Kozma, 2003). It emerged primarily from three intellectual traditions (1) lifelong learning, emphasizing the need to learn to learn and autonomous learning; (2) constructivism, emphasizing collaborative learning, real-world projects, authentic assessments, and student responsibility for learning; and (3) information literacy, especially the gathering and analyzing of information. The EPPP addressed many requirements of the knowledge society but has not yet explicated the full range of *ICT knowledge-based skills* required. Essential skills like critical thinking, deep understanding, and high-performance learning have yet to be integrated into the paradigm. In this regard, the knowledge-based framework (below) points to some neglected but essential issues and directions.

Student Knowledge Framework

In this section, a conceptual framework will be offered that flows from imperatives inherent in the information and knowledge society visions. The purpose of the framework is to explicate how societal knowledge demands suggest that learning activities and assessment strategies be structured. After a discussion of the framework, there will be discussion of the role of ICT in these learning activities. Ultimately, the argument is made that ICT and knowledge-related learning go hand in hand, helping to identify the desired direction of education in the twenty-first century.

Figure 1 shows how *knowledge-related skills* or capabilities go hand in hand with *knowledge-related task phases*. Skills are needed to carry out task phases of knowledge-related tasks. And completing these task phases helps develop knowledge-related

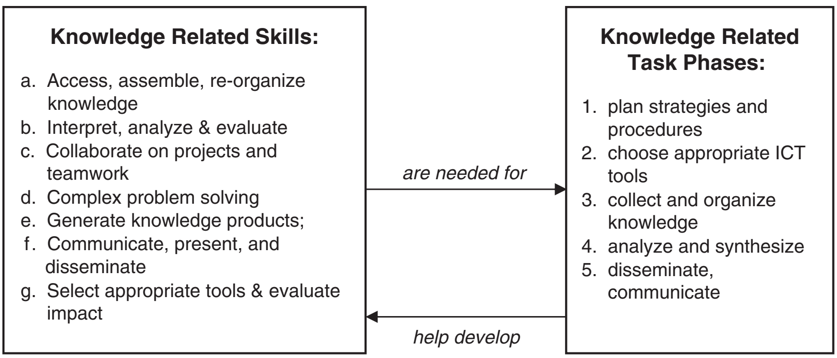

Fig. 1 The relationship between knowledge-related skills and knowledge-related task processes, with or without ICT

skills. We call these tasks "task phases" because to work effectively on such tasks requires a systematic approach consisting of a number of steps within each task, and a sequence of processes or phases.

Skills and task phases as illustrated in figure are mutually supportive. Carrying out task phases is only possible with knowledge-based skills, but doing task phases helps to develop knowledge-based skills. Complex tasks tend to require all five of the task phases. A project consists of a collection of tasks or task phases organized to achieve a specific outcome.

Knowledge-Related Skills

The following taxonomy of knowledge-based skills reflects priorities implicit in assumptions of the knowledge society, especially as it applies to the changing nature of most jobs. It is intended to guide the design of curriculum, learning activities, and assessment activities, particularly when students have access to ICT tools. Each skill category pertains to a set of tasks and should be analyzed with respect to the type of knowledge predominating in these tasks. Each skill category may pertain to multiple types or levels of knowledge: facts, principles, procedures, metacognition, and subjective states; however, some require predominantly one type. Each of the seven types of knowledge-based skills will be described briefly:

Access, assemble, and reorganize knowledge. It is generally recognized that in the age of databases and the Internet, the ability to effectively and quickly find and assemble information of all types is critical. Indeed, the concept of *information literacy*, which was invented about 35 years ago (cf. Spitzer et al., 1998), focuses upon this process. The skills required to search and organize information from the Web are what some have called *new literacy* or *e-literacy*. While the open Web is a great resource, there are numerous other sources of data and knowledge that are needed for many, if not most, knowledge questions. Considerable advances are being made in Internet-based systems that integrate browsing capabilities with additional tools that are pedagogically oriented (Soloway, 2000).

Critically interpret, analyze, and evaluate evidence. Integration involves evaluation of the quality and relevance of knowledge to make appropriate conclusions. Critical evaluation is also called *critical thinking* and *high-performance thinking*. A variety of tools, both general and specialized, can be used for these tasks as appropriate.

Collaborate on projects and teamwork. Sharing knowledge is an essential aspect of successful teamwork, as is the ability to consult with experts and others located at different levels of the hierarchy. Current options include e-mail, conferencing, and instant messaging, to name a few. Effective communication in most global organizations requires the skills associated with selecting communication tools as appropriate for various types of knowledge work. Intercultural communication, both with and without ICT, requires additional skills, which are in high demand.

Solve complex problems. Problem solving has always been a major human challenge, but with new global technologies the problems are more complex and the solutions are more critical for producing competitive products. Thus, the stakes are higher and the importance of planning strategies and higher-level thinking skills are more critical. Not only are complex problems central to school and the workplace, but they are relevant to everyday living as well.

Generate knowledge products. Knowledge products range from single ideas and tiny documents up to large, completed projects consisting of hundreds of documents and complex models. The skilled use of software tools is critical to effective completion of such tasks. Depending upon the goal of the task or subtasks, relevant software tools include word processors, spreadsheets, databases, concept mapping, and numerous other application software programs. Innovation and creativity should be considered both as a product and an outcome because of the importance of innovation and creativity to success in the twenty-first century.

Communicate, present, and disseminate. Knowledge workers are expected to present their knowledge either to report factual data or to persuade an audience to accept particular positions. The use of audio, video, and computing media for such presentations has been called *multimedia literacy*.

Select appropriate tools and evaluate their impact. This type of knowledge-based skill encompasses not only awareness of these secondary effects but also the ability to act according to existing legal and ethical boundaries. These tasks coincide with *technological literacy*, also called *sociotechnical literacy*, which has been defined as balancing tool and application potentials with practical constraints, especially social and ethical considerations. Rapidly evolving IT yields new opportunities for cheating, plagiarism, access to private, personal information, and access to adult materials. The new global economy depends upon preparing youth to deal with ICT both technically and responsibly.

Knowledge-Related Task Phases

1. *Plan strategies and procedures*. Planning is critical to knowledge-based tasks, although if the task is a familiar one, then the plans may be tacit, because the planning process may not be done consciously. Strategies involve larger sets of activities than do procedures and they take into account resources and power or control. For example, planning a new hospital should include several statistical subtasks to conduct a quality projection of future growth.
2. *Choose appropriate tools*. The process of selecting tools is highly context driven in that both the task and the context may constrain the number and type of tools that can be used. A number of different tools could be used for projections, but if no data are available for the projection, then another type of tool may be needed.
3. *Collect and organize knowledge and information*. Typically throughout the task process, information resources are needed for decisions of all types. For building a new hospital, not only would statistical data be needed, but also more subjective knowledge about building and staffing issues should be assembled and reviewed.
4. *Analyze and synthesize information and knowledge*. After knowledge or data have been collected, it has to be analyzed, interpreted, and integrated in the context

of the task. It is often useful to assemble the detail into a holistic summary or synthesis. Such a product may be the main intended outcome of a project.

5. *Communicating and disseminating knowledge products*. Once the previous stages of a knowledge-related cycle have taken place, the sharing or dissemination of outcomes or products is necessary for impact. In fact, this is sometimes the most critical phase of the whole process. Dissemination and communication of information about such knowledge requires considerable analytic attention in its own right.

These five knowledge-based task phases constitute a model project cycle or sequence. However, in practice these processes will be implemented within many different cycles where earlier processes are repeated after subsequent ones have been started. For instance, after evaluating preliminary reports, it may be necessary to go back to collect more data and/or to select another set of tools. Nonetheless, these five processes occur in most knowledge-related projects and each process a distinct set skills. The task phases are useful for thinking about the different types of software tools that are critical for knowledge-oriented projects. For instance, in the planning phase, it is particularly helpful to use project-based software for analysis of timelines, budgets, constraints, and priorities. For the collection and organization phase are browsers and database products. For the analysis phase are spreadsheet tools, modeling packages, and a variety of specialized software tools. And for dissemination, there are presentation and communication tools including writing enhancement aids.

Knowledge Capabilities and ICT Tools

The knowledge-related capabilities can be greatly expanded with ICT tools. Table 5 demonstrates this interrelationship by crossing knowledge capabilities with ICT tool types. The columns in Table 5 represent various categories of ICT tools, defined on the basis of what are considered the most useful ICT applications for teaching and learning. The taxonomy of tool types was adapted from Jonassen's (1999) classification of mindtools.

The cell entries of this table consist of student outcomes that could be used as evidence for the associated knowledge-related capabilities. The outcomes specified in the cells presume that the student is using one or more ICT tools in the associated row. It should be evident that this framework is intended for a performance assessment where the student has specific software applications available. In some of the cells, a specific software application, e.g., SIMCALC, a Web-based simulation tool widely used in science and mathematics instruction, is given to illustrate the type of tool available.

The concepts and categories for this framework were initially developed as an assessment framework. It emerged from dissatisfaction with traditional ways of defining computer literacy, IT literacy, and information literacy. The first large-scale IT literacy assessment was the 1979 Minnesota computer literacy assessment (MCLA) the investigators developed the first conceptual framework for the measurement of skills, knowledge, and attitudes relevant to computer utilization by students (Johnson et al., 1980). Their framework consisted of three subdomains: knowing basic

Table 5 Illustrative learning activities for knowledge capabilities (rows) by ICT tool types (columns)

Knowledge capabilities	Knowledge construction tool kits and database environment	Semantic organization tools	Dynamic modeling tools	Interpretation tools, e.g., visualization and search tools	Communi-cation, collaboration, and presentation tools
1. Access, assemble, and reorganize knowledge	Making inferences using, e.g., SIMCALC			Web searching and organ-izing using browser	
2. Critically interpret, analyze, and evaluate knowledge			Scenario simulation (see, e.g., in Bennett, 2001)	Using data mining tools to drill down to highly granular information	
3. Collaborate on projects and teamwork					Using groupware
4. Solve complex problem		Using qualita-tive analysis software	Using an optimization model for decisions	Interpreting data using visualization tools	
5. Generate knowledge		Constructing reasoning chains using concept maps			
6. Communicate, present, and disseminate					Using Power Point in net meetings
7. Select appropriate knowledge tools and evaluate their impact				Selecting ICT tools for a medical experiment and evaluate tool impacts	

Note: the table structure was substantially adapted from Anderson and Plomp (2002). The table contains some changes to improve clarity

computer concepts, knowing applications and their impact, and understanding and reading simple algorithms (Anderson and Klassen, 1981).

The next such assessment was the ETS Computer Competence Study in 1986 by the Educational Testing Service (ETS). The study was done under the auspices of National Assessment of Educational Progress (NAEP). Their framework was essentially the same as the earlier study except that computer programming was the predominate emphasis (Martinez and Mead, 1988).

In 1992, the IEA CompEd (Computers in Education) study (Pelgrum and Plomp, 1991) conducted the first international, technology-related large-scale survey and assessment. Nearly 20 different countries were involved in one or more segments of the study which developed the functional information technology test (FITT). Again, the subdomains were defined similarly to the earlier studies.

The IT fluency project was sponsored and administered by the National Research Council (NRC) of the United States, and the report was published by the National Academy Press (NRC, 1999b). A panel of mostly computer scientists was convened as the starting point for the conceptualization. Their framework consisted of a number of categories of IT fluencies within each of three major domains: IT concepts, IT skills, and intellectual capabilities. The first two domains were quite similar to the concepts and applications dimensions of earlier studies. But, the "intellectual capabilities" domain contained some rather complex and challenging topics expressed as behavioral objectives, specifically, "manage complexity" and "think about IT abstractly." Although this was never translated into a large-scale assessment, it marked an important advance. Specifically, it defined the prerequisites for literacy or fluency in terms of non-IT knowledge and how that related to IT.

A few years later, the IEA SITES project developed a knowledge management framework for assessing ICT-related skills (Anderson and Plomp, 2002) in an attempt to redefine IT or ICT literacy in terms of knowledge-related skills. It was from this work that the model in the previous section emerged. The framework had a similar flavor as that developed by the ICT Literacy Project at the ETS, which has been renamed the iSKILLS assessment (ETS, 2007). The core part of their framework defined it in terms of five capacities: the capacities to access, manage, integrate, evaluate, and create information. Many more models of ICT literacy are discussed in the next chapter in this section (Mioduser et al., 2008).

ICT literacy has traditionally been defined in terms of technical skills related to IT, whereas information literacy is usually defined in terms of information functions. If we view the intersection of these two domains with a third, a particular subject or knowledge domain, then we can define the intersection as ICT literacy. This is represented by the accompanying Venn diagram below (Figure 2). However, it is more appropriate to label it as "applied" ICT literacy because it consists of using IT and information manipulation toward the purpose of carrying out a particular knowledge-related purpose.

For an assessment framework, this model implies that to be ICT literate means that one has essential knowledge and skills from three domains: a technical one, a knowledge domain, and an information skill area, making it possible to use ICT appropriately with information in specific content areas. This implies that ICT literacy by definition is necessarily limited to tasks that require skills from all three domains. The traditional approach to defining ICT literacy would not require that ICT skills intersect with knowledge- and information-related skills. The knowledge-oriented model is more consistent with the integration of ICT into curricula and into more advanced applications of ICT.

Many publications about education in a knowledge society emphasize that for students to acquire knowledge-based skills, a "student-centered" didactical or pedagogical approach is needed (cf. Jonassen, 1999). The student-centered approach advocated by Jonassen is to let students develop or build new knowledge and he suggests putting the student into the role of designer. Both of these approaches illustrate

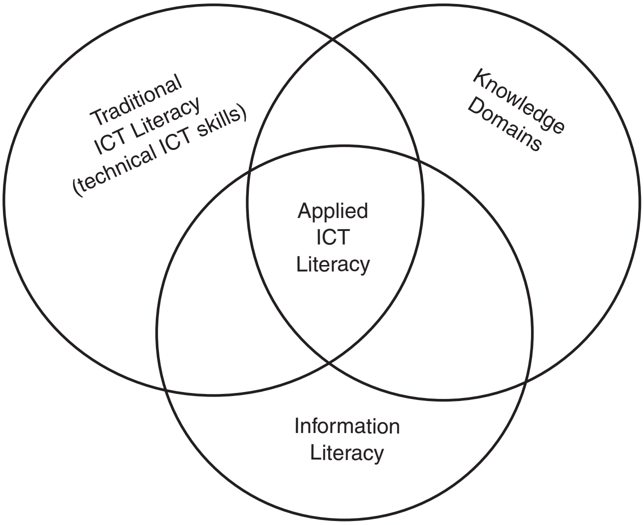

Fig. 2 Venn diagram of applied ICT literacy

how learning activities that require ICT can facilitate skills in ICT as well as in more knowledge-based areas such as self-regulation, creativity, and project management. This learning process can occur for well-defined learning tasks to very open problem-solving tasks aimed at producing "anything."

Knowledge Societies and Cooperative Work

More than any other technology-oriented research strands, computer supported cooperative work (CSCW) and computer supported cooperative learning (CSCL) have addressed the growing importance of knowledge societies. The professional association of CSCW holds an annual conference which is oriented to workplace research. International Society for the Learning Sciences (ISLS) holds a biannual research conference on CSCL. Software tools called *groupware*, which assist teamwork, are among the products from these communities. Software tools for interaction and exchange of knowledge are also investigated by researchers in these communities. Figure 3 shows a general model for cooperative work, which takes knowledge, works on it, and produces various knowledge products.

Tools that are used to facilitate interaction and networking are best represented on the upper half of this diagram, whereas tools that are designed to facilitate joint production are best represented by the lower half. Tools of the former kind would be threaded discussions and chat rooms. Joint reviewing/editing tools would be an example of the second type. Tools that help with knowledge mapping, note structuring,

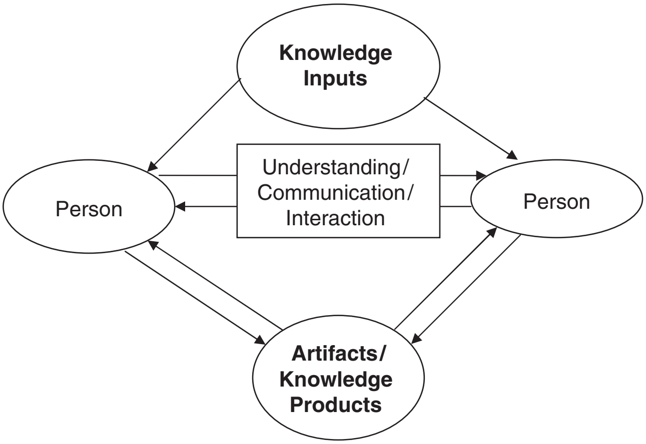

Fig. 3 Cooperative work framework

and so forth, should be seen as overlaying over the entire diagram. Examples of knowledge community projects in education can be found in the work of Bereiter (2002) and Scardamalia and Bereiter (1996). The most extensive review of CSCL can be found in Stahl (2006). His research investigations concentrate on mechanisms to support group formation, multiple interpretive perspectives, and the negotiation of group knowledge in applications as varied as collaborative curriculum development. Stahl discovered processes involved in the emergence of group meaning and outlines a theory of collaborative knowing. His work has yielded designs of optimal software environments for knowledge-based learning utilizing collaboration.

Assessment tools can be considered knowledge-based tools, but assessment is not very interesting in the context of knowledge development unless it is designed and oriented toward instructors and directly improving instruction. When computer-based content grading procedures become more refined, that will also help to integrate assessment and knowledge society functions. One thing that both groupware and assessment yield is input to improving instruction using scaffolding guides. That is, the teacher can be helped to design the best strategies for balancing between being too explicit and too vague in defining and assisting students.

Knowledge Societies and Learning to Learn

While this knowledge framework may appear to preclude other approaches to defining major skill requirements, it is not as narrow as it may seem. We illustrate this implication by describing some areas of overlap of the knowledge management framework with other approaches, most notably "learning to learn" and informatics.

A major tenant of the lifelong learning (also called "continuous learning") movement is that "learning to learn" is a critical skill for the twenty-first century.

ICT implicitly supports this by making possible new ways of obtaining "knowledge on demand" or "just in time" learning. There is a large literature on study skills, but contemporary advocates of "learning to learn" tend to argue that contemporary learning requires much more than study skills. Effective "learning to learn" requires attitudes and motivations such as motivation to learn and motivation to take self-responsibility to learn. Now, there is little consensus on how to define and measure the skills of learning to learn.

Many educational systems have a national informatics curriculum consisting of one or more courses at the elementary and/or secondary level that teach ICT skills. Traditionally, the content of informatics courses has emphasized beginning computer science principles along with some general principles of information management. In many instances, students taking informatics also receive hands-on instruction in the use of productivity tools such as word processors, Internet browsers, spreadsheets or databases, and other such technology. Some educational systems offer courses in ICT concepts and applications but do not call it informatics.

The knowledge may be useful in evaluating both curricula where ICT instruction is integrated into existing courses as well as traditional informatics curricula. A course on the use of productive tools teaches skills in constructing knowledge products such as document production, and retrieving and organizing knowledge with a database system or browser, and solving problems with spreadsheet or other software tools. A curriculum that includes instruction in computer programming typically may teach students these same information management skills but with different tools. Programming instruction usually puts a major emphasis upon the knowledge-oriented task phase that we have called "analyzing and synthesizing."

Implications for Education in the Era of Knowledge Societies

One should infer from this chapter that progress harnessing of technology for education requires progress in understanding the tools and their context, both educational and social. For that understanding to go forward effectively requires increments in theory and research. The theory part includes refining the concepts and specifying the underlying influences within the overall system. The concepts of the information and knowledge society are central to that understanding. In particular, we need to know much more about knowledge: how best to define it, how to utilize students' prior knowledge in the learning process, how to manage knowledge in organizational environments, how to let it guide the construction of assessments, and so on.

In support of this emphasis upon knowledge, Brown and Duguid (2000) argue that learning is the acquisition of knowledge and it "presents knowledge management with its central challenge" (p. 124). Furthermore, they state that learning is social and "it requires developing the disposition, demeanor, and outlook of the practitioners." While this very well captures the process of apprenticeship, professional, and most workplace learning, it also applies to general education. The point is not so much that the student is being socialized by the teacher, but that effective learning involves learning attitudes and values associated with any new knowledge. In other words, without the tacit dimension of knowledge, people do not learn when and how to apply the explicit part.

Looking beyond information to knowledge of various types gives us a much richer picture of learning. It also helps to clarify the ways in which learning and practice are interrelated. First and foremost, the link between learning and practice is a social one. And if we embed learning in a social context, then subsequent practice is much more assured.

Learning is not just about students. It is also an essential dimension of teaching and schooling. Teachers are not likely to be very effective on there own, hence the power of communities of practice (Wenger and Snyder, 2000). As teachers learning to work together and help each other, their productivity increases exponentially.

Finally, schools must learn to adapt, not just to change, but to new knowledge that helps them run more effectively (cf. Hargreaves, 2003). Hence, we see the power of schools as learning communities (Senge, 2000). School reform has a much higher chance of success when its leaders nurture the learning processes of the school community. Reform is not just a matter of vision, but it is a matter of vision, resources, community participation, and taking full advantage of social mechanisms for making learning maximally effective.

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1.2

NEW LITERACIES FOR THE KNOWLEDGE SOCIETY

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Introduction

What does it mean to be literate? The answer to this question was formulated over time in many different, often controversial ways. The notion of literacy evolved from being strictly focused on the realm of reading/writing skills, to embracing the comprehensive set of skills needed by individuals to learn, work, socially interact and cope with the needs of everyday life (Lemke, 2005; Lonsdale and McCurry, 2004).

It is now commonly accepted that this change in perspective is closely related to crucial changes in the life of individuals and societies resulting from recent developments in information and communication technologies (ICTs). This synergetic relationship between technological developments and individual/social functioning has received ample treatment in recent scholarly literature. However, the similarly symbiotic interaction between ICTs and the emergence of new literacies still needs further elaboration.

This is in fact the main purpose of this chapter. It will build on three main conceptual assumptions. The first is that at all times – not only in the current digital era – literacy should be perceived as a multifaceted construct, not constrained solely to knowledge and skills related to the written or printed word (Olson, 1994). The second is that for any epoch, specific prevalent literacies should not be considered as independent and isolated constructs (a set of objectively defined skills), but as the result of the intricate interaction between individuals' knowledge (inner or within-the-mind literacy) and the knowledge embodied in the technology (outer or artifacts-embedded

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literacy) (Mioduser, 2005; Olson, 1994). The third assumption is that any given literacy is far more than a set of acquired skills – it is first and foremost the person's stance toward knowledge-embedded objects of a wide range of types (e.g., textual, visual, haptic), behaviors (e.g., static, dynamic, permanent, volatile), media (e.g., print, digital, waves), and semiotic status. These premises, on which we will further elaborate in the next sections, set the framework for our discussion on *seven main literacies* for the knowledge society.

In the following, we will briefly present background work on the topic of new literacies, our rationale for defining and discussing the new literacies, a brief description and elaboration of seven key literacies, and a closing discussion on these literacies and their implications for education.

The Knowledge Society

In 1976, only 30 years since the first large-scale electronic digital computer (the ENIAC) was unveiled at the University of Pennsylvania, the sociologist Daniel Bell introduced the notion of the "information society" (Bell, 1973). Bell predicted that theoretical knowledge would become a main resource in society, affecting economy, labor, culture, and all venues of life. Today, only 30 years since Bell's prospective analyses, the "knowledge society" is an established fact, involving directly a considerable portion of the world's population, and undoubtedly affecting the lives of populations and countries still not included in it. For a detailed discussion on the characteristics of the knowledge society, see Anderson (2008). A key theme in the evolving identity of the knowledge society is the obvious but essential fact that technologies, specifically information and communication technologies, are at the core of the transformations taking place. One can claim that this is not new to history and that all important technological developments of the past triggered important social change (Olson, 1994). However, this claim should be revised when relating to the knowledge society. Unlike previous processes in history, multiple cycles of change took place within a few decades, with many defining parameters (e.g., technological developments, economical developments, amount of information and knowledge) either arising or transforming in a very short span of time. What may be considered only a quantitative – and merely a technical – change is in fact a profound qualitative transformation due to its implications for life.

On the positive side, fascinating processes took place. To name only a few, knowledge has become the key resource fueling the functioning and development of societies, displacing more concrete resources such as land, capital, or labor from their privileged status; moreover, knowledge as resource is a shareable and portable commodity, facilitating the creation of new economic and social configurations, the synergetic interaction between the human mind and knowledge technologies, has qualitatively accelerated the generation of new knowledge and advanced our understanding of complex natural, artificial, and social processes; people's communication and interaction space has been boosted, with the support of a wide range of synchronous and asynchronous means; computing and communication power has become ubiquitous (although mainly for economically privileged countries or population groups), allowing the creation of a virtually unlimited knowledge manipulation-and-sharing space, free of time and location constraints.

On the less positive side, the rapid immersion of large portions of the world in the knowledge-technologies revolution generated a series of phenomena to which we still do not have satisfactory answers. Among these, individuals and societies feel compelled to adjust to rapid changes taking place several times in a lifetime and on a continuous basis – this complex challenge finds most people unequipped with the appropriate means (knowledge and skills), which still remain mostly unidentified and undefined; the rapid economical and social transformations have added new knowledge-related gaps to the traditional divides among peoples and nations on dimensions such as level of mastery of up-to-date personal and social literacy's, extent of access to the core of knowledge-generation and policy making agencies, prospects for social mobility, roles fulfilled in the knowledge society (e.g., the digital divide between consumers and citizens) (David and Foray, 2002).

Even if we consider that we are only at the preliminary stages of consolidation of the characteristics of the knowledge society, it is already clear that there is a demand for substantial change in the quality and composition of the baggage of knowledge and skills with which educational systems and training agencies furnish their students. To function in the knowledge society, the educated person is expected to be an independent and lifelong learner, to master higher-order skills, to master information skills, to posses the capabilities of a skilled worker in knowledge-rich environments (e.g., formal knowledge, specialized skills), and to be able to learn and work in teams (Anderson, 2008; Leu et al., 2004).

This clearly represents a great challenge for the individual, but not less so for the educational agents and agencies that are expected to supply opportunities and develop appropriate pedagogies fostering the attainment of the above goals. Are current educational systems (a) aware of the challenge, (b) capable to reformulate their goals according to it, and (c) able to develop new pedagogies, learning configurations, and formation processes to meet the new goals? The debate on these questions, and the attempt to come up with sound answers, is being conducted today – in different ways – at the level of formal educational systems and by the "rest of us" (e.g., scholars, practitioners, corporations, worried parents, concerned citizens).

Formal educational systems tend to be conservative and cautious. In facing new realities, their modus operandi comprises mechanisms such as the establishment of evaluation and planning committees, thorough revision of existing curricular goals and materials, and planning of new ones; laborious attempts to balance between the implementation of innovations and the preservation of existing structures, and ponderous staff development processes. In trying to understand this state of affairs, two contextualizations are of relevance. First, formal systems do what their proprietors – societies – request them to do. Since the debate on the new challenges is still ongoing among the various social agencies responsible of educational policy making, this has clear repercussion on the conditions (e.g., goals stated, resources allocated) within which the systems have to perform. Second, aware of their responsibility as the deliverers of the next generation of educated citizens, formal systems cannot afford to become large-scale experimental settings for unproved ideas, implying radical changes. They prefer to assimilate proven innovations in evolutionary fashion.

On the other hand, other social agents have reacted (fairly rapidly) to the new reality by engaging in the systematic examination of its nature and implications for individual and social learning and functioning, and the devising of novel educational solutions. Researchers, corporate trainers, developers of educational materials, and practitioners are intensely working on a wide range of issues related to the educational implications of the knowledge society. A partial list of these issues includes the revision of the very notion of schooling and the role of teachers and students in the educational process, the revision of individual and group learning processes, the development of innovative organizational configurations for learning, or the development of advanced learning tools and systems.

Although there is a widespread conviction that the school as a social institution still has important roles to fulfill and that in the foreseeable future it will still be the fundamental building block of societies' educational apparatus, there is also strong awareness of the need to adapt its goals, structure, and functioning to the needs and requirements of the knowledge society (Drucker, 1994; Kozma and Anderson, 2002).

The "New Literacies"

To elaborate on *new literacies* necessarily requires first to clarify the definition of *literacy* and to depict its more recent evolution. The classic view of literacy refers to a person's capability to read and write, serving to transform thought into printed records and vice versa (Murray, 2000). Ample theoretical and practical work on literacy, far from constraining its scope to the basic definition, has enriched it over the last decades with many additional layers of meaning and perspectives.

Snow (2004) maps the varied perspectives for defining literacy into six main dimensions, suggested as continuums: *componential vs. holistic* (the view of literacy as an array of necessary skills or as integrated capability centered in meaning making), *solitary vs. social* (primarily an inside-of-the-head process or a collaborative activity with substantial social – and political – implications), *instructed vs. natural* (requiring the passage through successive teaching/learning stages or natural product of living in a literate environment), *functional/technical vs. transformational/cultural* (technical capabilities that facilitate functional performance in all kinds of tasks or essential force in the building process of individuals' identity and societies' culture), *singular/coherent vs. multiple/varied* (confined to a given set of skills – e.g., those required to pass a reading test – or the multiple literacies demanded by different readable objects such as a contract, a poem, or a bus timetable), and *school-focused vs. home- and community-focused* (focus on curriculum-based and standardized knowledge or on everyday life and multiple social environments naturally constructed knowledge). Integrating these dimensions, each extreme of the continuum leads to defining literacy either as "an instructed skill, accomplished by the child operating individually, as a technical achievement exercised primarily and most crucially in school settings, analyzable into component skills, and unconnected to political or cultural commitments," or as "social, community-based, culturally defined, varied, and potentially transformational" (Snow, 2004, pp. 276–277).

Social, cultural technological and political processes of the last 100 years gave rise to a variety of disparate perspectives in defining literacy. For example, emphasis on a society's view of the profile of its literate citizen is reflected in formal and legal formulations, as in the USA's National Literacy Act: "for purposes of this Act the term 'literacy' means an individual's ability to read, write, and speak in English, and compute and solve problems at levels of proficiency necessary to function on the job and in society, to achieve one's goals, and develop one's knowledge and potential" (Public Law 102–73, the National Literacy Act of 1991); emphasis on social and political aspects, highly relevant to the social and economical reality prevalent in many parts of the underdeveloped world, is at the basis of Freirean views of literacy (Freire and Macedo, 1987); and emphasis on thinking and performing in specific fields led to the definition of competencies such as scientific literacy, technological literacy, computer literacy, media literacy, or information literacy (Semali, 2001).

Along similar lines, emphasis on the defining characteristics of the emerging knowledge society, have guided researchers' and policy makers' efforts to identify the new literacies of the digital era. Nadin (1997) proposes a challenging characterization of our times, which he thought-provokingly calls "the civilization of illiteracy" to indicate that no one particular literacy dominates, but many literacies coexist based on a wide range of notation systems and representational modalities, involving all human senses, and supporting experiences of thinking and working above and beyond language.

Basic Issues Underlying Our Discussion of the "New Literacies"

In this chapter, four basic issues underlie our discussion on, and definition of, the new literacies. The first builds on the intimate relationship between technology and intelligence in general, and technology and literacy in particular. In any definition of literacy, and at any time in history, it should be taken into account that (a) artifacts (technology), being a creation of the human mind, are first and foremost knowledge-embedded entities – or physically embodied human knowledge and (b) the artifacts' object worlds (Bucciarelli, 1996) afford and demand particular thinking processes and performances – feeding back on the human minds that have created and are using them (Mioduser, 2005; Sternberg and Preiss, 2005). In consequence, literacies should be considered in light of this recursive interaction between cognitive processes and (cognitive) technologies.

The second issue refers to the transformation pace of both the technology and its related literacies. Unlike the tranquil pace of transformation of previous technological eras, today we are immersed in a highly dense process in which stages succeed each other at very short intervals. Skills only a few years ago believed crucial for living in the information era (e.g., programming or "computer literacy" skill sets from the "microcomputer" era), are no longer considered to be so, and were therefore rapidly dropped from the regular curriculum and replaced by new ones (for how long?).

The third issue builds on the previous, but relates to the character of the transitions between stages. It is accepted in the literature that paradigms borrowed from previous technological/literacy stages have always mediated the passage to new ones (e.g., Mancini, 2000). The initial perception of the cinema as filmed theater, or of cars as carriages with engines, are the most widely cited examples of this phenomenon. With time and laborious processes, new perceptions (and corresponding literacies) emerge. The transition is not free from controversies, uncertainty, and concerns as regards to the "endangered" previous literacies. For example, the intense conflict generated by the revolutionary invention of print is depicted in sensible and eloquent manner in Hugo's (2001) *Notre-Dame de Paris* (excerpts from book fifth, Chapter I):

> …opening the window of his cell he [i.e., the archdeacon] pointed out with his finger the immense church of Notre-Dame…[he] gazed at the gigantic edifice for some time in silence, then extending his right hand, with a sigh, towards the printed book which lay open on the table, and his left towards Notre-Dame, and turning a sad glance from the book to the church, – "Alas," he said, "this will kill that."

In Chapter II, an interpretation of the archdeacon's feelings is offered:

> …architecture is the great book of humanity, the principal expression of man in his different stages of development, either as a force or as an intelligence…the human race has, in short, had no important thought which it has not written in stone…It was a presentiment that human thought, in changing its form, was about to change its mode of expression; that the dominant idea of each generation would no longer be written with the same matter, and in the same manner; that the book of stone, so solid and so durable, was about to make way for the book of paper, more solid and still more durable.

The perspective of the 500 years that have elapsed since Gutenberg's invention allows us to conduct a mindful examination of the fate of the at first anxious and ambiguous emotions toward print, of the character and pace of the many transformations (epistemological, cultural, political, economical) attributed to it, and of the birth and evolution of varied literacies related to the book's object world. It also supplies us, by extrapolation, with solid background for the examination of the questions arising from current technological transformations, some of them already a commonplace: *Will this* – the use of electronic calculators and mathematical software packages – *kill that* – arithmetic skills and other key components of numeracy? *Will this* – the immersion in multimodal representational spaces – *kill that* – the mastery of fundamental skills of classic literacy? Are we able to identify and define the ways and directions in which *human thought is changing its form and mode of expression*?

The fourth issue in our rationale relates to the obvious – but nevertheless substantial – social (cultural, political, economical, ethical) aspects and implications of the dyad technological transformations/related literacies. Relevant throughout human history, these aspects have become even more so today because of the centrality of knowledge and knowledge technologies in the twenty-first century. The discussion centers on various foci and reflects conflicting perspectives. Among the issues under discussion are the politics and economics of knowledge (e.g., Apple, 2003); parallel forces acting in the knowledge society (e.g., grass roots initiatives and emergent distributed processes vs. corporate imposition of methods and tools); tension between situational and culture-dependent knowledge processes and globalization-oriented ones; newly emerging divides within and between societies; and conflicting perspectives on the role of literacy for the empowerment of individuals and societies: is it a means required for *functional adaptation* to the traits of the knowledge society (e.g., Drucker, 1994), or for mindfully coping with these demands in *defiant* fashion (e.g., critical approaches; Frechette, 2002).

Although brief and partial, the above survey of both the characterization of the knowledge society and the evolving definitions of literacy unveils the current intense intellectual endeavor to define the new literacies for the knowledge society. In the following section, we will survey seven of these, which we consider as representative components of a person's new literacies baggage.

Seven Literacies for the Knowledge Society

The literacies to be defined and discussed in this section relate to multimodal information processing, navigating the infospace, interpersonal communication, visual literacy, hyperliteracy (hyperacy), personal information management (PIM), and coping with complexity.

Multimodal Information Processing

Definition. Multimodal information processing literacy encompasses the skills and knowledge required to understand, produce, and negotiate meanings in a culture made up of words, images, and sounds. The multimodality of this culture derives from (a) the need to deal with multiple representational means and forms (e.g., printed words, static and moving images, sound, haptic information, texts, charts, or programming code), (b) the fact that it is accessed from, and/or addressed to, multiple information agents (e.g., peers, experts, scientific publications, blogs, or Web sites), and (c) its use of multiple processing tools, within (d) multicultural contexts.

Discussion. Multimodality characterizes our immersion in the (natural, social, artificial) world – all our senses are compromised, and many different processing functions are exercised on inputted and stored information of various kinds (e.g., texts, images, gestures, haptic information). Throughout the history of humankind, multimodal perception and processing were assisted by knowledge technologies of various kinds; however, current ICT has given a qualitative boost to the ways people gather, store, and process information (Drucker, 1994; Lemke, 2005).

The ability to process information by using ICT generic applications – namely to create and edit texts with word processors, to do complex numerical calculations using a spreadsheet application, or to process image or audio files – is claimed to be one of the most essential skills in the knowledge society. The wide availability (in the relevant parts of today's world) of these basic tools and the rich processes that they afford make products such as handwritten documents or hand-calculated budgets a rarity. Their usage is currently so common and widespread that it is sometimes hard to realize that only a few decades have elapsed since the early days of personal computing, when the first widely used word processing and spreadsheet applications were introduced. It is now obvious that the ability to manipulate and process multimodal information using ICT is quintessential for learning and working in the postindustrial society. The list of the required skills is lengthy, and the vast majority of the youngsters, belonging to the net generation, acquire these mostly in an unorganized and unsystematic manner, in both formal and informal settings.

However, the required and actually occurring transformation is not merely technical. It does not relate to just replacing paper and pencil with digits on a screen. It is also not just a matter of replacing previous technologies with new ones. Rather, it implies a critical change in the way people perceive, consume, create, and interact with information in everyday life. Our understanding of the nature and impact of these transformations is still limited. Moreover, when ICT skills and knowledge are formally taught, the learning takes place mostly at the technical or tool-mastery levels. Learners are usually not introduced to the deep meanings and implications of technology-assisted processes of digital representations of world phenomena. The work on these additional layers of understanding and consequent reshaping of thinking and performance still represents a real challenge to educational systems.

Navigating the Infospace

Definition. This literacy relates to the ability to know when and why there is a need for information; how and where to find it in, and retrieve it from the vast infospace; and how to decode, evaluate, use, and communicate it in both an efficient and ethical manner.

Discussion. Humankind's transition from nomadic to sedentary life brought about substantial changes, including the demarcation and appropriation of physical territories and the development of systemic production and storage of goods – including knowledge – within or nearby the demarcated space. Concerning *knowledge*, the technological developments of the last decades have implied a sort of reversal of the process: we are becoming nomadic gatherers of information (McLuhan, 1994).

The first phase of this process took place in the virtual realm – without leaving the workstation at work, school, or home, we were able to wander through the infinite paths of the infospace and gather information from disparate yet interconnected information geographies. But the next phase – already here – affords once again *physically* nomadic behavior: ubiquitous computing, mobile technologies, cellular networks, and large wireless bubbles (e.g., campuses, shopping malls, planes), even neighborhoods allow unconfined information gathering, processing, and transmission. The ability to navigate the infospace, thus, has become a critical skill.

A comprehensive definition of the required skills is still a matter of controversy – although different proposals can be found in policy documents and published academic work. Overall, the literate navigator of the infospace is expected to master skills such as to recognize the critical role of information for mindful decision making and problem solving, to identify potential sources of information, to know how to access these, to develop efficient search strategies, to evaluate found information and organize it for practical application, to integrate new information into an existing body of knowledge, and to be aware of ethical (e.g., plagiarism, copyrights) and moral issues in the use and manipulation of information (Lampert, 2004; Muir and Oppenheim, 2001). Besides all these, the mastery of skills related to the use of various information-manipulation tools and technologies is obviously required.

Educational systems, aware of the importance of the above skills, have devised ways to include them in the formal curricula. However, in most cases, these are still taught as a separate subject (e.g., information literacy courses). Given the major trends currently affecting the world of information and knowledge, these skills should be integrally embedded within and across the school curricula, as basic components of literacy for the twenty-first century.

Communication Literacy

Definition. This literacy relates to the skills required for mindful, knowledgeable, and ethical use of a wide range of communication means, using multiple communication channels (e.g., verbal, written, visual), in various interaction configurations (e.g., one to one, one to many, many to many), for different purposes (e.g., social interaction, team work, collaborative creation, media consumption and/or production).

Discussion. The constituent traits of communication behavior (e.g., generation and use of symbol systems of communication technologies) are shared by humans of all times since the "symbolic explosion" of the Upper Paleolithic period (Conkey, 1999). However, due to the sophisticated and complex affordances of today's technologies and tools, interpersonal and mass communication performance have entered a qualitatively new phase, implying the demand for a radical transformation in our stance toward communication, and for the acquisition of new skills.

Our communication landscape is saturated with technologies and tools which are caught in multidimensional characterization, for example: synchronous and asynchronous, based on the use of a wide range of representational media (e.g., text, image, sound), serving many different social configurations (e.g., one to one or many to many – from small groups to large communities), and for various purposes (e.g., interpersonal messaging, team work, special-interest-groups knowledge building or collaborative problem solving, broadcasting of textual, visual, or auditory information).

Relevant perceptions and skills relate to different levels. The *technical* level is obvious and implies acquisition of the necessary skills for using different tools (e.g., for e-mailing, chatting, or contributing to a collaborative project). The *psychological* and *affective* levels are less obvious and demand the evolvement of dispositions and attitudes unique to the novel communication situations with. Examples of these situations are (Blake and Tucker, 2006; Huwe, 2003) groups of people who use ICT to interact while working or learning – though they may never meet face to face; children or adolescents with special needs or concerns participating anonymously in support networks; broadcasting (e.g., Web logs, podcasting, posting of textual or visual information in public and interactive repositories); or virtual participatory spaces (e.g., for working, gaming, e-commerce transactions). All these require a reconsideration and redefinition of our perception of interaction and interaction modalities, partnership, distributed and collaborative work and learning, affiliation with communities of interest and reference, dissemination of personal and public information (including issues such as ownership or reliability), and a number of ethical and moral issues as well.

In the educational field, innovative collaborative learning environments have been developed using the new technologies, some of which have proved to be sustainable. For example, computer-supported intentional learning environments (CSILE), which enable knowledge building and development of thinking skills (Bereiter and Scardamalia, 2004); the Web-based inquiry science environment (WISE), which promotes inquiry-based science (Linn, 2006); or online networks designed to support collaborative knowledge building within schools, between schools, and beyond schools using wirelessly connected handheld computers (Zurita and Nussbaum, 2004).

In spite of these and many other thoughtful and proven endeavors, as the technologies are still evolving so is the conceptualization and definition of the required transformations in perception and the to-be-acquired skills. This intertwined development – since the early attempts to design "electronic agoras" (Mitchell, 1995) and multiuser environments (Mioduser and Oren, 1998) to the current intense intellectual and practical work focusing on people's involvement with tools grouped under the amorphous umbrella of the "Web 2.0" (O'Reilly, 2005) – represents a serious contribution to the apparatus of knowledge and skills comprising the new literacies. And the teaching of these constitutes a challenge for education as well.

Visual Literacy

Definition. Visual literacy is the ability to decode, evaluate, use, or create images of various kinds (e.g., still, moving, representational, directly recorded) using both conventional and twenty-first century media in ways that advance thinking, reasoning, decision making, communication, and learning.

Discussion. Before the word was the image. Humans have been generating and "reading" images for all kinds of purposes from times immemorial – as a means for dominating, enhancing, or venerating reality or aspects of it; for representing existing or invented realities; for conveying thought and communicating with other humans; for visualizing natural, social, and artificial phenomena and processes under study; and for performing formal manipulations with symbol systems that are alternative to word and number systems (Hauser, 1951; McLuhan, 1994; West, 1995). Since the very beginnings of human history, images have been acting as powerful conveyors of meaning, either as building blocks of notational systems or as self-contained representational objects. Moreover, many have attained the status of icons of a period or a culture – for example, the human imprints depicted in (a) the tapestry of hand stencils on the walls of the Chauvet-Pont-d'Arc cave and (b) Neil Armstrong's footprints on the moon. These images were generated more than 30,000 years apart. They are the product of drastically different contexts, cultural systems, belief systems, and technological knowledge and capabilities, which both served as background and supplied the means for their creation. Even so they share an essential feature: they are "readable." They are meaningful representational chunks enticing the literate observer to "read" the fascinating stories of each particular stage in the history of humankind – the settings, the state of knowledge, and the existential stance of each specific human community. With the passing of time, the original intentions behind the images may have been lost – but the action of a visually literate reader, aiming to distillate meaning out of the otherwise mere configuration of matter on a surface, allows the reformulation of a story, conjectures, and significance.

There were times in which visual literacy held a superior role – most obviously in prelinguistic and later on preliterate epochs (Olson, 1994). In an epistle to Serenus, Bishop of Marseilles, Pope Gregorius the Great reprimands him for destroying the images of saints, stating that: "For what writing presents to readers, this a picture presents to the unlearned who behold, since in it even the ignorant see what they ought to follow; in it the illiterate read…with regard to the pictorial representations…though ignorant of letters, they might by turning their eyes to the story itself learn what had been done" (Epist. 11 in Schaff, Ph., 1819–1893). In Medieval Europe, art was not an independent and self-contained aesthetic mode of expression but rather subservient to a pervasively religious culture, thus developing a visual language with an abstract and spiritual character which then became a powerful educational resource (Hauser, 1951).

More recently, following the nineteenth century move toward machine-based mass production of goods, a new kind of visual literacy became imperative, the one required to understand *the grammar of the machine* (Stevens, 1995). Technical drawing, formal representational notations, and continuous transitions between 2D spatial representations and the corresponding 3D represented realities were part of the new requirements – for engineers to express what they saw in their *mind's eye* (Ferguson, 2001) and for workers to interpret the represented worlds and produce the physical ones.

Today's massive reirruption of the visual into our lives appears to be, on the face of it, a move forward into the past, fostering a revival of visual talents and skills once highly valued, but long considered of lesser value in a modern culture long dominated by words (West, 1995, p. 14). However, the current rebirth of the visual is substantially different from previous cycles in terms of cultural status, epistemological functions, materials in which it is embodied, processing processes afforded, and tools involved in its creation and consumption (Leu et al., 2004; West, 1995). A widely cited definition of "visual literacy" was formulated by Debes (1968) several decades ago, concerning the competencies allowing "a visually literate person to discriminate and interpret the visible actions, objects and/or symbols, natural or man made, that he encounters in his environment…to comprehend and enjoy the masterworks of visual communication" (p. 14). Since this definition was formulated, a comprehensive visual culture has evolved.

Our visual culture has been defined as comprising the material artifacts, buildings and images, plus time-based media and performances, produced by human labor and imagination, which serve aesthetic, ritualistic, or ideological–political ends, and/or practical functions, and which address the sense of sight to a significant extent (Walker and Chaplin, 1997, p. 2). Its current essential features are of a very special kind: the raw material is the digit, the means are digital processing tools, and the products populate the digital world (Mitchell, 1995). Processes not so long ago unimaginable are today's routine features in on-the-shelf tools, e.g., software packages supporting graphic design, graphic user interface design, scientific visualization, digital video editing, computer-based design and manufacturing, animation, and creation of virtual worlds. Each and every option afforded by a process or a tool has profound epistemological implications, for both creators and consumers immersed in the ever-evolving visual world.

And where is formal education in the current phase of the story? Quoting Yenawine (1997): "there is virtually no instruction in visual literacy either in schools or out, nor even recognition that learning to look is, like reading, a process of stages. There is no accepted system by which to teach it either – that is, strategies sequenced to address the needs and abilities of an individual at a given moment, strategies that eventually allow one to come to terms with complex images" (p. 846). Yet another challenge for education in the knowledge society.

Hyperacy

Definition. This literacy refers to people's ability to deal, either as consumers or as producers, with nonlinear knowledge representations. The visible layer of this literacy relates to skills involved in either creating or using features such as links among knowledge units, or navigation aids. The more profound layers comprise abilities such as envisioning a consistent epistemic structure out of the various possible paths within a knowledge web, the evaluation of the relevance of each unit to the evolving meaning, or the ability to move back and forth from the link level to the whole knowledge-structure level.

Discussion. Our first encounter with Julio Cortazar's "antinovel" Rayuela (Hopscotch) in 1966 was an exciting challenge to our traditional reading habits: it comprises sets of seriated chapters and "expandable chapters" linked by suggested interconnections, in fact pieces that might be arranged in manifold ways; it supports the recurrent composition of stories within stories by the reader while moving back and forth in the book. The book does not present one definite narrative, and instead dedicates itself "to showing the possible paths one can take to knock down the wall, to see what's on the other side" (Garfield, 1978). "Rayuela," clearly, does not merely present a different type of *writing*, but undoubtedly also and correspondingly demands a different kind of *reading*.

It has been claimed that composite information units which include "semantic bridges" allowing, and indeed requiring us, to commute between different parts of a text, and even between different texts, have been with us for centuries, e.g., in reference texts that include detour tools (e.g., foot- and endnotes, cross-references in dictionaries and encyclopedias); in literary creations – e.g., Laurence Sterne's comic metanovel "The Life and Opinions of Tristram Shandy, Gentleman" published between 1759 and 1756 or 1766 (check with reference list), a nonlinear narrative including intertwined stories, authorial self-reflection on the very nature of the book and the process of writing it, among other elements, which resemble today's hypertext writing; or foundational Jewish texts like the Talmud, in which a typical page is a complex interlinked structure comprising the main texts as well as a dense array of marginal commentaries, interpretations, and expansions (Segal, 1996).

However, all the above precedents functioned under the constraints of the print technology – in contrast, their instantiation in electronic digital technology gave birth to a qualitatively different representational space, that of hypertext and hypermedia. Within this space, links are "alive," the "bridges" have assorted semantic and/or functional attributes, and the paths have become bi- and even multidirectional. Indeed, the book is now an interactive "machine" in which the producer as well as the consumer act as definers of the (ever-changing) scope and boundaries of the representational chunks, and their semantic and functional identities (Logan, 2000).

It has become clear that most knowledge manipulation functions we perform (e.g., storage, search, retrieval, exchange) for all kinds of purposes (e.g., learn, work, leisure time) take place within the huge interlinked repository of information on the Internet. The dissonance between the intellectual tools required for appropriate functioning in this new representational space (hyperacy) and the ones supplied by formal education (traditional literacy) is striking. Students are given tasks devised in terms of print technology (e.g., textbooks), but are sent to look for resources (search, read, synthesize) in hyperspace – without being equipped with the necessary literacy. If we replace "students" by "workers" or by "people," it is easy to understand the significance of the above dissonance between formally acquired and actually required skills for everyday life in the knowledge society. The actual challenge is to resolve this dissonance and supply the learners with the intellectual tools comprising the cognitive toolbox of hyperacy.

Personal Information Management Literacy

Definition. PIM is the process by which an individual stores his/her information items (e.g., documents, e-mail, Web favorites, tasks, contacts) to retrieve them later on.

Discussion. PIM is a fundamental aspect of people's interaction with computers – millions of computer users manage information items on a daily basis. Though people certainly managed physical information items before the age of the computer, PIM literacy developed in recent years as the amount of personal information that computer users need to handle increased dramatically. For example, users often create their own personal subset of the gigantic information world of the Internet (e.g., by using Web favorites) in their own computers to "keep found things found" (Bruce, 2005); they also receive large amounts of e-mail messages that typically pile up in their Inboxes, frequently with files attached (Whittaker and Sidner, 1996); and the ease of saving different versions of the same information item also added to the increase in the information to be handled. This vast increase of information items along with the inception of PIM systems that support its management (such as features in the operating system, the mailbox, or the browser) requires that users develop new PIM literacies.

The primary PIM skill is the ability to store information items in a way that facilitates its efficient retrieval. Components of this ability are, for instance, (a) giving meaningful names to information items and folders (meaningful to the user, as he/she will need to retrieve it later on); (b) avoiding creating folders with too little information items (as this increases the number of folders) or too many of them (as the user might find it hard to locate relevant information); (c) avoiding creating folders of ample hierarchal depth (as this hides information items and complicates their retrieval); (d) putting shortcuts to information items of high relevancy to the user on the desktop, to shorten their retrieval time and remind the user of their existence (Malone, 1983); and (e) avoiding clustering folders with irrelevant information items, which may compete for the user's attention (Bergman et al., 2003). Research has shown that in most cases, users remember where they put their information and so they navigate to the folder where it is stored to retrieve it (Boardman and Sasse, 2004). However, when they fail to remember the item's location, another PIM skill is required – the ability to search for an information item by using partial memory of past interactions with it as a cue.

Another important example of a PIM skill is "task management." This is not a novel form of literacy, but its importance has dramatically grown in the recent decade. Not only do "information workers" need to attend to more tasks, but also they are constantly being interrupted. When working on a task (e.g., writing a document), users also receive phone calls, e-mail messages, and instant messages (Czerwinski et al., 2004). These may distract users' attention and could result in neglecting the original task. However, the user cannot completely ignore the interruptions as some of them can be important or urgent. Learning to prioritize tasks is an essential PIM ability as it allows the users to stay in control of the order of tasks they are doing instead of drifting with the flood of information items and tasks that comes their way.

As with any literacy, PIM literacy can be taught. However, when teaching PIM literacy, one needs to remember that PIM is a field which involves particularly extensive individual differences and even idiosyncrasies – depending on users' personalities and the nature of their work. A great deal of research is still needed to identify strategies that account for individual differences and context variability, and for devising appropriate pedagogical solutions to teaching these strategies.

Coping with Complexity

Definition. This literacy encompasses the skills and methods required to *perceive* phenomena as complex (e.g., recognizing multiple actors or multiple layers, or emergent behavioral patterns), to *study and understand* these phenomena (e.g., devising multiple and alternative strategies, building and activating models), and to *implement* the gained understanding for coping with them.

Discussion. An enlightening passage in Brecht's (1982) play on Galileo's life presents the tremendous dissonance created in people's minds and lives as a result of critical shifts in perspective. Little monk, arguing with Galileo about his decision to give up science, says: "My parents…are simple people. They know all about olive trees, but not much else. As I study the phases of Venus I can visualize my parents sitting round the fire with my sister, eating their curded cheese…they are badly off, but even their misfortunes imply a certain order. There are so many cycles, ranging from washing the floor, through the seasons of the olive crop to the paying of taxes…They have been assured…that the whole drama of the world is constructed around them…What would my people say if I told them that they happen to be on a small knob of stone twisting endlessly through the void round a second-rate star, just one among myriads?" (pp. 65–66). The knowledge revolution that marked the beginnings of modern science required that people shifted from a world in which, in principle, all answers are known, to a world in which not even all questions are clear, to adopt a different cognitive and emotional stance, and to acquire a novel set of conceptual tools and skills. The world became less simple, less obvious, far more open to inquiry.

The current knowledge revolution, at the early stages of another paradigm shift in scientific thinking as embodied in complexity science (Phelan, 2001), once again poses the demand for new conceptual tools and skills. Simon (1996) claimed that the last century "has seen recurrent bursts of interest in complexity and complex systems," from the early interest in "holism," "Gestalts," "creative evolution," or "general systems" to the current work on "chaos," "adaptive systems," "genetic algorithms," and "cellular automata." A few centuries since becoming less simple, the world (natural, social, and artificial) has become definitely complex. And so have the questions about its workings, e.g., How is it that a group of cells can come together and organize themselves to be a brain? How do independent members of an economy each working chiefly for their own gain produce efficient global markets? (Mitchell, 1995). In the context of our discussion on new literacies, coping with complexity implies a challenge at three main levels: content, methods, and learning processes.

At the content level, the challenge derives from the conceptual reshuffling of the known world into novel configurations and entities (e.g., systems, networks), for which novel structural and functional traits are introduced (e.g., multiple levels, self-organization, chaotic behavior). The world, as object of study and learning, escapes the compartmentalized knowledge grids built over centuries, and rerepresents itself in hyperlinked knowledge configurations. Concepts – such as emergence, self-organization, interdependence, cellular automata, deterministic chaos, information flows and constraints, and system–environment interaction – are becoming key conceptual tools for qualitative reasoning and quantitative modeling and simulation (across disciplines) of real as well as synthetic complex systems (Jacobson and Wilensky, 2006).

At the methods level, it is fairly obvious that the above conceptual change is closely related to the knowledge technologies that allowed scientists to explore and redefine explanations about world phenomena as complex entities. Jackson (1996) claims that science is undergoing a metamorphosis as a result of the possibilities generated by the digital computer, which adds to the use of physical experiments and mathematical models (characteristic of the first metamorphosis which began about four centuries ago), the use of computer experiments as a powerful resource for scientific inquiry. New theoretical approaches have been generated, and new methodologies and tools as well (e.g., calculus-based differential equations, random walk or stochastic models, multiagent modeling tools). Adapting these methods and tools (from the scientific) to the educational milieu is not trivial, though some successful experience is already showing possible ways (e.g., Jacobson and Wilensky, 2006; Wilensky and Resnick, 1999).

Epilogue

What does it mean to be literate? The question with which we opened the chapter, apparently simple and straightforward, led us into the need to discuss an intricate body of definitions, changing perspectives, and clusters of skills and knowledge, in our search for a mindful answer to it.

From the first sections, which focused on the evolving definitions of literacy and the characteristics of the knowledge society, we have learned about the *complex nature* of what is conceived today to be "a literate person." From the third section, focusing on specific packages of knowledge and skills, we have learned about the *scope*, *content*, and *foci* of today's required literacies. It is obvious that the above-presented typology is neither exhaustive nor conclusive. Notwithstanding, it represents an effort to map the most salient sets of knowledge and skills both afforded and demanded by the new knowledge technologies – which, paradoxically, are mostly absent from the formal curricula in most educational systems.

In this concluding section, we briefly elaborate on the implications of the ideas and issues presented in this chapter for policy making and planning, and for assessment.

Concerning policy, the fundamental question to be answered relates to the way educational systems define their goals and plan their actions vis-à-vis the transformations undergoing outside school, in the knowledge society. The gap between the system's inner and outer worlds is evident, even though there is great variation among and within countries. The practical manifestations of this gap can be recognized at different levels, for example:

– *Accessibility*. While increasing number of youngsters gain access to computational and communication power on an individual basis, educational systems still struggle to pursue goals based on the optimization of computer: student ratios or school-computer-labs usage.
– *Teaching/learning processes*. While people in today's world learn about topics of their interest within digital repositories of information and networked communities of interest, not tied to time or space constraints, school systems' predominant processes are still textbook- and formal instruction-based, mostly also a digital, constrained to spatial and temporal fixed configurations.
– *Fostering literacy*. While the above survey in this chapter unveiled the complexity and multifaceted character of the skills and knowledge required for functioning as a literate person in the knowledge society, school systems' actually enacted curricula (regardless of declaratory rhetoric), still concentrate on a basic set of skills (e.g., "basics," 3R's), clearly attached to the tradition of the printed word technology. These are only a few examples of the contrasting visions, which policy and decision makers, and educational planners, will have to face while devising the future of educational systems.

Concerning the new literacies, the crucial policy questions relate to (a) the feasibility and (b) the ways and procedures – for bridging between the above and numerous other conflicting perceptions. The *feasibility* of the change depends primarily on policy and decision makers' openness and readiness to consider the defining characteristics of the knowledge society, among the factors that might assist in shaping the educational systems of the near future. Once this awareness is reached, the *how* should be defined, as answers to questions such as: How should essential literacies (e.g., visual, multimodal, hyperliteracy, coping with complexities) be integrated across the curriculum in all subjects? How to advance the transition from textbook-based *instruction* to digital hyperspaces-based *construction* of knowledge? How to foster sound syntheses between current and alternative spatial and temporal schooling configurations, for supporting individualized control over learning processes and information spaces management? And finally, there is the key question related to the proclaimed goal of "preparing the students for living in the future world." Future worlds are difficult to foresee, and in any case great portions of the current world are still "future" for many educational systems. A more appropriate phrasing of the question might be: How to prepare students first for functioning in the *current* changing world (the outer environment), and then how to prepare them to be able to *analyze* the features of, and *devise* ways to adapt to, upcoming (and still unknown) worlds?

Concerning assessment, the new literacies repertoire poses serious challenges at different levels. One aspect relates to the *complexity* of the ability to be measured: in most cases, it is a functional chunk comprising a number of interrelated skills and procedures. Measuring isolated components may result in a distorted depiction of the students' ability. Another aspect concerns the fact that most abilities are actually *processes* – proceeding in stages and involving different levels of cognitive activity. The assessment of processes – as opposed to outcomes – will demand a great deal of conceptual as well as methodological research and development work. An additional aspect refers to the *meta-level perspective*: new literacies encompass not only knowledge about how to use a tool or perform a procedure, but also the gradual construction of a digital-world stance. This may include abilities such as the understanding of what new possibilities are afforded by a tool besides those technically indicated by its manual; how new features and processing processes may emerge from the combinations of tools and procedures; or how to approach a newly developed technology.

The *quantitative* aspect is not less important than the previous: learning and working with ICT implies the use of numerous tools and the activation of endless abilities, sometimes in simultaneous fashion – thus, the space of candidates for the assessment is immense. Finally, the *scalability* challenge: supposing that all the previous aspects were faced and solved for the individual student, the question remains of if and how these solutions can be scaled to assess schools' or whole systems' populations.

In face of this complex reality, Anderson suggests that for practical purposes, "A project to systematically assess new literacies, particularly large scale studies, must narrow or delimit the scope of the assessment in various ways. If one is interested in a very new and novel media, the choices are likely to be very limited. But if one is interested in a broad scope of ICTs, then it is necessary to prioritize components and dimensions of the full range of potential content, knowledge, and skills that could be assessed" (Anderson, in press). Summarizing our above brief elaboration on the challenges for assessment, there is a need for considerable research and development work aiming to devise conceptual models and methodologies for measuring complex abilities, processes, performance, and overall stance, with large populations.

As a manner of concluding remark, the issues discussed along the chapter reflect the actual concerns of the educational community about the evolving new literacies. Many of these concerns are actually open questions still waiting for examination and for the devise of wise answers. However, we might close the chapter with a claim we believe is consensus: Literacies are cultural constructs, closely tied to the technologies affording and demanding them; societies, via their educational systems, should foster their young members' natural integration into the evolving cultural/technological landscapes by supporting the mastering of skillful functioning in the knowledge society as part of the formal education cycle.

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1.3

THEORETICAL PERSPECTIVES INFLUENCING THE USE OF INFORMATION TECHNOLOGY IN TEACHING AND LEARNING

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Overview

In conceptualizing the nature of schooling, the common parlance is to describe a curriculum that contains content and is conveyed by a particular set of pedagogies. Its learning outcomes are evaluated by a suite of assessments; and – in the case of technology-based instruction – various aspects of content, pedagogy, and assessment are instantiated via computer tools and applications, digital media, and virtual environments. Other chapters in this handbook describe the relationships between information technology and curriculum, content, and assessment. This chapter discusses how various theories of learning and forms of pedagogy shape the technologies used to instantiate them, and how the evolution of computers and telecommunications is widening the range of instructional designs available.

The Relative Roles of Content, Pedagogy, Assessment, and Technology in Learning

An easy way to understand the role of information technology in helping students learn a curriculum composed of knowledge and skills, delivered via pedagogy, and evaluated through assessment is to see the tools, applications, media, and virtual environments used as instrumental. Information and communication technologies (ICT) aid with representing content, engaging learners, modeling skills, and assessing students' progress in a manner parallel to how a carpenter would use a saw, hammer, screwdriver, and wrench to help construct an artifact. The two key points in this analogy are (1) the tools make the job easier and (2) the result is of higher quality than possible without the tools.

J. Voogt, G. Knezek (eds.) *International Handbook of Information Technology in Primary and Secondary Education, 43–62.*

A simple idealized example that illustrates the use of ICT in helping students learn one portion of a curriculum is presented below:

> Ms. Smith was using a graphing calculator application on her handheld device to demonstrate how the graph for a particular type of function alters as various parts of the function (e.g., constants, variables, operators) change. Her graphing calculator was linked to a data projector so that all students in the class could observe what she was doing. In small teams, the students then practiced the same approach, using their individual calculators to alter the graphs of functions and discussing in the teams what they saw. Ms. Smith walked around the room watching the students, now using a different application on her handheld device to note, in terms of standardized rubrics, at which level of mathematical understanding each student was performing. From time to time, she intervened to remediate a misconception held by a student.

This illustration depicts the basic use of three technologies (a graphing calculator application and an assessment application on a handheld device, as well as a data projector) to aid students in learning a particular set of knowledge and skills (how the form of a particular type of function determines its graphical representation) using a variety of pedagogies (e.g., presentation, modeling, students' active construction of knowledge, collaborative learning) and conducting individualized, formative assessment. The teacher could attempt a similar form of instruction without these technologies, but this would require much greater effort and would likely result in lower learning gains and less student engagement.

Note that, even in this simple example, the exact demarcations between content, pedagogy, and assessment are difficult to establish. Is the graphing calculator's capability to rapidly display changes in a graph a representational aspect of content, or a pedagogical affordance? Is the handheld's capacity to allow facile, mobile input into a sophisticated assessment rubric an instructional facet of diagnostic remediation, or a form of summative evaluation? Content, pedagogy, and assessment are not discrete containers; and a particular technology may provide affordances that simultaneously influence more than one of these aspects of curriculum.

People who espouse particular forms of instruction have sought to develop technologies specifically instrumental for that type of pedagogy. For example, PowerPoint is an application developed to aid with the process of lecturing, a form of presentational/assimilative pedagogy. This tool is not intended to facilitate assessment and is deliberately designed to communicate a broad spectrum of content – although in fact PowerPoint is better at conveying some types of material (e.g., bullet points of information) than others (e.g., dynamic representations of changes in a system over time). An instructor can use PowerPoint well or poorly, with concomitant effects on the audience's engagement and learning.

What are the major types of instructional technologies that educators have created – or adapted – over the past few decades to serve as their toolbox? On what philosophies about teaching and instructional design are these pedagogical tools, applications, media, and environments based? For what types of learning has each proven effective?

The Current Spectrum of Instructional ICT

Many alternative conceptual frameworks exist for describing the relationships among learning theories, pedagogical strategies, instructional designs, and information and communication technologies. For some parts of its analysis, this chapter draws on an *Instructional Design Knowledge Base* developed by Dabbagh (2006) (http://classweb.gmu.edu/ndabbagh/Resources/IDKB/models_theories.htm). In the matrix that represents this conceptual framework, each school of thought posits basic principles and theories about learning; these inform the goals and models that school of thought has for instruction, which in turn influences the group's perspective on the design of pedagogical media. Many category systems are available to characterize contrasting positions about these issues. Drawing on Ertmer and Newby (1993) and Driscoll (2005), Dabbagh lists three competing schools of thought on how people learn: Objectivism/Behaviorism, Cognitivism/Pragmatism, and Constructivism/Interpretivism:

1. Objectivism posits that reality is external and is objective, and knowledge is gained through experiences. Behaviorists believe that, since learning is based on experience, instruction centers on manipulating environmental factors to create instructional events inculcating content and procedures in ways that alter students' behaviors.
2. Pragmatism posits that reality is mediated through cognitively developed representations, and knowledge is negotiated through experience and thinking. Cognitivists believe that, since learning involves both experience and thinking, instruction centers on helping learners develop interrelated, symbolic mental constructs that form the basis of knowledge and skills.
3. Interpretivism posits that reality is internal, and knowledge is constructed. Constructivists believe that, since learning involves constructing one's own knowledge, instruction centers on helping learners to actively invent individual meaning from experience.

Each school of thought is not a single unified theory, but rather a collection of theories distinct from each other, but loosely related by a common set of fundamental assumptions. This chapter draws on Dabbagh's framework, but provides a somewhat different perspective on each school of thought and its work, based on material from the National Research Council report, *How People Learn* (Bransford et al., 2000). Also, given the limits on space for a single chapter, the descriptions presented for each position are necessarily oversimplified.

Of course, educational ICT do not neatly cluster into discrete categories. Any given pedagogical tool, application, medium, or environment may incorporate perspectives from more than one of these intellectual positions. Imagine a multidimensional design space in which various specific instantiations of instructional technologies are represented; the dimensions reflect assumptions about learning, teaching, and instructional design. Some areas of that design space are more densely populated with clusters of ICT. These represent the schools of thought sketched below, but many outliers (not delineated in this chapter for reasons of space) are also present.

Behaviorist Instructional Technologies

As Dabbagh describes, Behaviorist theories of learning assume that knowledge is an absolute, reflecting universal truths about reality. Human behaviors, such as learning, are purposive, but are guided by unknowable inner states. Relationships between contextual instructional variables (stimuli) and observable, measurable student behaviors (responses) are the means to generate learning. Learning is indicated when a correct response follows the presentation of an instructional environmental stimulus. Instruction uses immediate consequences to reinforce behaviors to be learned and to repress incorrect responses to a pedagogical stimulus.

> As a basic example of this model of teaching and learning, a drill-and-skill instructional application is presenting a student with a series of single digit addition problems. Each time the student gets an answer correct, music plays and an entertaining animation is shown. Each time an incorrect answer is entered, a message is displayed, such as "Wrong; Try Again." The problems are programmed to repeat occasionally, with problems previously answered incorrectly displayed more frequently. The instructional program keeps track of right and wrong answers, so the teacher can access information about the learner's performance over time.

The psychological theories that underlie Behaviorist instruction initially were developed about a century ago and are associated with researchers such as Skinner (1950), Thorndyke (1913), and Watson (1913). Some Behaviorist researchers were willing to acknowledge the existence of inner states that might influence learning (Hull, 1943; Spence, 1942). Elaborate, modern instructional design strategies predominantly based on Behaviorist theories include Gagne (1988), Dick and Carey (1996), Smith and Ragan (1999), and Merrill (2002).

As Dabbagh indicates, in this school of thought, the purpose of education is for students to acquire skills of discrimination (recalling facts), generalization (defining and illustrating concepts), association (applying explanations), and chaining (automatically performing a specified procedure). The learner must know how to execute the proper response as well as the conditions under which the response is made. Knowledge and skills are transferred as learned behaviors; in classic Behaviorist instruction, internal mental processing is not considered as part of instructional design or assessment. Student motivation to achieve these goals is extrinsic, by associating pleasant stimuli with correct answers and neutral or even negative stimuli with incorrect responses.

Computer-assisted instruction (CAI) and learner management systems (LMS) are the two types of instructional technologies most closely associated with this school of thought, although many other ICT tools and applications utilize some aspects of Behaviorist design. Atkinson (1968) and Suppes (Suppes and Morningstar, 1968) were pioneers of computer-based instruction, as exemplified by the development of the PLATO and TICCIT CAI systems used in some schools in the 1970s. Instructional designers have since utilized this educational philosophy to create huge amounts of educational software, training students on content and skills in fields as disparate as reading, geography, history, mathematics, typing, science, and the operation of military equipment.

What the parts of these diverse subject areas taught by CAI have in common is an emphasis on factual knowledge and recipe-like procedures: material with a few correct ways of accomplishing tasks. So, for example, CAI can teach simple skills such as alternative algorithms for division, or contrasting ways to assemble and disassemble a gun, in which number of permissible variants is small and the end result is always the same. Factual knowledge, such as the year Columbus discovered America, is similar in its cognitive attributes: one right answer, basic mental processes primarily involving assimilation into memory. A contrasting illustration of knowledge and skills not well taught by CAI is learning how to write an evocative essay on "My Summer Vacation." Behaviorist instruction can help with the spelling and grammar aspects of this task, but effective literary style is not reducible to a narrow range of "correct" rhetorical and narrative processes.

Learning management systems, prevalent in the 1990s and still operational today, involve more elaborate forms of Behaviorist instruction via Web-based media, with embedded, sometimes elaborate multimedia presentations; limited branching that provides alternative explanations for struggling students; multiple types of extrinsic engagement; and detailed recordkeeping that presents analytic summaries for teachers and parents. However, the underlying pedagogies in LMS closely resemble CAI.

Many research projects have evaluated the effectiveness of CAI as contrasted with conventional instruction, including meta-analyses that combine results across large numbers of studies. Typical of the latter is a recent meta-analysis of CAI in science education (Bayraktar, 2001): An overall effect size of 0.273 was calculated from 42 studies yielding 108 individual effect sizes, suggesting that a typical student moved from the 50th percentile to the 62nd percentile in science when CAI was used as compared to conventional classroom instruction. Effect sizes in the range of 0.15–0.3 are typical of meta-analyses for modern forms of CAI and LMS, if those instructional media are used for the type of content and skills for which they are best suited (Waxman et al., 2003).

CAI and LMS as pedagogical applications are limited both in what they can teach and in the types of engagement they offer to learners. As discussed above, only some forms of content and skills are effectively mastered by Behaviorist instructional methods, and much of modern curriculum lies outside the range of these pedagogical media. Also, learning involving low-level retention is typically not deeply interesting no matter what form of motivation is used; so many students quickly tire of music, animations, simple games, and other CAI forms of extrinsic reward, leading to apathy about mastering content and skills. This weakness is exacerbated by a fundamental assumption of Behaviorist instructional design that no complex knowledge or skill is learnable until the student has mastered every simple underlying subskill. This tenet leads to long initial sequences of low-level CAI in which students often lose sight of why they should care about learning the material, which may seem to them remote from the eventual goal-state of a more complex knowledge or skill with real-world utility.

Cognitivist Instructional Technologies

As Dabbagh describes, Cognitivist theories of learning assume that reality is objective, but mediated through symbolic mental constructs. Students learn through mastering building blocks of knowledge based on preexisting relationships among content and skills. Instructors organize and sequence these building blocks to facilitate optimal mental processing. Knowledge acquisition is a mental activity that also entails internal coding and structuring by the student. Successful learning is dependent not only on what the teacher or pedagogical medium presents, but also on what the student does to process this input, storing and retrieving information organized in memory.

> An example of this type of teaching and learning is the Andes Physics Tutoring System (VanLehn et al., 2005). Andes aids college students with physics homework problems. Its screen simultaneously presents each problem and provides specialized workspaces for learners to draw vectors and coordinate axes, define variables, and enter equations. These are actions that parallel what students do when solving physics problems with pencil and paper. However, unlike pencil and paper representations, Andes generates immediate feedback: Correct student entries are colored green; incorrect, red. Also unlike pencil and paper, variables are defined by filling out a dialogue box that forces students to precisely state the semantics of variables and vectors; for example, if students include an undefined variable in an Andes equation, the equation turns red and a message box pops up indicating which variable(s) are undefined. In addition, Andes includes a mathematics package: When students click on the button labeled "$x = ?$", Andes asks them for what variable they want to solve, then tries to solve the system of equations that the student has entered. Andes provides three kinds of help: It pops up an error message whenever a slip in problem solving is likely due to lack of attention rather than lack of knowledge, it enables students to ask for help in understanding why Andes has flagged what they have just entered as an error, and it enables learners who are confused to ask what they should do next. The help Andes provides is a sequence of increasingly specific hints. As the student solves a problem, Andes computes and displays a score that is a complex function of degree of correctness, number of hints, and good problem-solving strategies.
>
> Contrasting this example to the Behaviorist illustration presented earlier provides a sense of the differences in pedagogical media developed by these two schools of thought.

The various psychological theories that underlie differing models within the general framework of Cognitivist instruction were developed by diverse groups during the second half of the twentieth century. Researchers whose theories were formative in developing this school of thought include Anderson (1993), Bruner (1960), Mayer (1977), Norman (1980), Newell and Simon (1972), and Palincsar and Brown (1984). Instructional design strategies based on Cognitivist theories often are designed to help students understand disciplinary knowledge (Case, 1992; Lee and Ashby, 2001; Hunt and Minstrell, 1994).

An example of an extensively developed, empirically grounded Cognitivist theory is Richard Mayer's work on multimedia learning. As summarized by Mayer and Moreno (1998):

> In multimedia learning, the learner engages in three important cognitive processes. The first cognitive progress, selecting, is applied to incoming verbal information to yield a text base and is applied to incoming visual information to yield an image base. The second cognitive process, organizing, is applied to the word base to create a verbally based model of the to-be-explained system and is applied to the image base to create a visually based model of the to-be-explained system. Finally, the third process, integrating, occurs when the learner builds connections between corresponding events (or states or parts) in the verbally based model and the visually based model.

Mayer's theory illustrates goals for instruction characteristic of the Cognitivist school of thought, which include (National Research Council, 2005):

- Providing a deep foundation of factual knowledge and procedural skills
- Linking facts, skills, and ideas via conceptual frameworks – organizing domain knowledge as experts in that field do, in ways that facilitate retrieval and application
- Helping students develop skills that involve improving their own thinking processes, such as setting their own learning goals and monitoring progress in reaching these

Student motivation to achieve these goals is determined by a variety of intrinsic and extrinsic factors, such as satisfaction from achievement, contributing to others, and challenge and curiosity (Pintrich and Schunk, 2001).

Although a wide variety of instructional technologies incorporate some principles from Cognitivism, intelligent tutoring systems (ITS) like Andes are veridical examples, illustrating pedagogical media based on this school of thought. As VanLehn (2006) describes, ITS have two loops by which the computer guides learning. The outer loop executes once for each task, where a task usually consists of solving a complex, multistep problem; its purpose is to select an appropriate task for the learner, given the student's past performance. The inner loop executes once for each step taken by the student in the solution of a task; its purpose is to provide feedback and hints on that specific step, as well as to assess the student's evolving competence and to update a model of what the student is judged to know at this point in the instructional sequence. That model of presumed student knowledge is eventually used by the outer loop to select a next task that is appropriate for the student.

The National Science Foundation (NSF)-funded Pittsburgh Science of Learning Center (http://www.learnlab.org/) is dedicated to designing and studying this type of instructional strategy. Core research questions this Center is currently addressing include:

1. *Cotraining*. When, how, and why do students' use of multiple inputs, representations, or strategies facilitate learning, by providing an avenue for "self-supervised" learning that goes beyond learning supported by teacher and peer feedback?

2. *Dialogue*. When, how, and why does classroom talk and tutorial dialog, whether by human or computer, promote robust learning?
3. *Refinement*. How do learners determine the causal connections between cues in the environment, their actions, and desired knowledge; and how can instructional support and feedback facilitate learners in making such connections?
4. *Fluency*. How does more isolated learning of knowledge components interact with learning within larger authentic performances, and how can instruction support such interactions to yield more fluent and robust learning?

Scholars disagree on how broad a range of knowledge and skills Cognitivist instructional technologies can teach. What the diverse subject areas now taught by pedagogical media like ITS have in common is well-defined content and skills, material with a few correct ways of accomplishing tasks. Current examples of ITS usage include mathematical reasoning, problem solving in scientific fields, learning a second language, and learning to read. The range of knowledge and procedures is somewhat similar to what is currently taught by Behaviorist instructional technologies, but more complex in detailed learning outcomes. Proponents of Cognitivist approaches believe that eventually ITS-like educational devices, coupled with human instructors, will teach most of the curriculum, including less-well-defined skills such as the rhetoric of writing an evocative essay. However, three decades of work toward this ambitious goal have yielded limited progress to date.

Some research studies have evaluated the effectiveness of ITS (illustrative of veridical Cognitivist instructional technologies). Illustrating typical results, Ainsworth and Grimshaw (2004) found that their REDEEM system for authoring intelligent tutors improves learning by about the same amount as nonexpert human tutors do compared to classroom teaching (REDEEM/CBT = 0.59 sigmas, human tutor = 0.4 (nonexpert) to 2.0 (expert)). Effect sizes for passage comprehension gains using an intelligent reading tutor, compared to silent reading, ranged from 0.48 to 0.66 (Mostow et al., 2003). VanLehn et al. (2005) reported that the overall effect sizes for the Andes intelligent tutoring system, compared to conventional methods of doing homework, ranged from 0.25 on the course final exam to 0.61 on the course hour exams; the latter were more representative in content and format of the knowledge and skills taught by Andes. Overall, these and similar findings about other ITS indicate a higher level of educational effectiveness than CAI or LMS instructional technologies.

Constructivist Instructional Technologies

As Dabbagh describes, Constructivist theories of learning assume that meaning is imposed by the individual rather than existing in the world independently. People construct new knowledge and understandings based on what they already know and believe, which is shaped by their developmental level, their prior experiences, and their sociocultural background and context. Knowledge is embedded in the setting in which it is used; learning involves mastering authentic tasks in meaningful, realistic situations. Learners build personal interpretations of reality based on experiences and interactions with others, creating novel and situation-specific understandings. Instruction can foster learning by providing rich, loosely structured experiences and guidance (such as apprenticeships, coaching, and mentoring) that encourage meaning-making without imposing a fixed set of knowledge and skills.

Constructivist pedagogical media span a wide range. An example that illustrates many aspects of this approach is the Jasper Woodbury mathematics curriculum (National Research Council, 2000, p. 208). Middle school students in math class view 15 min video adventures that embed mathematical reasoning problems in complex, engaging real-world situations. One episode depicts how architects work to solve community problems, such as designing safe places for children to play. This video ends with this challenge to spend the next week of class meetings designing a neighborhood playground:

> Narrator: Trenton Sand and Lumber is donating 32 cubic feet of sand for the sandbox and is sending over the wood and fine gravel. Christina and Marcus just have to let them know exactly how much they'll need. Lee's Fence Company is donating 280 feet of fence. Rodriguez Hardware is contributing a sliding surface, which they'll cut to any length, and swings for physically challenged children. The employees of Rodriguez want to get involved, so they're going to put up the fence and help build the playground equipment. And Christina and Marcus are getting their first jobs as architects, starting the same place Gloria did 20 years ago, designing a playground.

Students in the classroom help Christina and Marcus by designing swingsets, slides, and sandboxes; then building models of their playground. As they work through this problem, they confront various issues of arithmetic, geometry, measurement, and other subjects: How do you draw to scale? How do you measure angles? How much pea gravel do we need? What are the safety requirements?

Contrasting this example to the two schools of thought depicted earlier provides a sense of the differences in pedagogical media developed by these differing theories of learning and teaching. In particular, note that these students are learning simpler skills in the context of a complex task, in sharp contrast to Behaviorist instructional design.

The various social science theories that underlie differing models within the general framework of Constructivist instruction were developed by diverse groups over the past century. Researchers whose theories were formative in developing this school of thought include Bransford (Cognition and Technology Group at Vanderbilt – CTGV, 1993), Cobb et al. (1992), Dewey (1916), Johnson and Johnson (1989), Lave and Wenger (1991), Papert (1980), Piaget (1973), Rogoff (1990), Spiro et al. (1991), and Vygotsky (1978). Instructional design approaches based on Constructivist theories include anchored instruction (CTGV, 1993), case-based learning (Kolodner, 2001), cognitive flexibility theory (Spiro et al., 1991), collaborative learning (Barron, 2000), microworlds and simulations (White, 1993; White and Frederickson, 1998), mind-tools (Jonassen, 2005), and situated learning in communities of practice (Lave and Wenger, 1991).

As Dabbagh indicates, this school of thought is characterized by goals for instruction that include:

- Instruction is a process of supporting knowledge construction rather than communicating knowledge.
- The role of the teacher is a guide, rather than an expert transferring knowledge to novices' "blank slates."
- Learning activities are authentic and center on learners' puzzlement as their faulty or incomplete knowledge and skills fail to predict what they are experiencing.
- Teachers encourage students in reflecting on experiences, seeking alternative viewpoints, and testing viability of ideas.

Student motivation to achieve these goals is determined by factors such as challenge, curiosity, choice, fantasy, and social recognition (Malone and Lepper, 1987; Pintrich and Schunk, 2001).

A broad spectrum of instructional technologies incorporates some principles from Constructivism. Many of these pedagogical media utilize tools and simulations to enable students to collect data via probes, to focus on complex skills while a tool does simple underlying tasks, to comprehend complicated ideas through visualizations that take advantage of the mind's ability to recognize patterns in sensory data, to test alternative models of reality via simulation, and to learn science, math, and technical skills through using programming to develop personally expressive representations such as digital art and movies (National Research Council, 2000). Providing examples that illustrate the full range of these features in various forms of Constructivist technologies is beyond the scope of this chapter.

Potentially, Constructivist approaches can teach a very broad spectrum of knowledge and skills, in contrast to current versions of Behaviorist and Cognitivist instructional designs. However, the efficiency of Constructivist learning technologies for material that these other two schools of thought can teach is questionable. Content and skills that are relatively invariant regardless of individual perspective (e.g., arithmetic operations, Newtonian physics) are learned more quickly when taught as "truths" than when found through exploration that, in extreme unguided forms, involves students slowly reinventing civilization (Kirschner et al., 2006). Proponents of Constructivism respond that their pedagogical media help students learn these types of knowledge with more depth and engagement and with greater meaning and transfer to life settings. Ultimately, as with all decisions about pedagogy, what is "best" depends on the instructional situation: the goals of the learning experience, the attributes of the students, the type of content, and the timeframe and resources available.

Identifying a suite of research studies that assess the power of all types of Constructivist pedagogical media is difficult. The range of these instructional technologies is quite broad, and the kinds of knowledge and skills they aid in learning are diverse and sophisticated, undercutting attempts to identify quantitative measures that span this range of teaching media. Projects such as the Jasper Woodbury series, described earlier, have extensive research results that document the effectiveness of this pedagogical approach. For example, compared to students receiving conventional mathematics instruction, students in Jasper classrooms showed greater effectiveness in solving complex problems and had more positive attitudes toward mathematics and complicated challenges (CTGV, 1992). (A detailed exposition of many types of research findings about Jasper is available in "The Jasper Project: Lessons in Curriculum, Instruction, Assessment, and Professional Development" (CTGV, 1997).)

A second Constructivist curriculum with substantial research findings is the ThinkerTools project by White and Frederickson (in press). Middle school students with no direct physics instruction taught with this approach did significantly better in solving a set of classic, qualitative force and motion problems than did high school students taught using traditional methods. Pupils at a young age displayed high level of interest and competence in "doing science." Students were capable of thinking at an abstract level both about the domain theories that they were developing and about the relationship of theory and evidence. High school and college students saw how models of a physical system may take many forms, each focusing on different objects and interactions as elementary units of analysis, and each employing a different type of reasoning process. Middle school students who were initially classified as low achieving (based on a standardized test used in the school districts) were able to approach the level of high-achieving students in the quality of their inquiry projects. The use of software advisors to model inquiry processes and general cognitive, social, and metacognitive processes – combined with the activity of having students take on the roles of advisors – was effective in improving students' inquiry skills and in developing their metacognitive theories and capabilities. Similar types of results showing high engagement and solid learning and metacognitive outcomes characterize many high-quality Constructivist curricula.

"Next-Generation" Pedagogical Media

As ICT continue to advance, new types of instructional opportunities are emerging. Another chapter in this handbook, "Emerging Technologies for Collaborative, Mediated, Immersive Learning" (Clarke et al., 2008), describes the evolution of the human computer interface:

- The familiar "world-to-the-desktop" interface provides access to distributed knowledge and expertise across space and time through networked media. Sitting at their laptop or workstation, students can access distant experts and archives, communicate with peers, and participate in mentoring relationships and virtual communities of practice. This interface provides the models for learning that now underlie most tools, applications, and media in K-12 education.
- Emerging *multiuser virtual environment (MUVE)* interfaces offer students an engaging "Alice in Wonderland" experience in which their digital emissaries in a graphical virtual context actively engage in experiences with the avatars of other

participants and with computerized agents. MUVEs provide rich environments in which participants interact with digital objects and tools, such as historical photographs or virtual microscopes. Moreover, this interface facilitates novel forms of communication among avatars, using media such as text chat and virtual gestures. This type of "mediated immersion" (pervasive experiences within a digitally enhanced context), intermediate in complexity between the real-world and paint-by-numbers exercises in K-12 classrooms, allows instructional designers to construct shared simulated experiences otherwise impossible in school settings.

– *Augmented reality (AR)* interfaces enable "ubiquitous computing" models. Students carrying mobile wireless devices through real-world contexts engage with virtual information superimposed on physical landscapes (such as a tree describing its botanical characteristics or an historic photograph offering a contrast with the present scene). This type of mediated immersion infuses digital resources throughout the real world, augmenting students' experiences and interactions.

That chapter depicts how the latter two interfaces enable immersion in rich simulated contexts, in which collaboration among learners is mediated and supported by a wide range of tools and applications. The reader is urged to scan that chapter for vignettes depicting how these new types of pedagogical media can accomplish this.

Early designs utilizing these immersive interfaces, such as the author's work on the River City MUVE (http://isites.harvard.edu/icb/icb.do?keyword=harp) and the Alien Contact! augmented reality (http://education.mit.edu/arworkshop/), illustrate that these pedagogical media can incorporate and intermingle all three schools of thought, bringing to bear whichever form of instruction is most appropriate as dictated by the immediate situation of the student. Preliminary research results are promising, particularly for the large proportion of students who now give up on themselves and school because they are not taught in ways compatible with their learning styles, strengths, and preferences (Dede, 2005). These immersive media also offer powerful laboratories for studying teaching and learning, because a detailed, time-stamped record of student actions and utterances is automatically collected (Ketelhut et al., 2007). This offers great potential for assessment, both from a research perspective and in terms of real-time, formative, diagnostic information that could help tailor instruction to individual needs.

Illustrative Historic Controversies About Technology and Pedagogy

As discussed above, the history of ICT documents waves of technologies (e.g., computer-assisted instruction, intelligent tutoring systems, tools, hypermedia, computer-supported collaborative learning, games) designed to empower particular forms of instruction in vogue at that time. Given decades of developing information technologies that aid various kinds of teaching and learning, what debates have emerged about media and pedagogy?

Is Learning via Media Intrinsically Inferior to Learning Face to Face?

Historically, technology-based education in general, and distance education and online learning in particular, have suffered from widespread misconceptions that these forms of learning are inferior to the traditional "gold standard" of face-to-face instruction (Dede, in press). Such false beliefs, which are contrary to considerable evidence across multiple research studies (Dede et al., 2002; Cavanaugh, 2001; Schacter, 2001), have retarded the adoption of powerful models for teaching based on sophisticated computers and telecommunications. Now, many levels of education are finally recognizing the value of ICT to aid learning, whether used as a complement to face-to-face instruction (termed hybrid, blended, or distributed approaches) or as a means of instruction without collocated personal presence (distance education).

The learning styles, strengths, and preferences for students of all ages are changing as their usage of media alters the processes by which people receive, create, and share knowledge (Dede, 2005). In the author's studies of "mediated learning" (Dede et al., 2002), many students reported that the use of asynchronous learning environments positively affected their participation and their individual cognitive processes for engaging with the material. Students also indicated that threaded discussions online often fostered better quality conversations than they had experienced in traditional classrooms. In addition, students generally indicated that the use of synchronous media enhanced their learning experience and complemented other delivery modes used in the course, including face to face. They indicated that synchronous virtual media helped them get to know classmates with whom they might not otherwise individually interact within a classroom setting; synchronous media also provided a clear advantage over asynchronous media in facilitating the work of small groups.

Overall, many students silent and passive in face-to-face settings "find their voices" in various forms of mediated interaction. Unfortunately, most instructors mistakenly assume that, because face to face is the form of learning/teaching with which they are most comfortable and adept, their students must be similar in their learning preferences and styles.

Do Media Influence Learning?

Historically, controversies have also arisen about the relationship between information technologies and pedagogy. A classic example of this is the extended debate between Richard Clark and Robert Kozma on the role of media (if any) in influencing learning. Beginning in the early 1980s, Clark wrote a series of widely read articles (e.g., 1983, 1994), arguing that media are "mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition." The core of Clark's thesis is that no single media attribute serves a unique cognitive effect for some learning task, because the same effect can be accomplished via various types of media, and therefore such attributes must be proxies for some other variables that are instrumental in learning gains. Clark (1994) further claimed that "media not only fail to influence learning, they are also not directly responsible for motivating learning," citing research evidence that students' beliefs about their chances to learn from any given media are different for different students and for the same students at different times.

During the early part of the 1990s, Kozma responded with a series of articles (e.g., 1991, 1994), taking a different position and fueling a lively scholarly debate. Kozma argued various studies showed that innovative applications of new media resulted in improved learning outcomes (e.g., the Jasper Woodbury curriculum described earlier). Clark was unconvinced, replying that such studies failed to control for instructional method and were therefore confounded; he argued that, without using a visual medium, teachers could present mathematics via engaging storylines based in real-world situations. Ultimately, Kozma (1994) suggested a reframing of the debate, "I believe that if we move from 'Do media influence learning?' to 'In what ways can we use the capabilities of media to influence learning for particular students, tasks, and situations?' we will both advance the development of our field and contribute to the restructuring of schools and the improvement of education and training" (p. 18).

Kozma's proposal to shift the debate to an instrumental point of view makes sense. We can imagine scholars of carpenter's tools arguing about whether a screwdriver can aid construction. One side of the debate posits that, because one can use the edge of a hammer's claw to clumsily turn a screw, the screwdriver does not influence construction, because another tool (or even a very strong fingernail) could do a poorer version of the same job. Certainly, how the screwdriver is helping construction is through the application of torque, and one can generate torque in a variety of ways. However, screwdrivers are specifically designed to facilitate torque, so from an instrumental point of view to argue that the screwdriver cannot influence construction seems an overly narrow perspective about cause and effect.

No instructional ICT is a technology comparable to fire, where one only has to stand near it to get a benefit from it. Knowledge does not intrinsically radiate from computers, infusing students with learning as fires infuse their onlookers with heat. However, media are able to aid various aspects of learning, such as visual representation, student engagement, and the collection of assessment data. Determining whether and how each instructional technology can best enhance some aspect of a particular pedagogy is as sensible instrumentally as developing tools that aid a carpenter's ability to construct artifacts. But are some media "off limits" because they are antithetical to learning and the objectives of education?

Can Some Media Undercut the Purposes of Education?

Beginning in 1980 with his book *Mindstorms*, Seymour Papert posited that some instructional technologies are detrimental to education because they encourage a pedagogy that is inimical to "true" learning. In *The Children's Machine* (1993), he argued that schooling "remains largely committed to the educational philosophy of the late nineteenth and early twentieth centuries" by attempting to "impose a single way of knowing on everyone." This type of instruction, according to Papert, is based on segregation by age, teachers who shape passive minds, an emphasis on reading as the "essential route to knowledge" through presentation/assimilation of information, and testing as the sole measure of success. He criticized schools for holding back learning through too much emphasis on abstract-formal knowledge, labeling students' knowledge as second-rate if it lacks precision.

Papert (1996) applied this philosophy about learning and teaching to make judgments about the value of various information technologies for education. He saw uses of ICT for CAI and ITS as flawed, because they emphasize Behaviorist and Cognitivist views of learning rather than what he termed a "constructionist" perspective on learning. In constructionism, a variant of Constructivist approaches, media of various types are used by learners to develop their own knowledge (rather than assimilating content and skills from a teacher) through constructing some external, shareable artifact (e.g., a computer program). Overall, Papert argued that some types of media are intrinsically better for learning and teaching, because instructionist (e.g., Behaviorist, Cognitivist) media control children's learning, while constructionist media empower students to take charge of their own education.

Given that people disagree both about what constitutes good pedagogy and about what are appropriate goals for schooling, that some scholars argue for certain types of instructional media and against others is not surprising. The core issue is whether there is just one preeminent way of learning/teaching for every student, for every subject, for all legitimate purposes of schooling. Ironically, in arguing that some types of instructional technology should be avoided because they impose a single way of knowing, Papert's perspective on learning, teaching, and media ends up itself narrowly oriented toward constructionism as the one right answer. He presents constructionism as if it were as perfect a solution for all learning as is presentational/assimilative pedagogy for the instructionist philosophers he labels as inflexible and dogmatic.

Reconceptualizing Media as Empowering Diversity in Learning

In fact, as the spectrum of theories about pedagogy discussed earlier suggests, learning is a human activity quite diverse in its manifestations from person to person. Consider three activities in which all humans engage: sleeping, eating, and bonding. One can arrange these on a continuum from simple to complex, with sleeping toward the simple end of the continuum, eating in the middle, and bonding on the complex side of this scale. People sleep in roughly similar ways; if one is designing hotel rooms as settings for sleep, while styles of décor and artifacts vary somewhat, everyone needs more or less the same conditions to foster slumber.

Eating is more diverse in nature. Individuals like to eat different foods and often seek out a range of quite disparate cuisines. People also vary considerably in the conditions under which they prefer to dine, as the broad spectrum of restaurant types attests. Bonding as a human activity is more complex still. People bond to pets, to sports teams, to individuals of the same gender and of the other gender. They bond sexually or platonically, to others similar or opposite in nature, for short or long periods of time, to a single partner or to large groups. Fostering bonding and understanding its nature are incredibly complicated activities.

Educational research strongly suggests that individual learning is as diverse and as complex as bonding, or certainly as eating. Yet theories of learning and philosophies about how to use ICT for instruction tend to treat learning like sleeping, as a simple activity relatively invariant across people, subject areas, and educational objectives. Current, widely used instructional technology applications have less variety in approach than a low-end fast-food restaurant.

Moreover, many educational designers and scholars seek the single best medium for learning, as if such a universal tool could exist. Some believe that one way of learning is universally optimal and therefore develop instructional ICT that embody that approach; others favor a slightly broader Swiss-Army-Knife design strategy that incorporates a few types of instruction into a single medium touted as a "silver bullet" for education's woes. As Larry Cuban documents in his book, *Oversold and Underused* (2001), in successive generations pundits have espoused as "magical" media the radio, the television, the computer, the Internet, and now laptops, gaming, blogging, and podcasting (to name just a few).

Of course, other gurus violently oppose each new type of instructional ICT, seeing that pedagogical approach as undercutting both the true objectives of education and the ways students can best learn. For example, at present, parents and politicians alike are decrying cell phones in schools and banning social networking technologies such as MySpace, despite widespread usage of equivalent tools in twenty-first century workplaces. Given all these claims and countercharges, it is unsurprising that the general public is confused about what types of ICT infrastructures – if any – are effective in education and about how much to invest in instructional technologies.

Investments in Instructional ICT Infrastructures

In light of this confusion, scholars such as Cuban (2001) argue that instructional ICT are far less useful than advocates claim and that other forms of educational investment may well produce better results in increasing student learning. Cuban documents that educational technologies divergent from teachers' current pedagogies are often unused, or utilized ineffectively. He also shows that advocates of ICT in education frequently make extravagant claims that prove hollow; and he expresses doubt that instructional technologies will ever have a transformative effect on learning, teaching, and schooling.

A weakness in this position is the tacit assumption, pervasive in most discussions about educational ICT, that instructional media are "one size fits all," with narrow types of tools (e.g., Logo programming, learning management systems) debunked to the chagrin of those who touted them. This instructional improvement strategy is the equivalent of asking a carpenter to build artifacts with only a screwdriver, or only a hammer – then concluding such tools are not useful because each in isolation has limited utility, as well as many weaknesses when broadly applied. In contrast, from an instrumental perspective, the history of tool making shows that the best strategy is to have simultaneously available a variety of specialized tools, rather than a single device that attempts to accomplish everything.

Further, all these pundits – pro and con – typically ignore the research literature on discipline-specific pedagogies (Shulman, 1986; Becher, 1987; Lampert, 2001). Numerous studies document that no optimal pedagogy – or instructional medium – is effective regardless of subject matter. As one example of research on subject-specific pedagogy, Garvin (2003) documents that the Harvard Law School, Business School, and Medical School have separately strongly influenced how their particular profession is taught, each by espousing and modeling sophisticated "case-method" instruction. Garvin's findings show that what each of these fields means by case-method pedagogy is quite different and that those dissimilarities are shaped by the particular content and skills professionals in that type of practice must master.

Thus, the nature of the content and skills to be learned shapes the type of instruction to use, just as the developmental level of the student influences what teaching methods will work well. No educational ICT is universally good; and the best way to invest in instructional technologies is an instrumental approach that analyzes the natures of the curriculum, students, and teachers to select the appropriate tools, applications, media, and environments.

Conclusion

Historic controversies about technology and pedagogy illustrate an apparently endless search for a universal method of teaching/learning that is best for all types of content, students, and instructional objectives. Parallel to this is a perennial belief that each new interactive medium is a "silver bullet" for solving education's problems, despite massive evidence from both research and experience that old content/pedagogy in new instructional containers does not produce major gains in effectiveness. To progress, the field of instructional design must recognize that learning is a human activity quite diverse in its manifestations from person to person, and even from day to day. The emphasis can then shift to developing pedagogical media that provide many alternative ways of teaching, which learners select as they engage in their educational experiences.

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1.4

STUDENTS IN A DIGITAL AGE: IMPLICATIONS OF ICT FOR TEACHING AND LEARNING

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Introduction

The 'information society' is a label often applied to describe the way in which our society has come to function following the rapid proliferation of information and communication technologies (ICTs). The term 'information society' is a somewhat nebulous one. Webster (2002) argues that there is little agreement on what the defining features of an information society are, with many commentators struggling to identify how our society can be differentiated from previous societies at a fundamental level. Common definitions focus on the types of technological advancements that have occurred or the resultant changes in the world's economy (Webster, 2002). Regardless of the definition used, it is generally agreed upon that the information society is characterised by the exchange of information and knowledge, primarily through ICT, and Anderson (2008) argues that these concepts are particularly helpful in attempting to explicate the process of incorporating technology in education.

ICT Use: Access and Confidence

Large-scale international studies assessing student competence in various areas of study provide a unique opportunity to gain information about students' educational opportunities and access to educational resources. The findings from the Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS) can provide an indication of the extent

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to which participating students from around the world have access to ICT and their degree of proficiency in using such technologies.

The PISA is a triennial assessment of 15-year-old students' literacy in reading, mathematics and science. Developed by the Organisation for Economic Co-operation and Development (OECD), PISA assesses the extent to which students, at the end of their compulsory schooling, are prepared to meet the challenges they face as young adults in today's society (OECD, 2004). Forty-one countries participated in PISA 2003,[1] which encompassed an in-depth assessment of mathematics and a less detailed assessment of science, literacy and problem solving (OECD, 2004). As part of the PISA 2003 assessment, participating countries could elect to administer a short questionnaire on students' familiarities with ICTs. The questionnaire asked students to provide information about their level of access to, and use of, ICT, their level of confidence in performing various tasks on the computer and their attitudes towards computers (OECD, 2006). Of the 41 participating countries, 32 elected to administer the ICT questionnaire (OECD, 2006).

The TIMSS is conducted every 4 years and examines students' proficiency in mathematics and science. Conducted by the International Association for the Evaluation of Educational Achievement (IEA), TIMSS examines the extent to which Year 4 and Year 8 students have mastered skills in a number of areas common to mathematics and science curricula throughout the world (Martin et al., 2000). At the Year 4 level, 26 countries participated in TIMSS 2002/2003 and 48 countries participated at the Year 8 level. As part of TIMSS 2002/2003, students were asked to provide an indication of the extent to which they are able to access a number of educational resources, the extent to which they have access to, and use, computers at home and at school.

Throughout this chapter, the relevant results from PISA 2003 and TIMSS 2002/2003 are presented for only a select number of countries. The results displayed are intended to provide an indication of what can be considered average across countries and the extent to which there is deviation from this average. Comprehensive data tables including data for all participating countries can be obtained from the relevant references cited below the tables.

Students' Access to ICT

According to the PISA 2003 findings, the majority of students across the countries who participated have access to a computer at school, and a slightly smaller percentage of these students have access to computer at home (see Figure 1 for results for a selection of countries). There is greater variability in access to computers at home than at school, with a much lower percentage of students in countries such as the Russian Federation, Thailand and Turkey having access to a computer at home than students in Australia, Korea and Sweden.

While students may have access to a computer at school, their access can be restricted by demand from other students. Consequently, it is also important to consider the nature of the access students have to computers at school. The PISA 2003 school questionnaire asked principals to provide an indication both of the overall number of computers in the school and the number of computers in the school available for students to use (OECD, 2006). On the basis of this information, the number

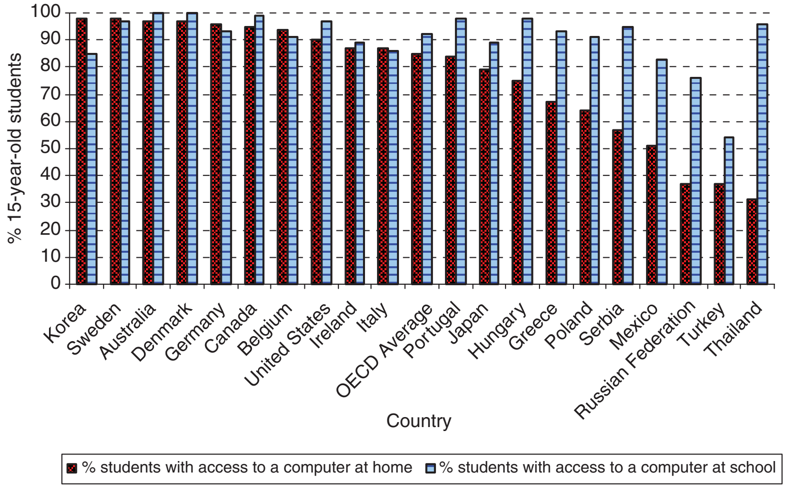

Fig. 1 Students' access to computers at home and at school in selected participating countries (PISA 2003) (source: OECD, 2006)

Table 1 Number of computers in schools per student in selected participating countries (PISA 2003)

Country	Number of computers per student
United States	0.30
Australia	0.28
Korea	0.27
Hungary	0.23
Canada	0.22
Denmark	0.19
Japan	0.19
Sweden	0.16
OECD average	0.16
Belgium	0.15
Italy	0.13
Ireland	0.11
Mexico	0.09
Germany	0.08
Greece	0.08
Portugal	0.07
Poland	0.07
Thailand	0.05
Turkey	0.04
Serbia	0.03
Russian Federation	0.03

Source: OECD (2006)

of computers available per student can be calculated (OECD, 2006). Table 1 presents the number of computers available in schools per student on average in a selection of countries participating in PISA 2003.

On average across the participating countries, the number of computers per student was 0.16, indicating that there are approximately six students to each computer. However, there is a large difference between the countries with the lowest number of students per computer and those with the highest. For example, the average across schools in the United States is around 3 students per computer, whereas in Serbia and the Russian Federation it is around 33 students per computer. These findings suggest that, while access to a computer at school is fairly similar across the nations, there is a large gap between the participating countries in the number of computers available for students to access.

The findings of TIMSS 2002/2003 also provide an indication of the opportunity students have to access computers at home and at school (see Table 2). Although TIMSS 2002/2003 was conducted at both the Year 4 and Year 8 level, data from the Year 8 level only will be considered here to facilitate comparisons with the PISA results previously discussed. Of those Year 8 students participating in TIMSS 2002/2003, approximately 60% indicated that they have access to a home computer. However, access to a computer at home varies considerably across the surveyed nations from as high as 98% of students in Sweden to as low as 16% in Egypt. Countries which have a high percentage of students with access to a computer at home

Table 2 Computer access at home for Year 8 students in selected countries (TIMSS 2002/2003)

Country	Percentage of students who have access tox have access at home	Percentage of students using computer at home and at school	Percentage of students using computer at home not at school	Percentage of students using computer at school not at home
Sweden	98	78	17	3
Australia	96	83	10	5
Singapore	94	79	14	5
United States	93	79	11	8
Slovenia	86	51	34	8
Italy	84	39	39	9
Japan	82	55	16	26
Cyprus	82	70	7	16
Hungary	75	61	8	26
Slovak Republic	67	26	33	16
International average	60	39	18	19
Lebanon	59	39	16	21
Malaysia	57	26	26	24
Lithuania	48	26	22	35
South Africa	37	16	11	18
Romania	32	15	16	25
Russian Federation	30	12	19	28
Ghana	24	9	9	21
Tunisia	22	5	20	16
Indonesia	17	7	2	31
Egypt	16	18	5	62

Source: Mullis et al. (2004)

also tend to have a high percentage of students using computers both at home and at school, rather than one or the other. In countries where only a small percentage of students have access to a computer at home, it also appears that few students are using a computer at school. This suggests that students only have limited opportunities to use computers in these countries.

Students' Proficiency in ICT

According to Mioduser et al. (2008), there is a discrepancy between the ICT skills students are being taught in formal education and the literacy skills they need to function effectively outside the school environment. Given the predominance of ICT, particularly in the work environment, the extent to which students are gaining appropriate skills in ICT, whether these skills are attained at school or elsewhere, is an important issue. Findings from PISA 2003 provide an indication of students' perceptions of their ability to carry out various ICT tasks and their confidence in performing these tasks.

To gain an indication of their ICT skills, students participating in PISA 2003 were asked to indicate, for a number of ICT tasks, how well they could perform that task on a scale from '0 – I can do this very well by myself' to '3 – I do not know what this means' (see for further details OECD, 2006). Figure 2 shows the percentage of students on average across the OECD who indicated that they could perform the task very well by themselves. The majority of students indicated that they could perform routine tasks, such as opening a file or deleting a computer document, on their own. Most students also indicated that they felt they could perform a range of Internet tasks without assistance, though a lower percentage of students felt they could attach a file to an e-mail message without help. Higher-level tasks, such as creating a multimedia presentation or constructing a web page, seem to present more of a challenge to students, with a much a lower percentage of students reporting that they can undertake these sorts of tasks by themselves than for routine or Internet tasks.

The results indicate that there are considerable differences between countries in terms of the percentage of students who indicate that they can conduct various ICT tasks alone. These differences are particularly pronounced for Internet tasks; perhaps reflecting differences in level of Internet access across countries. As would be expected, countries where the percentage of students indicating that they had access to a computer at home or at school was comparatively low also tended to have fewer students indicating that they could perform the ICT tasks listed.

An index of students' confidence in performing routine, Internet and high-level tasks was also calculated for the participating countries on the basis of students' indications of how well they could perform the various ICT tasks (OECD, 2006). Students who responded that they could perform a task very well on their own were deemed to have a high level of confidence and students who responded that 'I could do this with some help from someone' were deemed to be somewhat confident (OECD, 2006). Based on scale where '0' represents the average level of confidence across all the participating OECD students, a positive index score indicates that students' confidence in that country is higher than the average for all participating students in OECD countries, and a negative index score indicates that students' confidence is

Fig. 2 Percentages of students who could perform various ICT tasks by themselves, OECD average (PISA 2003) (source: OECD, 2006)

lower than the average for all participating students in OECD countries. The index values for a selection of countries are presented in Table 3.

Index values tended to be consistent across the three types of tasks for most countries; where students indicated a comparatively high degree of confidence in performing one type of task, they also tended to report a comparatively high degree of confidence in the other tasks. Generally, student confidence in performing tasks was lower in countries where a lower than average percentage of students reported having access to a computer at home.

Gender differences were observed in students' degree of confidence in performing various ICT tasks, with males reporting higher levels of confidence on average than females across the tasks (OECD, 2006). This gender gap was particularly pronounced for high-level tasks, with the largest differences observed for creating a web page or

Table 3 Index values for confidence in performing computer tasks among 15-year-old students for selected countries (PISA 2003)

	Index of confidence in relation to ICT tasks		
Country	Routine	Internet	High-level
Australia	0.39	0.41	0.42
Canada	0.33	0.57	0.35
United States	0.26	0.39	0.43
Sweden	0.21	0.39	0.00
Portugal	0.21	−0.22	0.12
Denmark	0.15	0.11	0.06
Germany	0.15	0.13	0.08
Belgium	0.11	0.23	0.04
Korea	0.08	0.77	−0.09
Poland	0.04	−0.17	0.20
OECD average	0.00	0.00	0.00
Ireland	−0.03	−0.37	−0.24
Hungary	−0.12	−0.44	−0.33
Italy	−0.20	−0.39	−0.15
Greece	−0.38	−0.45	−0.22
Russian Federation	−0.57	−1.27	−0.49
Serbia	−0.60	−0.93	−0.43
Mexico	−0.68	−0.54	−0.13
Turkey	−0.74	−0.55	−0.16
Japan	−0.80	−0.71	−0.71
Thailand	−0.91	−1.36	−0.68

Source: OECD (2006)

creating a multimedia presentation (OECD, 2006). The comparatively low degree of confidence expressed by females about their ability to perform more complex tasks is of some concern as it suggests that fewer females are likely to undertake more complex computing subjects at school or to pursue careers in this area (OECD, 2006). There is evidence that in 2001 in Australia, male enrolment levels in information technology subjects at school were double those for females (Fullarton et al., 2003).

The results of PISA 2003 provide an indication of the types of ICT tasks students are capable of performing and the extent to which different groups of students have acquired similar degrees of proficiency with ICT. While it is valuable to consider student proficiency at an individual task level, it is also useful to conceptualise the general capabilities students are developing through their interactions with ICT. Building on the work of previous commentators, Mioduser et al. (2008) suggest that it is appropriate to view students' literacy in terms of the comprehensive set of skills they require to cope with everyday life. They suggest that these skills can be represented in terms of seven 'new literacies', each of which describes a set of skills which relate to the relationship between technology and individual functioning: multi-modal information processing, navigating the infospace, communication literacy, visual literacy, hyperacy, personal information management literacy and coping with complexity

(Mioduser et al., 2008). The notion of 'new literacies' should provide a useful framework to guide future research.

Engagement with ICT

A key question associated with the use of ICT in schools is the extent to which such technologies are able to capture students' attention and promote student engagement with educational material. Fredericks et al. (2004) suggest that engagement is best conceptualised as a multi-dimensional construct, consisting of three different components: a behavioural, an emotional and a cognitive component. The behavioural component refers to the participatory nature of engagement; i.e. an individual must be actively involved in something to be engaged (Fredericks et al., 2004). For example, behavioural engagement might encompass the frequency with which students use various types of technology. Emotional engagement refers to an individual's emotional reaction to a task (Fredericks et al., 2004). In the context of information technology, this might refer to a student's attitude towards technology and their motivation to learn with such technologies. Finally, cognitive engagement refers to the mental effort that is expended to understand concepts or ideas (Fredericks et al., 2004). This form of engagement might be reflected in students' approaches to learning, their investment of effort in learning and their learning outcomes.

The findings of PISA 2003, some of which were discussed in the previous section, also have the potential to shed light on the behavioural and emotional engagement of 15-year-old students with ICT. Students' cognitive engagement will be considered in terms of several theories about the way in which students approach learning using ICT.

Behavioural Engagement

The PISA 2003 results provide some indication of the behavioural engagement of students through data relating to the frequency with which students are using computers and various computer programs. The frequency with which students are using computers at home and at school needs to be considered within the context of the opportunities students have to access computers in these places (see Table 4).

Across the selected countries, the majority of students who have access to a computer at home tend to use this computer at least a few times each week. Japan is perhaps the only exception to this trend, with around 79% of students having access to a computer at home but only 37% of students indicating that they use this computer at least a few times each week. In contrast, while a relatively high percentage of students on average across the participating countries indicated that they have access to a computer at school, a much lower percentage reported using a computer at school at least a few times each week. In Germany, for example, 93% of students responded that they had access to a computer at school but only 23% indicated that they use a computer at least a few times a week at school. This suggests that, while students have the opportunity to access a computer at school, students are not necessarily using this computer on a frequent basis as part of their studies.

Table 4 Percentage of 15-year-old students using computers at least a few times each week for selected countries (PISA 2003)

Country	Percentage of students using computers at home at least a few times each week	Percentage of students with access to a computer at home	Percentage of students using computers at school at least a few times each week	Percentage of students with access to a computer at school
Canada	90	95	40	99
Sweden	89	98	48	97
Australia	87	97	59	100
Korea	86	98	28	85
Denmark	84	97	68	100
Belgium	84	94	27	91
United States	83	90	43	97
Germany	82	96	23	93
Portugal	78	84	34	98
Italy	76	87	51	86
OECD average	74	85	44	92
Hungary	67	75	80	98
Ireland	61	87	24	89
Poland	59	64	44	91
Greece	57	67	45	93
Serbia	50	57	57	95
Mexico	48	51	54	83
Turkey[a]	48	37	46	54
Russian Federation[a]	43	37	43	76
Japan	37	79	26	89
Thailand	30	31	55	96

Source: OECD (2006)

[a]For these two countries, there appears to be an anomaly in that the percentage of students using a computer at home on at least a weekly basis exceeds the number of students who indicated that they have access to a computer at home. Regardless of this discrepancy, the data indicate a low level of use of, and access to, computers

As part of the PISA 2003 student questionnaire, students were asked to provide an indication of the extent to which they use various ICT resources on a scale from ‘1 – Almost everyday’ to ‘5 – Never’ (OECD, 2006). These resources were grouped into two categories: Internet and entertainment, and programs and software. Activities relating to the Internet and entertainment included communication via e-mail or chat, playing computer games and downloading music or software. Some of the programs and software activities listed were word processing programs, educational software such as mathematics programs and programming applications.

An index of ICT use for accessing the Internet and entertainment and an index of ICT use for accessing programs and software were created (OECD, 2006). To create each of these indexes, students’ responses to the questions relating to ICT use were combined to form a composite score (OECD, 2006). The composite scores were then represented as index numbers, such that the average score for all participating OECD students was ‘0’ (OECD, 2006). The index allows for comparisons across countries. A positive index score indicates that students’ use of these resources in that country is higher than the average for all participating students in OECD countries, and a negative index score indicates that students’ use of these resources is lower than the average for all participating students in OECD countries. Table 5 presents the index scores for a selection of countries who participated in PISA 2003.

Countries whose students indicated that they use a computer at home at least a few times a week tended to have positive Internet and entertainment index scores, suggesting greater use of such resources in these countries than on average across the OECD. The exceptions were Germany and Italy whose index scores for Internet and entertainment use fell below the OECD average. A number of the countries with index scores below the OECD average for Internet and entertainment had index scores above the OECD average for programs and software, including Italy, Mexico and Poland. This pattern suggests that students in these countries are using information technology more for the purposes of learning and education than communication or entertainment.

Gender differences in ICT use were observed for both indexes, with males reporting more frequent use of computers for Internet and entertainment purposes than females,

Table 5 Indexes of ICT use for the Internet and entertainment and ICT use for programs and software for selected countries (PISA 2003)

Country	Index of ICT use for the Internet and entertainment	Index of ICT use for programs and software
Canada	0.63	0.15
United States	0.46	0.33
Korea	0.34	−0.33
Sweden	0.28	−0.17
Australia	0.27	0.23
Belgium	0.14	−0.19
Denmark	0.11	0.17
Portugal	0.07	0.23
OECD average	0.00	0.00
Germany	−0.06	−0.03
Poland	−0.06	0.22
Greece	−0.11	0.11
Italy	−0.16	0.23
Mexico	−0.21	0.18
Turkey	−0.23	0.10
Hungary	−0.24	0.03
Ireland	−0.43	−0.35
Serbia	−0.48	0.07
Thailand	−0.64	−0.05
Russian Federation	−0.81	−0.30
Japan	−0.91	−1.03

Source: OECD (2006)

as well as more frequent use of computers for accessing programs and software (though the differences in this area were less pronounced) (OECD, 2006). The largest difference between males and females was in their use of computer games, with a much higher percentage of males than females reporting frequent use of the computer for this purpose. This is consistent with other research findings in the area, which suggest that males engage in more frequent use of computer games, particularly online computer games, than females (Colley and Comber, 2003; Griffiths et al., 2004).

Overall, there is considerable variation in extent to which students use ICT for Internet and entertainment purposes and for accessing programs and software. This variability may reflect cultural differences in perceptions about the appropriate uses of ICT or the ways in which leisure time should be spent or it may reflect differences in levels of access to various ICT resources.

Emotional Engagement

Emotional engagement refers to an individual's emotional response while undertaking a particular task (Fredericks et al., 2004). One way to gauge the extent to which students are engaging emotionally with ICT is to examine their attitudes towards technology. As part of the PISA 2003 student questionnaire, students were asked to respond to four questions relating to their experience of working with computers. Specifically, students were asked to indicate the extent to which it was important to them to work with a computer, they found working with a computer fun, they used a computer because they were very interested and they lost track of time when working with a computer (OECD, 2006). Table 6 presents the percentage of students who strongly agreed to each of the four statements for a selection of countries who participated in PISA 2003.

The figures displayed in Table 6 provide some indication of the importance of computers to 15-year-old students. Approximately half of the students surveyed indicated that they strongly agree that working with computers is very important, suggesting that these students see a significant role for computers in their lives. Interacting with computers seems to be an enjoyable pastime for a number of students, regardless of whether this interaction is for the purposes of leisure or work.

There is variation across the countries in the percentage of students who strongly agree with each of the four statements, suggesting differences across countries in the importance of computers in students' lives. While 69% of students in Tunisia strongly agreed that it was very important for them to work with computers, only 27% of those students surveyed in Finland responded similarly. These differences may reflect differences in the extent to which working with computers is seen as something special or novel because of differences in the prominence of computers in different societies as well as whether students have greater access to computers in schools.

There are a number of factors which are likely to influence students' attitudes towards computers, some of which were considered as part of the PISA 2003

Table 6 Percentage of 15-year-old students who strongly agreed with four statements related to their experience with computers in selected participating countries (PISA 2003)

Country	It is very important to me to work with a computer	To play or work with a computer is fun	I use a computer because I am very interested	I lose track of time when I am working with the computer
Tunisia	69	53	55	62
Austria	64	73	59	47
Iceland	63	69	43	38
Liechtenstein	60	72	56	43
Germany	59	73	56	46
Portugal	58	50	55	50
United States	56	58	37	39
Canada	54	58	46	44
Poland	53	49	50	54
Turkey	53	59	40	54
Belgium	51	53	46	48
OECD average	49	53	43	40
Switzerland	48	57	44	42
United Kingdom	47	50	41	45
Czech Republic	46	48	42	38
Australia	45	43	35	34
Russian Federation	42	49	49	48
Sweden	41	55	40	36
Latvia	35	36	37	34
Hungary	32	48	37	35
Japan	30	42	33	29
Ireland	28	40	28	34
Finland	27	37	32	23

Source: OECD (2006)

data analysis (OECD, 2006). The considered factors included a student's gender, whether or not the student has access to a computer at home, the frequency with which a student uses a computer and whether or not the student taught himself or herself to use a computer (OECD, 2006). The extent to which each of these factors influenced students' attitudes towards computers varied across countries. For example, whether a student was female had a comparatively large influence on students' attitudes in Denmark; however, this factor had no influence on students' attitudes in Japan. Whether a student had access to a computer at home explained a larger percentage of the variance in students' attitudes towards computers in Portugal than in Korea. These findings suggest that there is likely to be a unique combination of factors influencing student attitudes towards computers in different countries, perhaps reflecting different cultural influences or different educational policies. While the four factors considered in PISA 2003 had some influence on student attitudes, a considerable amount of variance remained unexplained by these factors (OECD, 2006).

Cognitive Engagement

Cognitive engagement refers to the mental investment that is made to understand complex concepts or ideas (Fredericks et al., 2004). ICT is a medium through which concepts and ideas are conveyed. Consequently, when considering students' cognitive engagement, the focus is not on whether students are engaged with the technology itself but, rather, on whether this technology affects the nature of students' cognitive engagement with learning material. Of particular interest are the following questions: Are students more willing to invest effort when information is presented through ICT? Does the nature of ICT promote different approaches when expending effort to understand information? Do these different approaches lead to better learning outcomes?

Given the difficulty educators face in engaging students' attention, particularly in the latter half of their schooling, the issue of whether students will be more willing to expend effort to understand concepts which are presented using ICT is one worthy of consideration. Several theorists suggest that students who have grown up with digital technology have a fundamentally different way of thinking than previous generations (Jukes, 2005; Prensky, 2001). Prensky (2001) coined the term 'digital natives' to describe students who, through extensive experience with ICT, speak the 'digital language' of computers, video games and the Internet. According to Prensky (2001), these 'digital natives' have fundamentally different preferences for the way in which they receive information. They are likely to prefer to receive information quickly and to work through information randomly and are likely to enjoy multi-tasking rather than focusing on one task a time (Prensky, 2001). Their approach to learning is likely to be characterised by a rapid trial and error approach, rather than a systematic appraisal (Jukes, 2005). Prensky (2001) argues that, to maximise these students' attention and effort, information needs to be presented in a way that best suits this approach and this is likely to involve ICT.

Contrasting with digital natives, digital immigrants, who have acquired knowledge of digital technologies later in life, prefer to access information logically from a limited number of sources (Jukes, 2005; Prensky, 2001). The critical issue is not which approach is superior but, rather, whether these differences in approaches to learning have implications for the way in which different generations interact in the school environment. Jukes (2005) suggests that, given that many teachers are likely to be digital immigrants, teachers may find it difficult to present material to students in a way that is likely to engage them. Potential strategies to overcome this problem include increasing the speed at which information is presented, providing opportunities for multi-tasking and interactive learning, and presenting information through a variety of media (Jukes, 2005). Prensky (2001) argues that presenting information through the medium of ICT should allow teachers to speak the right language and to encourage students to exert greater effort to understand the concepts they are presenting.

While the use of ICT in classrooms may promote greater student effort in learning new material, it is as yet unclear whether there are any corresponding increases in performance associated with the use of such technologies. In a national science assessment of fourth, eighth and twelfth grade students in the United States, which was conducted as part of the National Assessment of Educational Progress (NAEP), students whose teachers indicated that they used computers as part of their instruction obtained higher scores than those students whose teachers did not (O'Sullivan et al., 2003). Using data from the Iowa Tests of Basic Skills and Test of Academic Proficiency, Ravitz et al. (2002) found a positive relationship between proficiency in computer software and student achievement. It should be noted, however, that an inverse relationship was found between in-school computer use and student achievement (Ravitz et al., 2002). On a much smaller scale in the United Kingdom, Valentine et al. (2005) found a positive association between the use of computers at home and performance on mathematics tests. An analysis of the PISA 2003 data revealed an association of computer use at home with mathematics performance and an association of confidence in the use of computers with mathematics performance (OECD, 2006). However, some of the relationships were non-linear, with moderate use being associated with better performance than the highest levels of computer use. This finding suggests that it may be premature to conclude that there is a clear linear association between computer use and student achievement. The difficulty in conducting studies to investigate this relationship lies in incorporating adequate controls for other factors that might influence both computer use at home and test performance (Wenglinsky, 1998; Roschelle et al., 2000). Future research should seek to carefully explore potential factors which may mediate the relationship between computer use and test performance and to include these factors as variables in their analyses.

ICT and Learning

From a pedagogical perspective, it is important to understand how teachers are making use of ICT to enhance students' learning experiences. The rapid growth in ICT has been accompanied by recognition of the potential for such technology to transform the classroom environment and it has prompted consideration of the way in which ICT can facilitate student learning and engagement. Ainley and Armatas (2006) highlight the potential of technologically rich learning environments to transcend the limitations of time and space in their offerings to students. The extent to which students engage with technology-rich learning environment depends on the quality of the instructional message (Mayer, 1997), the interaction with the learner (Mayer and Chandler, 2001) and the design and interactivity of the instructional material (Salzman et al., 1999). Kozma (2003) notes that there have been a number of nations, including Chile, Finland, Singapore and the United States, who have identified national goals and policies recognising the significant role ICT is likely to play in improving their education systems. However, it should be acknowledged that despite the recognition of the importance of information technology in the school curriculum, changing the way in which ICT is integrated into the curriculum is likely to be a lengthy process. As Mioduser et al. (2008) acknowledge, the structures supporting formal education systems are not known for their flexibility and rapid response in the face of new developments. In addition, there is currently little understanding of the way in which ICT is used in schools and classrooms around the world.

Findings from PISA 2003 suggest that the majority of students across the participating countries engage in at least moderate use of computers at school, with 44% of students reporting frequent use. What is unclear, however, is whether this use of computers occurs primarily in information technology classes or whether information technology is also integrated into other areas of the curriculum. At this stage, further research is required to understand how ICT is generally used in classrooms around the world.

While few studies have considered the way in which ICTs are generally used, one study has examined uses of ICT to create innovative educational practices. Rather than focusing on how computers are typically used in a particular country, the Second Information Technology in Education Study (SITES – Module 2) sought to identify unique cases of innovative educational practices using ICT. The study was based on 174 case study reports drawn from 28 participating countries, each of which described an innovative use of technology to enhance pedagogy. Through a combination of qualitative and quantitative methods, the study examined the similarities across cases and across countries to identify patterns of innovative pedagogical practices. Seven different patterns of practices emerged as a result of a cluster analysis, each of which is summarised in Table 7.

Table 7 Patterns of innovative uses of ICT (SITES – Module 2)

Pattern	Characteristics of pattern
Tool use	A strong emphasis on the extensive use of technology tools, such as e-mail and productivity tools, to communicate, to search for information and to create products. These tools included word processing, spreadsheet and database programs, as well as multimedia applications
Student collaborative research	These cases were characterised by students working collaboratively in pairs or groups to conduct research or, less frequently, to collect and analyse data. Information and communication technologies were used to conduct research or to create a presentation on the group's ideas or their solution to a problem
Information management	The primary use of information and communication technologies in this cluster was for the purposes of searching for – organising, managing and using – information for teaching and learning purposes. Some use of productivity tools was apparent, particularly for the purpose of presenting information gleaned from information searches
Teacher collaboration	Emphasis on teacher collaboration with both students and other teachers, often for the purpose of designing instructional materials or activities. The majority of these cases were from upper secondary school
Outside communication	Characterised by the tendency for students to make use of communication technologies such as e-mail, the Internet, conferencing software or listservs to work with other students outside of the classroom environment
Product creation	The primary use of information technology in this cluster was to facilitate the design and creation of digital products using software packages
Tutorial projects	Characterised by the use of tutorial or drill-and-practice software to allow students to work independently, to receive feedback on their performance and to refine their skills. The majority of these cases were from the primary level

Source: Kozma and McGhee (2003)

Each of the seven patterns illustrates a different way in which information or communication technologies have been used to facilitate learning or instruction in the classroom. However, it should be noted that, while ICT was instrumental in the innovative pedagogical practices described, the dominant technologies used by students and teachers in these cases were those technologies which are commonly available (Kozma and McGhee, 2003). For example, many of the practices described involved the use of the Internet, e-mail or productivity tools such as word processors and spreadsheets. These findings suggest that it is technologies which are easily accessible which tend to be used in the classroom and that these technologies can be utilised to facilitate student learning and engagement.

Conclusion

The rapid growth and development of ICT have prompted two key questions in the minds of educators and policy makers – to what extent are our students receiving adequate training in this area? And, how best can we use such technologies to facilitate student learning and engagement? This chapter considered these questions in light of the findings from two international studies, PISA 2003 and TIMSS 2002/2003, and research conducted in the area of student engagement with ICT.

Overall, students' proficiency in ICT is growing, particularly with respect to routine and Internet computer tasks, and students generally feel comfortable using a computer to access the Internet, create or edit a computer document or send an e-mail. However, a comparatively small percentage of students indicated that they would feel comfortable performing higher-order tasks, such as creating a multimedia presentation or constructing a web page, without assistance. This suggests that while students are receiving a good grounding in routine and straightforward ICT skills, training in more complex functions is less rigorous. This finding prompts some consideration of the types of ICT skills students should be expected to have obtained by the conclusion of secondary school and the extent to which provision of training in such skills is occurring.

While students' access to computers is on the rise, there is still considerable variation between countries in terms of the extent to which students are able to access a computer at home or at school and their level of comfort in performing various ICT tasks. Findings from PISA 2003 indicate that while there is an average of six students per computer at schools across the participating countries, in some countries, the number of students per computer is as high as 33. This suggests that access to ICT is by no means equivalent across countries. Lack of access to computers appears to have ramifications for student proficiency in ICT tasks. Countries whose students reported a comparatively low level of access to computers at school also tend to have a comparatively low percentage of students reporting that they could perform various ICT tasks, including routine ICT tasks, without assistance. The findings suggest that ensuring students have adequate access to a computer at school is essential to students' development of key skills in ICT.

The development of increasingly sophisticated ICT has prompted consideration of the way in which these technologies can be used to facilitate student engagement and learning. Exposure to ICT from an early age has changed the way in which students approach learning, with students tending to employ rapid trial and error, rather than systematic, approaches. Students also appear to have different preferences for the way in which they receive information – preferring to receive it quickly, to access it in a more haphazard fashion and also enjoying the opportunity to multi-task. Traditional approaches to learning struggle to meet these preferences and consequently students are often unengaged by the activities they are required to undertake in the classroom. More sophisticated ICTs have the potential to transform the nature of the learning experience and create a more interactive and engaging learning environment for students. Future research should be directed towards understanding the extent to which such interactive learning can lead to improved engagement, motivation and, ultimately, learning.

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Note

1. At the time of publication, results from PISA 2006 were not available.

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1.5

TRADITIONAL AND EMERGING IT APPLICATIONS FOR LEARNING

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Introduction

The introduction of information technologies (ITs) in education has been identified strongly with a variety of applications over the years. Computers, Internet, educational software, laptops and PDAs are concepts largely used in education as technological icons to show to what extent schools are in line with modern life. However, these technologies are often considered fads but also they show the tip of the iceberg in educational issues. In this chapter, the different sides of this iceberg will be analysed to understand more comprehensively, why and how IT applications are used for learning.

"General Background: IT in Education" section presents a general background of the introduction of IT in education, examining the rationale for the introduction of IT in educational systems, particularly in levels K-12. This sets up the scenario in which emerging and traditional technologies are actually being used in schools for learning. "Potential Impacts of IT" section presents the range of possible impacts of IT in students, which helps to understand the expectations that can be drawn on the use of these technologies.

"Factors Affecting the Use of IT for Learning" section presents a range of possible choices of IT applications derived from the combination of the context of use, the possible technologies to select and the instructional moment in which it could be used. Also, it presents examples of emerging applications of IT in schools that

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illustrate some particular choices of these applications and some of the trends of emerging technologies that are being researched. Finally, "Trends in Emerging Technologies and Learning" section discusses the main trends and possible development pathways of the use of IT for teaching and learning.

General Background: IT in Education

The introduction and use of ITs in education are a worldwide phenomenon, including developed and developing countries. The main arguments in which this international trend is sustained at a policy level can be summarized as:

1. IT is an essential "life skill" in the same way as literacy and numeracy.
2. IT is an opportunity for economic development and a requirement for employability.
3. IT is a tool for educational management.
4. IT is a tool that can improve teaching and learning.

(see Organisation for Economic Co-operation and Development – OECD, 2001).

The first two groups of arguments are related to the possible socio-economic benefits of "mastering IT". Although the exact definition/quantification of these impacts is still a matter of debate (see for example, proposals and discussions about the economic benefit of IT in OECD, 2003), there is a generalized consensus that there are benefits and that IT does have an impact on human development. Moreover, one of the UN Millennium Development Goals (http://www.un.org) explicitly asks to "make available the benefits of new technologies – especially information and communications technologies".

Regarding the use of IT as a tool for educational management, there are a growing number of arguments that support the idea of improving education using these tools to improve management-related tasks (see for example, Becta, 2006). Related to this, there is also the concept of using IT as an "instrument" that helps to bring about change and innovation in schools (Fullan, 2007). In fact, this concept has changed through time, first from considering IT as a Trojan Horse (Olson, 2000) then as a catalyst (McDonald and Ingvarson, 1997), and then as a lever – a tool that must be applied purposefully to a task to be of value – (Venezky, 2002), and lately, based on an ecological perspective, as "invasions of exotic species" (Zhao and Frank, 2003). These different categories illustrate the evolution of the role that IT plays in educational innovation, but more importantly show the prevalence of the search for an answer about the role of IT in the process of educational innovation.

Finally, the argument of considering IT as a tool for improving teaching and learning is still an arena for debate (see for example, Balanskat et al., 2006). The main arguments are that:

– The use of IT in teaching and learning can improve students' outcomes. This argument is still used either through explicit reference in policy design documents (McMillan Culp et al., 2003) or implicitly used while reporting the progress of national IT in education policies. For example, the British Educational Communications and

Technology Agency (BECTA) reported in its annual review of the IT in education national strategy that “there is a growing body of evidence indicating that IT use has a positive, if small, impact on learner attainment and other outcomes” (Becta, 2006, p. 44). Several studies have tried to find a positive correlation between high levels of students’ achievements and good practice with IT. Among them, some qualitative studies have tried to identify the conditions and definition of good practices with IT (Kozma, 2003b; Venezky, 2002) and other quantitative studies have tried to show a correlation between the use of IT and higher achievement, while some others have combined both methods (Harrison et al., 2002). In general, results of these studies did not show clear evidence that helped to sustain this argument. In this respect, as McFarlane et al. (2000) point out, “the problem is analogous to that of asking whether books are having an impact on learning: books are a medium for transmitting information, they cover a vast range of content, structure and genres, they can be used in an infinite variety of ways. It is therefore extraordinarily difficult to make generalised statements about their impact on learning” (p. 9). Despite the present debate on the actual effectiveness of IT as an aid to improve students’ learning achievement, it must be realized that there is widespread interest and a definite need to find evidence of the impact of IT on students’ attainment.

– The use of IT is only one element in what must be a coordinated approach for improving curriculum, pedagogy, assessment, teacher development and other aspects of the schools’ culture. This argument alleviates the expectation of a causal relationship between the use of IT and improvement in learning outcomes, arguing that it enables key conditions for learning (OECD, 2001; Roschelle et al., 2000).
– IT enables a new scenario for teaching and learning. Based on the opportunities offered by IT, authors promoting this argument advocate more radical changes in the way children learn and teachers teach, this is, to move from “traditional” pedagogical practices to more learner-centric, “constructivist” learning models (Dede, 2008), active engagement, frequent interaction and feedback and others (Roschelle et al., 2000). The important issue in this case “is not the availability and affordability of sophisticated IT, but the ways this technology enables powerful learning situations that aid students in extracting meaning out of complexity. New forms of representation (e.g. interactive models that utilize visualization and other means of making abstractions tangible and sensory) make possible a broader, more powerful repertoire of pedagogical strategies” (Dede, 2000, p. 299).
– The proliferation of IT in society calls for a new curriculum. In this case, the argument is based on the assumption that IT both underlines a *need* for curriculum change and affords the *means* whereby the desired change could be achieved (OECD, 2001). In this argument, authors claim that the knowledge society is demanding new skills that are not yet considered in the traditional curriculum, such as knowledge building (Scardamalia and Bereiter, 2006), capacity for change (Roschelle et al., 2000) and lifelong learning skills (Voogt and Pelgrum, 2005). See Anderson (2008) for an extended discussion of this argument.
– IT as a tool for learning. This argument, although not often used, places IT as simple resources that complement students’ learning. In doing so, it relieves the pressure on the expected transformational capacity of IT.

The co-existence, and periodic emergence, of different perspectives about the role, benefits and problems of the use of IT in education, generates an almost permanent state of debate around these issues and does not leave enough time to settle down arguments and produce foundational ideas (Dillon, 2004). This special characteristic of this research area can be explained, because:

– Technology evolves/changes too rapidly; therefore, there are always "new technologies" that entail new promises about impact in students' learning, renewing expectations and possibilities. For example, multimedia educational software (1980) was replaced by integrated learning systems (early 1990), that were replaced by Web systems (late 1990), which in turn were replaced by learning objects (2002), which are now being replaced by software to be used in portable devices (2004) and classroom applications, such as smart boards (2005), wearable technologies (2006), etc.
– Technology is very often used as "flag ship" by educational policy makers and politicians. Therefore, newly installed political administrations usually define new IT-related goals and propose the use of "new technologies", which in turn shifts researchers' interest (or funding possibilities) so as to investigate these new proposals.

Given this scenario, it is difficult to keep the focus of the discussion and to elaborate conclusions that can be sustained in time, since once some conclusion is met, the technological scenario has changed, and a new discussion starts. All in all, IT continues producing the expectation that it will transform and revolutionize teaching and learning processes and the idea that this technology better prepares students and teachers for a "knowledge-based" society (Anderson, 2008). These assumptions are directly related to the potential impacts of IT that will be presented in the next section of this chapter.

Potential Impacts of IT

This section describes the current discussion about the possible areas of impact of IT in education reported in the literature. To be able to focus the discussion, from this section onwards, we will focus on the relationship of IT and students' learning. Because of clarity, it does not consider other areas in which IT has shown impact such as teachers' professional development and motivation, school management, schools' enrolment, image, etc.

Students' Achievement

From a general perspective, the research on the impact of IT in student achievement has not been able to provide conclusive statements about positive or negative effects (see discussions in Balanskat et al., 2006; Cuban, 2001; Harrison et al., 2002). The most promising findings found that IT has a positive impact in primary schools in the home language (i.e. English) and science (Balanskat et al., 2006).

Against this backdrop, some authors question the assumption that IT is likely to produce a major identifiable and uniform effect on the performance of learners and therefore we are seeking results in the wrong way (McFarlane, 2001). Underwood and Dillon (2004), in their study about the possible evidence of the effect of IT on learning in national education tests in the UK, state "we were measuring the wrong thing. Perhaps new technologies are delivering new forms of learning for which we have yet to develop adequate assessment techniques" (p. 216). On the other hand, what has prevailed as a consensus is that IT enables key conditions for learning and enriches the school curriculum. Roschelle et al. (2000) provide a good example of these conditions:

– Real-world contexts
– Connections to outside world
– Visualization and analysis tool
– Scaffolds for problem solving
– Opportunities for feedback, reflection and revision

Students' Development of IT Skills

As regards as IT-related skills, there are at least two groups of definitions. The ones aimed at defining skills oriented towards mastering the hardware and software, such as those defined by, for example, the European Computer Driving License (http://www.ecdl.com). The other group of definitions is oriented at characterizing a set of competencies that students can develop while using software, often called "twenty-first century skills" (Anderson, 2008). These competences include "thriving on chaos" that means making rapid decisions based on incomplete information to resolve novel situations; the ability to collaborate with a diverse team – face to face or across distance – to accomplish a task; and creating, sharing and mastering knowledge through filtering a sea of quasi-accurate information.

Regarding the former group, especially in developing countries, research has shown that the introduction of IT does have an impact on students' IT skills (Hinostroza et al., 2005). Concerning the latter, although there is a consensus that students develop certain higher-order skills, its characterization is still a matter of debate (Anderson, 2008). On the other hand, while examining the actual use of IT in schools, the evidence suggests to embed IT literacy within more complex skills such as information handling, communication and collaboration (Voogt and Pelgrum, 2005).

Students' Motivation, Engagement and Self-Esteem

It is a consensus that IT does have an impact on students' motivation and other related variables (OECD, 2005). Complementary, other authors present different theories of enhanced learning through the use of IT developed in the last two decades. Among others, they mention extrinsic reinforcement, intrinsic rewards, challenge and increased self-esteem.

Factors Affecting the Use of IT for Learning

The range of ways in which IT (computers, Internet, PDAs, mobile phones, etc.) can be used in a teaching and learning situation varies enormously, and there are no recipes that can ensure that its use will produce gains in students' learning. This situation has been discussed from several perspectives, including arguments related to the quality of the research in this field (Underwood, 2004), the type of outcomes to expect (McFarlane, 2001), the emphasis given to IT in learning (Cuban, 2001) and others. In this section, we argue that one of the main problems is the complexity of designing specific uses of IT for teaching and learning due to the overwhelming number of options available that result from the combination of four sets of elements: (1) the different contexts in which IT can be used, (2) the variety of pedagogical approaches that can be used, (3) the range of activities that occur during a lesson, and (4) the set of IT options to select from. Additionally, all these elements are permanently evolving and yet, the impact of a given combination is uncertain. Following sections provide a description of these elements.

Context

The first set of elements deals with the large number of contextual variables that act at different levels and that influence education and consequently the use of IT in teaching and learning. Kozma (2003a) describes three levels which may influence IT use in education:

1. *Macro-level* or system factors such as cultural norms, social context, educational policy, curriculum standards, etc.
2. *Meso-level* or school factors such as IT infrastructure available, IT integration plans, school leadership, innovation history, parents, etc.
3. *Micro-level* or individual factors for teachers, such as pedagogical practice, innovation history, educational background, experience with technology, etc; and for pupils, such as experience with technology, social and cultural background, etc.

These variables influence the way in which technology can be used in schools and therefore, the combination of particular values of these factors draws different scenarios that convey particular challenges and possibilities for the use of IT.

Pedagogy

The second set of elements corresponds to the type of pedagogy that the teacher implements. For example, Table 1 presents two pedagogical approaches, one fitting in the industrial society and one that suits the information society (Voogt and Pelgrum, 2005).

Despite of the particular approach in use, Table 1 illustrates the variety of activities available for teachers to develop during their lessons. Additionally, although there is a tendency to associate the use of IT to the more innovative type of activities

Table 1 Overview of pedagogical approaches that fit the industrial vs. the information society

Aspect	Pedagogy in an industrial society	Pedagogy in the information society
Active	Activities prescribed by teacher	Activities determined by learners
	Whole class instruction	Small groups
	Little variation in activities	Many different activities
	Pace determined by the program	Pace determined by learners
Collaborative	Individual	Working in teams
	Homogeneous groups	Heterogeneous groups
	Everyone for him/herself	Supporting each other
Creative	Reproductive learning	Productive learning
	Apply known solutions to problems	Find new solutions to problems
Integrative	No link between theory and practice	Integrating theory and practice
	Separate subjects	Relations between subjects
	Discipline-based	Thematic
	Individual teachers	Teams of teachers
Evaluative	Teacher-directed	Student-directed
	Summative	Diagnostic

Voogt and Pelgrum (2005, p. 158)

(i.e. the ones associated to the information society), particularly among teachers that use IT as an instrument to express how they want to be seen as teachers (Olson, 2000), there is enough research to illustrate how IT can be used in activities corresponding to both pedagogical approaches, thereby expanding the possible types of activities to implement.

Range of Activities: The Instructional Instances

The third dimension corresponds to the design of the instructional instances of the lesson. Regarding this dimension, there are several "traditional" proposals for structuring a lesson, such as the ones proposed by Gagné (1987) or others that are more related to particular pedagogic roles. In this last vein, Leinhardt et al. (1987) define routines as systems of exchange that are set up to accomplish tasks and included three types: (a) management routines that include housekeeping, discipline maintenance and people moving tasks; (b) support routines, i.e. specific behaviours and actions necessary for a learning–teaching exchange to take place, for example "how to pass in papers", and (c) exchange routines, i.e. the interactive behaviours that permit the teaching and learning exchanges to occur. They govern the language contacts between teachers and students – for example, routines for choral responses.

For instance, a teacher can structure the lesson, considering that the initial activity of a lesson can be designed to motivate students (management routine), a second part for demonstrating concepts or ideas, after that the teacher can trigger discussions (exchange routine), and finally illustrate how to perform an experiment (support routine), etc.

Regarding this dimension, there is not much research that focuses on the use of IT only for specific activities or routine activities during the lesson (see discussions in Hinostroza and Mellar, 2001). On the other hand, there are a growing number of proposals that relate IT applications to activities during the lesson. It highlights the principles for designing effective learning activities proposed by Boettcher (2007). Some principles include scaffold learning on students' prior knowledge, teach children how to learn, apply concepts in multiple ways and varied contexts, and so on. These principles provide thoughtful rules that prescribe how to design activities for a lesson, but they do not clarify what to do in a lesson (i.e. activities and its sequence).

Technologies

The fourth set of elements corresponds to the technologies. In fact, for each configuration of the previous elements, there are a variety of technologies that have different characteristics and affordances. Table 2 presents a classification of different IT applications and its possible educational use (OECD, 2001).

All these IT applications can be used to enhance learning, but as it has been argued before, the question is what is the best technology to support a teaching and learning activity in a particular context?

The sets of elements presented above define a space of opportunities from which teachers, in a given context, need to select a pedagogical approach, design a set of activities that will be developed during the lesson (instructional instances) and choose the best IT applications that support these activities. As it can be imagined, the variety of options is large, for example, what particular piece of software would be recommended in the following:

> A sixth grade mathematics teacher of a semi-rural school has 6 computers. There are 30 students in her class. These students are from a low-income socio-economic background. They only have access to computers at school. The teacher's vision on education is to value and respect the environment. She wants to implement problem-based learning in geometry (properties of geometric corpus) and is in the phase of starting to present some background information to state the problem.

The main problem is that there is not enough evidence available to produce responsible recommendations for technology choices for a given pedagogical approach and instructional instance that has to be implemented in a particular context. One explanation for this is that the availability of choices is permanently changing either because of new pedagogical approaches and new curriculum demands, or due to opportunities arising from new technologies that are being introduced in schools (e.g. interactive whiteboards – IWB) or that are being adopted by the learners (e.g. mobile phones, PDAs). This sets a highly dynamic and uncertain scenario in which arguments about best technology option change before they can be proved to be right or wrong.

In this vein, some authors argue that the design of pedagogical uses of technology requires the development of a new type of knowledge that they call technological pedagogical content knowledge (TPCK). Particularly, they argue that, "in practical terms, this means that apart from looking at each of these components in isolation, we also need to look at them in pairs: pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and

Table 2 Classification of different IT applications

Type of application	Examples	Educational use
General tools	Word processing, presentation, spreadsheet, multimedia authoring, including Web publishing	Becoming more and more important; require innovative and creative thinking from the teacher; quality is in the application, not the tool itself, since such tools are not dependent on particular content
Teacher tools	On-line lesson outlines; computer-projector systems; interactive whiteboards	Lesson preparation; whole class teaching with shared view of screen; interaction managed by teacher
Communications	E-mail, e-learning; video-conferencing, Internet browsers	Require a view of education as reaching beyond school, for which they offer huge potential; familiar in the out-of-school context
Resources	Especially Web-based, whether general or specifically educational	Used according to availability, in whatever way wished; for resource-based, skills-oriented learning
Computer-assisted instruction (CAI)	Drill-and-practice, related to a certain kind of content and relatively unsophisticated	Offers individual learning opportunities without expensive development; appears to fit well with transmission models of teaching and learning
Integrated learning systems (ILS)	Individualized task assignment, assessment and progression, including CAI, with recording and reporting of achievement	These appear to sit outside teacher-led instruction and learning, but are only truly effective as an integrated part of the learning process, which may have to be re-thought
Computer-based assessment tools	Examination boards are developing computer-based examinations, which attempt to mimic paper-based tests	Components give advantage to the computer literate; teachers will need to incorporate some elements of similar tasks in their teaching, to prepare students adequately
Management tools[a]	Classroom procedures	Students' progress, deficiency analysis, etc.
	School administration	Financial, personnel and educational resources
	Publication of results	Parents, governors, inspectorate, general public
	Communication	e.g. school to home and vice versa

OECD (2001, pp. 38–39)

[a]Little is known about the effects of these four kinds of management tools on the quality of teaching and learning

all three taken together as technological pedagogical content knowledge (TPCK)" (Mishra and Koehler, 2006, p. 1026). In fact, we would argue that TPCK is the type of knowledge needed to design a lesson.

On the other hand, despite this large set of options, international evidence shows that the most commonly used IT applications in schools are general tools, e-mail and the Web (Kozma, 2003b; Pelgrum and Anderson, 1999; Venezky, 2002). Although one could argue that these technologies are the most "traditional" ones, this research also shows a quite innovative pedagogical practices using technology. Moreover, Anderson (2003) reported that diversity is the outstanding characteristic of these cases and that "any given innovation was likely to utilize diverse pedagogies concurrently" (p. 215).

The fact that these practices used a variety of technologies to support different pedagogical approaches supports the claim that the space of IT choices is much more complex than it appears to be and that teachers in schools are already making this type of decisions, probably using rules based on intuition and experience. In this vein, teachers look for ways to fit new technologies into classroom "business as usual" or as Lankshear and Knobel (2003) called it, the "old wine in new bottles" syndrome.

Bearing this in mind, we argue that to reduce this complexity, there is a need to recognize the different elements that interact in this decision and develop understanding of the role of IT in specific situations defined by a particular context, pedagogy and activities during the lesson.

Trends in Emerging Technologies and Learning

We have focused on previous sections in the more known or "traditional" use of IT and we have argued that this use struggles with a number of variables which gives the bases of some use patterns. In this section, we describe, from the technology standpoint, what new or "emerging technologies" are being explored so as to improve existing teaching–learning processes or to create new ones. In particular, we suggest that emerging technologies can be grouped, based on its intention, as belonging to one of these three groups:

1. Expanding learning opportunities (learn anywhere and anytime)
2. Creating new learning scenarios in traditional contexts (tools for students focused on improving learning in schools)
3. Improving teaching and learning process (tools for teachers focused on improving teachers' classroom teaching)

Expanding Learning Opportunities

Attempts to create new learning opportunities are largely based on the use of mobile technologies. In fact, its use in education is evolving rapidly and there are high expectations on its potential. For example, Chan et al. (2006) argue that "three factors – (1) ubiquitous access to mobile, connected, and personal, handhelds, (2) the relentless pace of technological developments in one-to-one computing, and (3) the evolution of new innovative uses of these handhelds – will create the potential for a new phase in the evolution of technology-enhanced learning, characterized by seamless learning spaces" (p. 23). Some projects that use mobile technology to expand learning opportunities use e-mail and voice communication to support students' learning and to promote their participation in Web communities. Other projects are looking at the provision materials, including multimedia games, SMS text messages and context-aware content and services for the learners (Lonsdale et al., 2004).

Based on these types of experiences, Stead (2006) argues that now it is known that mobile learning can empower and engage and that the engagement and motivation can continue beyond the initial "gadget honeymoon". Also, he reports that learners are more comfortable engaging in personal or private subject areas using a mobile device than doing so using traditional methods and that these devices can be powerful tools for self-evaluation and reflection.

Digital television, due to its interactivity, is emerging as a technology that can expand learning opportunities since it is slowly moving from a mass to a more personalized medium. In this vein, Bates (2003) argues that t-learning (TV-based learning) can be an alternative solution to utilizing an Internet-enabled computer, but research is still limited in this arena.

From a different perspective, *Wikis* – i.e. Web sites that allow several users to easily add, edit and remove content in collaborative way (Cych, 2006; Engstrom and Jewett, 2005) – are another emerging technology that are expanding the learning opportunities. In this regard, Cych (2006) argues that the main learning opportunity of *Wikis* is that "each person shares a part of what they know to construct a whole – in effect another form of peer-to-peer constructivist learning" (p. 35).

Examples of ways in which *Wikis* are used include creating encyclopaedias (Wikipedia), brainstorming sessions, project development, practicing language and promote creative writing (Cych, 2006). Additionally, there are authors that confer upon *Wikis* an important opportunity for knowledge democracy.

Creating New Learning Scenarios in Traditional Contexts

Due to its (potential) wide availability, mobile devices are being used in classroom scenarios, for example to support collaborative activities in the classroom (Zurita et al., 2005), using PDAs to create simulated scenarios or landscapes in which students assume the role of animals in a Savannah (Facer et al., 2004), and others in which students develop behaviourist, constructivist, situated, collaborative, informal and lifelong learning activities for computers, for example, in schools serving disadvantaged communities in which the installation and maintenance of computers are not feasible (Leach et al., 2005).

Classroom communication systems (CCS) are also new technologies that show an accelerated penetration in schools. CCS – also known as classroom response systems (CRS), personal response systems (PRS), electronic voting systems (EVS), classroom network and audience response systems (ARS) – are basically receivers that input on-line signals from 30 or more remote devices used by students. In general terms, research results show that these technologies are used to enhance questioning and feedback, to motivate and monitor the participation of all students, to foster discussions of important concepts, to promote collaboration and competition, to energize and activate students' thinking and to enable to collect data for further analysis of the lessons or evaluations (Roschelle et al., 2004). Also, when used in conjunction with interactive teaching strategies, such as peer discussion, it has been shown that they produce gains in conceptual understanding in subjects such as science (Crouch and Mazur, 2001). Additionally, some current research in this field is looking toward expanding the theoretical basis of its application, based on a socio-cultural perspective (Penuel et al., 2006).

Finally, learning objects (LO) have also created new learning scenarios. In fact, they are becoming very popular, especially among the computer-based instruction researchers. In general terms, a learning object can be defined as any digital resource that can be re-used to support learning and in this sense is a new type of computer-based instruction, grounded in the object-oriented paradigm of computer science (Wiley et al., 2004). Although the concept is attractive for education, there is much debate about the real possibility of re-using LO (Collis and Strijker, 2001; McKenney et al., 2008), particularly because the conditions for its re-use are based on technical considerations, rather than on pedagogical ones. Actually, many studies report that the main difficulty while re-using LO is that students' learning needs are very particular and therefore each class needs a new set of instructional conditions and strategies (Collis and Strijker, 2001; Wiley et al., 2004).

Improving Teaching and Learning Process

The teaching activity has not always been considered as an opportunity to use technology for improving learning; only recently, new initiatives are focusing in the use of digital technologies to improve what teachers do in the classroom, hence to improve learning.

In this vein, the first of these technologies are the IWB. Although IWB are relatively old technologies, its massive introduction to schools started with the millennium and its use is expanding rapidly. The main potential of this technology is that the software developed for its use in the classroom can expand the resources available for the teacher and its manipulation resembles the use of a traditional blackboard.

Research has shown that the main benefits to use IWB for teaching and learning are:

- Versatility with applications for all ages; increases teaching time; more opportunity for interaction and discussions in the classroom; increases enjoyment of lessons for students and teachers.
- Enables teachers to integrate IT into the lessons; encourages spontaneity and flexibility; enables teachers to save and print what is on the board; allows teachers to share and re-use materials; widely reported to be easy to use; inspire teachers to change their pedagogy and use more IT.
- Increases enjoyment and motivation of students; provides more opportunities for participation and collaboration; reduces the need to note taking; students are able to cope more complex concepts; different learning styles can be accommodated;

enables students to be more creative in presentations to their classmate; students do not have to use a keyboard to engage with the technology (good for younger children).

(see Smith et al., 2006).

On the other hand, there is evidence that IWB bring about learning improvements within more traditional pedagogical approaches rather than learning transformations.

Conclusions

The reviews and discussions presented in the previous sections of this chapter represent a good sample of the issues being discussed today regarding the introduction of IT in K-12 education.

Regarding the role of IT in education, it was argued that IT can be considered to facilitate student learning, may change the curriculum and may improve teaching and learning. It was showed that IT might have a variety of impacts on learning, which includes achievement, IT competencies and student behaviour. Several factors affecting the selection and use of IT applications in teaching and learning situations were discussed, such as context, pedagogical approach and instructional instance. Finally, emerging IT applications were explored for their potential to expand learning opportunities, create new learning scenarios and improve the process of teaching.

All these perspectives on IT provide a complex tapestry, in which it is becoming increasingly difficult to keep positions and/or opinions at such a level of generality. However, the analysis of this information allows extracting some general tendencies in the field:

– Despite the increasing social- and economic-related benefits of the introduction of IT in education, there is still an ambition to impact student achievement, particularly achievement measured through national-level tests. This has been the "Holly Grail" for IT in education researchers and policy makers, and apparently it will continue to be for some time. On the other hand, there are a growing number of researchers that argue for "changing the target", this is, to define and measure the set of learning aims that are in fact affected by the use of IT. However, there is also a discussion about the definition of these "new" learning aims.
– Research has shown that the introduction and use of these technologies depend on a large set of interrelated variables including the context of use, the pedagogical approach and the instructional instance, in which particular pieces of hardware and software can play particular roles. The combination of these elements forms a large set of options which are difficult to characterize and therefore to research and test. In this context, we claim that there is a need for research that systematically defines and explores combinations of these dimensions.
– There is a rapidly growing availability of new types of digital technologies that are challenging research to look for their potential impact on education. This situation widens substantially the concept of "IT" and expands the "IT in education research field" since now it includes all sort of digital devices.

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1.6

DRIVING FORCES FOR ICT IN LEARNING

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Introduction

Information and communication technology (ICT) has a prominent place in students' lives. In Western societies, students grow up in an information society, using all sorts of ICT applications. Blogs, social networking sites and interactive games have created new modes of interaction and expression. Intensive use of ICT is fully integrated in their daily lives. The rise of this so-called digital generation poses serious questions for teachers with regard to the use of ICT in education and ways to stay connected with their pupils. To build a bridge between the educational system and the digital generation, most schools have invested in the availability of an ICT infrastructure. As a result, most teachers in Western societies have computer facilities at their disposal for their lessons (Pelgrum and Anderson, 1999; Kozma, 2003; Balanskat et al., 2006).

However, it is becoming increasingly clear that the availability of an adequate ICT infrastructure, while necessary, is not in itself a sufficient condition for effective use of ICT in education. At many schools, teachers are struggling with the question how to use ICT for instructional purposes. In this chapter, various driving forces and contrasting issues on using ICT in education for teaching and learning are discussed on the basis of a conceptual framework.

Conceptual Framework

For a good understanding of the role and potential of ICT for learning, it is necessary to identify the key elements or driving forces underlying a learning process. Driving forces are responsible for changes in the arrangement of a learning process.

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Four key elements determine the learning process: the teacher, the student as a learner, the learning content and the learning materials (Plomp et al., 1996; Voogt and Odenthal, 1997). Figure 1 presents the key elements of the learning process and the influencing components. The horizontal dimension represents the relation between the actors in the learning process: the *teacher* and the *learner*. The vertical dimension represents the learning infrastructure, consisting of *content* in terms of what has to be learned and *learning materials*, including ICT *infrastructure*. The learning process takes place at the cross section of these dimensions, as a result of the interplay between the four driving forces: teacher, learner, content and materials. The level of school organization and management, represented by the outer circles, provides the context or environment of the learning process. The figure illustrates the view that a learning process is the result of both structural conditions derived from the school environment and the learning infrastructure, and the individual characteristics of the actors and their interaction.

The arrangement of the learning processes can be approached from different angles. If the main driving force is learning content, complementary attention has to be paid to learning infrastructure, learner characteristics and the role of the teacher. By the same token, the choice of learning infrastructure, the learner characteristics or the role of the teacher may also be the main driving force. We argue that the dominance of one of the driving forces is not neutral in relation to the ultimate arrangement and results of the learning process. The dominance of a driving force can be seen as an instructional paradigm for learning. Within this context, an instructional paradigm is defined as a set of assumptions, concepts, values and practices that constitutes a way of viewing reality for the community that shares them (derived from American Heritage Dictionary). When inconsistencies arise within a given paradigm or when an instructional paradigm no longer meets the demands of society, other driving forces may

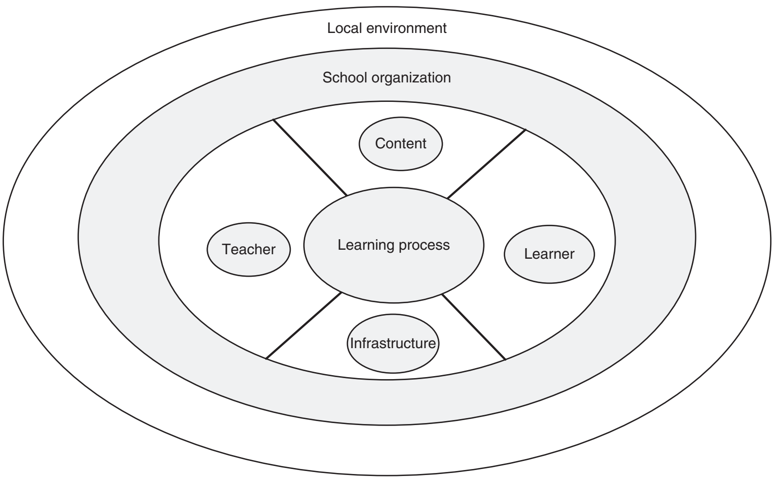

Fig. 1 Driving forces of ICT in the learning process (Plomp et al., 1996; Voogt and Odenthal, 1997)

gain in importance to create new arrangements that solve the unsolvable problems of the old paradigm. A substantial change can therefore be called a *paradigm shift* (Kuhn, 1970) and implies new assumptions, views, expectations and standards of practice for the arrangement of learning processes.

In the next section, we first elaborate on the four separate components or driving forces that influence the learning processes at classroom level, focusing on the actors (teacher and learner) and factors (content and infrastructure) which mediate learning processes involving ICT. However, all four driving forces work together to affect the ultimate arrangement of these learning processes. This implies that finding a balance between the driving forces is important for learning to take place. In "Example of a Contrasting Position in Instructional Practices: Teacher or Student as Regulating the Learning Process" section, therefore, we will focus on some examples of conflicting issues that can be found in educational practice and that illustrate the consequences of taking one particular driving force as starting point.

ICT Infrastructure as Driving Force

If a learning process is driven by capabilities of technology without any specific need from the perspective of the teacher, the learner or the learning content, it refers to "technology push". Technology push starts with the acquisition of ICT materials and then appropriate applications are sought that fit into a learning process. If a learning process is not driven by technology but led by the demand or need of the teacher, the learner or the learning content, it refers to "educational pull". The concepts technology push and educational pull refer to two well-known positions connected with the relation between technology and education: the belief which regards technology as a catalyst for educational change and the belief that technology has to follow educational needs.

The underlying assumption of "technology push" is the expectation that the availability of ICT materials is a powerful driving force for implementing ICT in education. During the past decade, this approach was dominant in many countries with regard to the introduction of ICT in education (Plomp et al., 2003). As a result, many schools have invested in ICT infrastructure and in ICT materials and superimposed them on traditional materials and teaching methods, without changing existing educational practices. In addition, many countries have established national or regional portals that offer content for teaching and learning. The assumption is that providing rich sources of digital information will enhance the transfer of knowledge (Digital Media Project – DMP, 2006). Easy access to vast quantities of educational content is seen as an enabler for schools to implement new pedagogical methods for teaching and learning. The availability of an ICT infrastructure is expected to boost the use of ICT and the transformation of learning processes within schools. An illustrative list of national or regional portals can be found for example at http://www.eun.org or http://www.kids.gov/k_states.htm. Advocates of technology as a driving force also mention that digital content is easier to find, to access, to manipulate, to remix and to disseminate (DMP, 2006). It is also argued that digital content and the corresponding digital distribution methods permit students:

- convenient access to learning materials
- quicker turnaround for time-sensitive work
- use of hypertext to allow access to more detailed information
- incorporation of audio or (archived) video clips
- collaborative discussion of work on an ongoing basis (e.g. submitting responses, linking to other resources).

Furthermore, according to the Digital Media Project (DMP, 2006), it is expected that "open" forms of digital learning allow efficient creation and distribution of varied educational content. Open forms of learning will allow everyone to become teacher as well as student, as illustrated by the rise of Wikipedia. It is a development which, according to this view, will reduce the involvement of traditional institutions such as schools. However, it also presents problems in terms of monitoring the quality of content, protecting the copyright system that acknowledges the creator of an original work and striking a manageable balance between supply of digital content and actual use (DMP, 2006).

The availability of an ICT infrastructure is seen as the foundation for what is variously referred to as digital learning, ubiquitous learning and life-long learning. Technology provides the opportunity to learn beyond the formal institutions of schools and to involve everyone, at any time, and at any place with Internet access. According to this view, technology expands opportunities for learning by bringing real-world problems into the classroom and providing possibilities for building local and global communities that include teachers, students, parents and experts (Bransford et al., 2000).

The dominant approach of stimulating ICT infrastructure in the past decade is reflected in many studies that have tried to measure ICT integration into education in terms of infrastructure and access, such as availability of computer hardware, the pupil–computer ratio, the average number of computers per school and levels of connectivity and bandwidth (Balanskat et al., 2006).

The results of policy programmes aiming at improving the ICT infrastructure show the risks of technology push: technological applications that do not meet the pedagogical needs of either teachers or learners and that do not fit within the school organization (ten Brummelhuis, 2006). Furthermore, ICT in education is mainly used as a replacement within existing practices in teaching and learning. The contribution that the provision of ICT materials to schools and teachers has made to the implementation of innovative practices seems to be limited (Kozma, 2003). The creative potential of ICT usage and the use of ICT for communication with and between pupils is still in its infancy (Balanskat et al., 2006). More and more evaluation studies on the impact of ICT on learning reveal that the benefits of ICT cannot only remain technology driven but also should be in balance with other preconditions, such as the pedagogical beliefs and skills of teachers (Balanskat and Blamire, 2007; Machin et al., 2006; Kennisnet ICT op School, 2006; Harrison et al., 2002; E-learning Nordic, 2006). The dominant approach of integrating ICT in education through the large-scale acquisition of ICT materials and ICT infrastructure raises the question "Are computers in schools worth the investment?" (Cuban, 2001).

Content as Driving Force

This driving force takes learning content as the dominant feature of the learning process. From this perspective, setting clear targets and instructional goals for student learning is the starting point in the design of the learning process, which is arranged according to the following key questions (Atkin et al., 2001):

– What do you want to learn?
– Where are you now?
– How can you get there?
– How do we test what you have learned?

In this orientation, the main purpose of the learning process is to introduce students to learning content such as subject matter disciplines. The content and level of knowledge are predefined and students have to meet these learning goals or quality standards. For teachers, this approach implies the understanding of learning continua to monitor and support the learning process on the basis of assessments. This driving force was important in traditional forms of schooling that treat learning goals as a fixed commodity. Knowledge has to be delivered by teachers and for that purpose, the teacher makes use of supporting materials. The curriculum is laid out in a fixed sequence and every student goes through the same schedule, which is planned beforehand. To obtain feedback about student progress, the teacher makes use of standardized tests and assessment. This is an assessment-centred learning design and learning is seen as arriving at an understanding of a predefined body of general knowledge.

The setting of high levels of learning goals and examinations is in the general interests of the business community and the job market. Not all students are able to meet these goals, and some members of this group are turning away from school. To reduce drop-out rates and to make school more attractive for students, both educational policy and practice are interested in other approaches to learning which focus on meeting learners' interests to a higher degree. "Teaching for understanding" is based on a different assumption about learning and learning goals. It assumes that knowledge is a human construct and that learners must play an active part in changing their minds, making sense, connecting prior ideas with new ones, thinking actively about what they learn, and creatively applying knowledge in novel situations (Bransford et al., 2000; Wiske et al., 2001). According to this view, the function of assessment is to provide feedback to learners with recommendations for improvement. This feedback is provided by the teacher in the role of a coach, as well as by peers and self-assessment. In this conception, the goal of learning is to construct knowledge and this process calls for a mix of suitable educational media together with the presentation of information and arrangement of practice and feedback (van Merriënboer and van Kester, 2004). According to van Merriënboer and van Kester, this type of complex learning calls for an instructional model consisting of four interrelated components:

1. *Learning task*: meaningful whole-task experiences that are based on real life
2. *Supportive information*: information that is supportive to the learning and performance of problem solving and reasoning aspects of learning

3. *Procedural information*: information that is prerequisite to the learning and performance of routine aspects of learning
4. *Part-task practice*: additional exercises for routine aspects of learning tasks for which a very high level of automaticity is required after the instruction

The above components cover two different types of learning goals: deep and surface (Biggs, 1996). Deep learning is associated with interest in the learning content and searching for meaning by the learner. This kind of learning is driven by an intrinsic motive to seek meaning and understanding. Surface learning is characterized by acquiring sufficient knowledge to complete tasks and by meeting predefined knowledge. As such, a student relies on memorization and reproduction of knowledge. This approach is often driven by an extrinsic motive to gain a certificate or to pass an exam.

The Teacher as Driving Force

The role of the teacher can be defined as creating conditions for learning. It is evident that, in this process, a teacher makes choices based on a particular set of pedagogies or his vision of teaching and learning (see also Dede, 2008 in this handbook). This means that, within the context of the school and the social environment, the teacher is responsible for realizing the best fit between the professional qualities of the teacher himself on the one hand and learner characteristics, learning goals and learning materials on the other hand.

A key pedagogical question is to ask which learning activities are under the control of the teacher and which activities are more the responsibility of the learner. The activities of the learning process for which responsibility and control have to be divided between teacher and learner cover three main tasks: preparatory activities, instruction and regulatory activities (Simons and Zuylen, 1995). The preparatory activities cover orientation towards learning goals and learning activities, including generating interest and getting started. Instruction includes building knowledge, practising skills, reflecting, formulating conclusions and relating to what is being learned. Finally, the regulatory activities refer to monitoring progress, generating feedback and evaluating results to improve learning.

When the teacher is mainly responsible for choice of learning activities and transmission of knowledge, this is referred to as externally regulated or teacher-centred learning. If the learner is mainly responsible for the learning activities, this is referred to as self-regulated learning or student-centred learning (Boekaerts, 1997; Lea et al., 2003). The learner-centred approach is described in more detail in “The Learner as Driving Force” section.

Research results show a strong association between the use of ICT and the pedagogical beliefs of teachers (Riel and Becker, 2008; Drent, 2005). Teachers who believe their role is to transmit an externally mandated curriculum through a highly controlled pedagogy tend to avoid computers; teachers who support collaborative learning and individual student work on topics of personal interest tend to use computers frequently (Becker and Ravitz, 2001). Findings in a study on effectiveness of reading and mathematics software show that teachers using selected software products were more likely to facilitate individual student learning rather than lead whole-class activities (Dynarski et al., 2007). On the other hand, an interactive whiteboard can be an effective medium for teacher input to whole-class activities and an effective medium to support teacher-led group work (Smith, 2001). These results show that effective use of ICT is not related to a teacher-centred or a learner-centred approach. Teachers linked with effective use of ICT in the learning process are able to find coherence between teaching style, learning content and ICT materials (Zhao et al., 2002).

The Learner as Driving Force

The basic principle of the learner as driving force in the learning process is finding a connection with student characteristics and students' needs in learning. This means that the teacher gives primacy to the strengths and interests of learners in terms of knowledge, skills and attitudes (Bransford et al., 2000). The learning process provides personally satisfying experiences for the learner. In this perspective, there is widespread agreement on several educational ideas. These include constructivism, authentic problem-solving and life-long learning (Bereiter, 2002). Learners are stimulated to express, experiment, make mistakes, obtain feedback and discover. To create challenging learning situations, the teacher needs a thorough awareness of the basic cognitive processes that influence the learning process, such as motivation, attention, information processing, comprehension and transfer (Darling-Hammond and Bransford, 2005). This paradigm moves the concept of learning beyond the rote memorization of facts to learning as a process of knowledge creation (Kozma, 2003). It envisions a learning process in which students set their own goals, plan their activities and select their learning materials. Students also monitor their levels of mastery and understand what is referred to as *metacognition* (Bransford et al., 2000).

The rise of the learner as a driving force in learning processes seems to result in a re-orientation of testing practices towards methods, such as self-assessment, peer assessment and co-assessment. This kind of assessment involves an assessor, which can be a teacher, a student or an expert, in reviewing, summarizing, clarifying and giving feedback. Research has produced promising findings on these forms of assessment, in which learners share responsibility, collaborate and conduct continuous dialogue with their peers (Sluijsmans et al., 1999). It is argued that this type of assessment is cognitively demanding and fosters deep rather than surface learning (van Lehn et al., 1995) and can be supported by several representations of ICT, such as a portfolio assessment, blogs, wikis or tools within e-learning environments.

The "primacy of the learner" approach is child-centred and aims at integral development in cognitive as well as affective, social and moral development. Such a perspective is also strongly related to the lifestyle of students and is often labelled "new learning" (Simons, 2000; Veen, 2005). Veen and Vrakking (2006) argue that young learners of today have grown up with electronic devices and have learned how to navigate efficiently through information, how to communicate and how to build effectively on a network of peers. It is assumed that students develop exploratory learning approaches while attempting to give meaning to the information provided. It is also argued that, for current education, these developments imply the challenge of bridging the gap between learning situations at school and the needs of the "net-generation" or "digital natives" who have become disengaged from traditional instruction (Prensky, 2006). Nowadays, many learners require multiple streams of information, prefer inductive reasoning, want frequent and quick interactions with content, and have exceptional visual literacy skills (Oblinger and Oblinger, 2005). These characteristics correspond closely to the demands made by digital games. Games often have the stigma of "play" and the opposite of "learning", and are strongly associated with leisure activities. But more and more people believe that games can also be an effective element within the learning processes. However, much remains unknown about the conditions under which games can be integrated into the learning process to maximize learning results (Leemkuil, 2005).

Even in the situation in which the primacy is on the learner, there is still a key role for the teacher in facilitating learning. Thus, the teacher has to decide *why* to use *which* ICT tools within his own instructional approach, since educational technology is a tool that can be used to support a variety of approaches to instruction. This puts the teacher in the position of having to decide on several contrasting positions in instructional practices. Irrespective of whether the primacy is on the learner, the materials or the learning goals, every teacher has to deal with these contrasting positions.

Example of a Contrasting Position in Instructional Practices: Teacher or Student as Regulating the Learning Process

In the previous section, we presented separate discussions of the four driving forces that influence the learning process. However, these forces all exert an influence on any specific learning situation in which ICT is used. To illustrate the interaction between driving forces, in this section, we elaborate as an example the contrasting position between the roles of the two actors that influence the learning process: the teacher and the learner/student.

When viewing both teacher and student (or learner) as acting driving forces within learning, learning processes may be characterized in terms of the amount of control or regulation and responsibility or autonomy of each actor. We will discuss this issue by starting with the student as most prominent actor, moving gradually towards the teacher as prominent driving force.

ICT-Based Learning and Student Control

Since the first uses of ICT in the classroom, the opportunities it offers for students to control their own learning have been prominent. ICT-based learning can indeed provide students with greater flexibility in terms of learning time, location and pace. On a small scale, this can be seen in students using the school computer in the classroom to practice spelling or maths. On a much greater scale, there are all kinds of initiatives with regard to e-learning, Web-based learning and distance education which offer learners the opportunity for "life-long learning" without the restriction of any system-related boundaries. Moreover, the growth and widespread use of the Internet in education and in society as a whole emphasize the shift from "knowing what" to "knowing how": factual knowledge is considered as being equally or even less important than being able to find your way in the information society. As a consequence, the role of the teacher is seen as changing from knowledgeable expert or "fountain of knowledge" to a coach of students' learning processes or a "guide at the side" (e.g. Schofield, 1995). Moreover, the use of technology as a learning tool in the classroom often means a shift of power in another sense, since in many cases the students' technical mastery of ICT tools exceeds that of their teachers.

Influence of the Educational Context: The Role of the Teacher

However, as Snyder (1998) states: "No technology […] can guarantee any particular change in cultural practices simply by its 'nature'. […] The use and effect of a technology is closely tied to the social context in which it appears" (p. 140). Is there indeed a shift in the control of learning processes taking place in classrooms, under the influence of ICT use? Smeets and Mooij (2001) reported on an international study of teaching–learning characteristics and the role of the teacher in ICT learning environments. Their results show that, in many cases, ICT is used to facilitate traditional, teacher-centred ways of teaching. Although many teachers acted as coaches, they also tended to stay in control of the learning environments, with little room for student initiative. This illustrates the complexity of terms like "student-centred" or "student control". Smeets and Mooij define student-centred learning environments as fitting into a constructivist view of learning, with learners as active constructors of knowledge. Such learning environments require differentiation of lesson content and curriculum activities, in which ICT may be a useful tool. Smeets (2005) emphasizes the importance of teachers being aware of the potential of ICT to stimulate students' active and autonomous learning. In this study, only a minority of the teachers used resources such as open-ended ICT applications that may contribute to such learning.

Although e-learning and distance learning may enable students to study in their own place, in their own time and at their own pace, this does not necessarily mean that they also control their own learning. In other words, their autonomy may be mostly limited to practical circumstances while the most important part of their learning – the content – is beyond their control. The teacher may still control the curriculum and the assessment of students' learning; only the way of delivering the curriculum has changed. As a result, the student may be as active or passive as in a traditional classroom. This is also illustrated by the widespread use of educational software that closely resembles traditional school curricula. One may question the fundamental difference between practising maths in a traditional classroom and practising maths on the computer. Most modern educational software at primary school level uses advanced technological features and may be more motivating for students than a traditional textbook. Yet here again, student control only extends to time, place and pace.

Another example may be the use of the Web as an information resource in education. Potentially, the Web offers students new opportunities to organize their own learning, because of its accessibility and the abundance of information it offers. It can easily be used as a motivational alternative for traditional print resources. However, as already stated by Laurillard (1998), "The paradox of interactive media is that being a user-control medium the learner expects to have control, and yet a learner does not know enough to be given full control" (p. 241). Many students do not have the necessary skills to use the Web in a critical way and for their own knowledge construction (Kuiper et al., 2005). Thus, students still need a great deal of guidance and support from the teacher if they are to realize the Web's full potential as a learning tool.

Limitations of Student Control

Rogoff et al. (1996) have juxtaposed two models of teaching and learning which both originate from theories that view learning as a one-sided process. Learning is seen either as transmission of knowledge from experts to passive learners (a teacher-centred approach), or as the spontaneous acquisition of knowledge by learners themselves (a learner-centred approach). In the first model, the teacher controls the learning process, with the student acquiring knowledge and demonstrating adequate knowledge acquisition. In the second model, the individual student controls the learning process, with the teacher providing learning opportunities and encouraging students. Although these models may be applied to all learning environments, ICT can be seen as a tool that offers new opportunities for the second model. However, is such a shift in control desirable in all circumstances? Sutherland (2004) studied how teams of teachers and researchers have developed ways of embedding ICT in everyday classroom practices to enhance learning. She questions the casualness with which policy makers and practitioners tend to think that "…ICT is so 'new' that its use will be accompanied by 'new' pedagogies that will somehow transform teaching and learning" (p. 413). The changing role of the teacher, becoming a facilitator of students' learning, is seen by these authors as an over-simplified polarization which fails to do justice to the complexity of the task facing a teacher when integrating ICT in subject teaching.

Rogoff et al. (1996) criticize models that view learning as a one-sided process. They propose a two-sided model, in this case learning in a community of learners in which both students and teacher share responsibility for learning taking place, with the teacher having an important role in creating conditions for learning.

ICT as Facilitating Teacher Control of Students' Learning Processes

From a different angle, ICT may also facilitate a teacher's control of and insight into students' learning processes. Thus, ICT may serve as a tool for curriculum differentiation, providing opportunities for adapting learning content and tasks to the needs and capabilities of each individual student (Smeets and Mooij, 2001, p. 404). Several ICT-based applications give teachers possibilities to adapt the curriculum to individual students' levels of performance, for example through using software that records the way students work and their results, thereby giving teachers insight into both the level and the nature of students' mistakes. Other well-known examples are electronic learning environments such as Blackboard. These offer teachers new opportunities for communicating with students, which may be seen as a form of teacher control. Such programs also give new opportunities for communication between students and teachers. Students may be asked through Blackboard to comment on certain literature, and thus to share their comments with other students and to comment on each other's comments. Because teachers are able to control the way students comment on each other's input (e.g. by providing guidelines for discussing literature) as well as to participate in the communication themselves, they may determine to a great extent both the content and the process of students' communication. Teachers may also take the quantity and quality of students' contributions into consideration when awarding them marks.

The use of electronic learning environments in educational practices often reflects the "technology push" discussed in "ICT Infrastructure as Driving Force" section. Educational institutions make an electronic learning environment available to teachers and students because of its potential surplus value for students' learning. However, they often fail to take into account the precise conditions for learning to take place, as well as the workability of an electronic learning environment for teachers and students. Because it takes a great deal of time and effort on the part of the teachers to integrate the use of an electronic learning environment in their teaching, there is also a risk of it being outdated by the time it is finally implemented.

Discussion: Technology Push vs. Educational Pull

In this chapter, we discussed four driving forces for ICT learning, each representing a key element of learning processes: the teacher, the learner, the learning content and the learning materials. A learning process is the result of both structural conditions and individual characteristics. We have argued that the dominance of each driving force can be seen as an instructional paradigm for learning. To illustrate the mutual influence and dependence of the four driving forces, we have elaborated on one example of the way driving forces interact, i.e. the teacher or student as regulating the learning processes in which ICT is involved.

In this final section, we discuss some major implications derived from the various paradigms of ICT in learning and the controversies teachers face when integrating ICT in classroom practice: technology push vs. educational pull, and the necessity of leadership and personal entrepreneurship.

Results presented in this chapter show that the benefits of ICT materials and ICT infrastructure cannot be separated from other building blocks that influence the learning process: learning goals, the learner and the teacher. No miracles can be derived from the mere presence of ICT in a school. The more powerful technology becomes, the more indispensable good teachers are. The professional development of teachers can be characterized as the most crucial factor for both the adoption and the effective use of ICT in learning processes. Technology push seems to be a poor approach to introducing ICT in education. Educational pull based on a clear vision of learning seems to be a more powerful strategy for the sustainable use of ICT in learning. Sustainable use of ICT in education requires investment in building long-term capacity for improvement, such as the development of teachers' skills. These skills will stay with teachers forever, long after the (project) money for acquisition of ICT materials has gone (Stoll, 1999).

We can conclude that the discussion about ICT in education is increasingly shifting from ICT as a technical issue to ICT as a topic of teaching and learning. It is not ICT that determines the arrangement of learning processes but the educational ambitions of teachers, learners, schools and society; these are the aspects which provide the driving forces for improvement in schools. ICT is only part of the solution. Today, the effectiveness of ICT distracts from educational goals and visions of teaching and learning. Research shows that ICT can make a powerful contribution to solving the educational problems that schools are facing in preparing their students for the information society. However, these same findings show that the use of ICT is not a guarantee for success. ICT offers attractive opportunities for improving the quality of education, but at the same time there are controversies and threats that need to be overcome.

The introduction of ICT raises several contrasting issues, of which one example is highlighted in "Example of a Contrasting Position in Instructional Practices: Teacher or Student as Regulating the Learning Process" section. As these issues show, ICT brings to the forefront debates about education as the transmission of information vs. education as learning and experience. Moreover, assessment should be in congruence with learning. In line with the evolution of new learning arrangements supported by ICT, the nature of the assessment of student learning has to be reconsidered (Birenbaum, 1996).

The great number of choices that have to be made before ICT is adequately integrated within the learning process illustrate that the incorporation of ICT into education is not neutral: its introduction into the learning process implies educational change. According to Hargreaves (2005), educational change will fail if it does not take into account the initiative and enthusiasm of teachers. In a study by Drent (2005), "personal entrepreneurship" among teachers appears to be the key factor for innovative use of ICT. The term "personal entrepreneurship" refers to teachers who create possibilities for experimenting with ICT applications, researching the use of ICT in their education, reflecting on their outcomes and exchanging ideas with colleagues. Despite the crucial role of the teacher in arranging learning processes with ICT, it is an impossible task for a single teacher to realize effective use of ICT within the school organization. The use of ICT is complex and may be overwhelming, requiring teachers to work on too many fronts at once.

It follows, therefore, that the effective use of ICT in schools also needs good leadership and coordination. Both personal entrepreneurship and leadership are necessary factors for success. The contribution of leadership involves working together with teachers to develop a clear vision of what the school should achieve with ICT over time and managing coherence between the building blocks and driving forces of a learning process: learner characteristics, learning goals, ICT materials and the beliefs and competencies of teachers.

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Section 2

IT AND CURRICULUM PROCESSES

2

IT AND CURRICULUM PROCESSES

Joke Voogt
Section Editor

It is generally accepted that our society is changing from an industrial to an information society, in which citizens need to be able to manage huge amounts of information that can be disclosed and processed with the help of information and communication technology. Many students who are about to start their school career will eventually get a job that does not exist yet. Society – through formal and informal schooling – needs to create opportunities for their citizens to develop lifelong learning competencies (see also Section 1). The implication is that many countries in the world have to move toward drastic changes in their curricula. Design and implementation of curricula aiming at contributing to lifelong learning competencies is one of the major challenges of curriculum change and improvement efforts nowadays.

It is obvious that the change toward the information society will amplify the role of IT in the curriculum and will change the curriculum as such. Many have high expectations about the potential of IT in this regard. However, research has shown that students' use of IT at school is considerably less than at home (Organization for Economic Co-operation and Development [OECD], 2005). Numerous factors frustrate the implementation of IT in the curriculum (Mumtaz, 2000). Curriculum-related factors such as courseware that is not clearly linked to national standards or examination syllabuses (Harding, 2001), or IT applications that require more time than a usual 45-min lesson period are only an illustration of the issues teachers have to cope with when integrating IT in their educational practice. In addition, research consistently has had difficulty in providing convincing evidence on the impact of IT on student performance (e.g., Dynarski et al., 2007). This is mainly due to the fact that the use of IT often contributes to the mastery of complex cognitive skills, which cannot be determined by means of standardized tests. From a curriculum perspective there is a gap between the intended, the implemented, and the attained curriculum.

This section deals with the potential of IT for the present curriculum, IT's potential to realize curriculum change and the factors that inhibit integration of IT in the curriculum.

J. Voogt, G. Knezek (eds.) *International Handbook of Information Technology in Primary and Secondary Education, 115–116.*

In Chapter 2.1, Voogt presents an overview of issues relating to the integration of IT in the curriculum. The chapter provides an overview of the intentions for IT in the curriculum and a discussion about the extent to which these intentions have been implemented in schools and have resulted in different educational outcomes.

International research (Kozma, 2003) on IT-supported pedagogical practices has shown that IT can be beneficial for learning subjects as well as for multidisciplinary projects. The impact of IT on learning specific subject matter domains will be illustrated in two chapters.

Chapter 2.2, written by Webb, zooms in on the impact of IT for the science curriculum. There is extensive research on the added value of IT for science education. How IT impacts science education is discussed in this chapter.

Chapter 2.3, by Van Scoter, reviews the potential of IT to foster literacy skills. The chapter particularly addresses literacy skills of young children. Research in this domain is limited, but is increasingly becoming more relevant and part of the public debate in many countries.

Nachmias, Mioduser, and Forkosh-Baruch address in Chapter 2.4 the potential of IT to renew curriculum practices. Based on data from international case study research the authors show that IT facilitates multidisciplinary curriculum approaches and change curriculum toward goals that better fit the information society.

Curriculum change also requires changing assessment practices. To what extent IT is impacting assessment, either by facilitating existing practices or initiating new practices, is reviewed by Erstad in Chapter 2.5.

IT not only impacts the primary and secondary school curriculum, it also has the potential to support curriculum development. In Chapter 2.6, McKenney, Nieveen, and Strijker address computer-support for curriculum development and implementation.

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2.1

IT AND CURRICULUM PROCESSES: DILEMMAS AND CHALLENGES

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A Curricular Perspective on IT in Education

Curriculum deals with the goals, content, and organization of learning at several educational levels (Walker, 2003). Increasingly assessment is also seen as an integrated part of curriculum. Curriculum content and goals need to be well attuned to the other elements of the curriculum, viz., the organization of the teaching and learning process and assessment. For this reason several scholars (e.g., van den Akker, 2003) propose that it is useful to more specifically define the components that are at stake in a curriculum. Van den Akker mentions ten curriculum components that need consideration in designing and implementing curricula: rationale, content, aims and objectives, learning activities, teachers' role, grouping, materials and resources, location, time, and assessment. By using the metaphor of the spider web, van den Akker illustrates the interconnectedness between curriculum components and shows the need for a comprehensive approach to change curricula.

For a long time the implementation of IT was perceived by policy as a matter of provision of hardware and software only. Just recently attention has been paid to the implications of the use of IT for curriculum content, learner activities, teacher role, assessment practices, etc. The integration of IT in the curriculum is a complex endeavor in which many stakeholders are involved.

To better understand the problems related to the implementation of complex changes as the integration of IT in education, curriculum researchers (e.g., Goodlad et al., 1979, van den Akker, 2003) use an analytic framework to articulate different representations of the curriculum. They distinguish among the intended, the implemented and the attained curriculum. The competencies needed for citizens in the information or knowledge society (Anderson, 2008) can be considered the intended curriculum – the rationale and goals for learning. However, there may be a gap between the needs of the information society as expressed by the policy

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makers and the way these needs are understood and taught by schools and teachers, the implemented curriculum. The attained curriculum describes the (cognitive and affective) learning outcomes of students. It is obvious that these learning outcomes are particularly influenced by what has been taught – the implemented curriculum. One of the major challenges in realizing sustainable curriculum change is to create consistency and balance between these different curriculum representations.

This chapter provides an overview of the intentions for IT in the primary and secondary school curriculum and a discussion about the extent to which these intentions have been implemented in schools and have resulted in different educational outcomes.

Rationales for IT in Education

In 1990 Hawkridge described several rationales for IT in education. These rationales are helpful in interpreting intentions of policy makers for the role they attribute to IT in the curriculum. The *social rationale* is related to the preparation of students for their place in society. The *vocational rationale* emphasizes the importance of giving students appropriate skills for future jobs. The *pedagogical rationale* is focused on the enhancement of teaching and learning with the help of computers. The *catalytic rationale* assumes an important role for IT in realizing educational change. The *information technology industry rationale* is related to the promotion of the IT industry in education (see also Davis, 2008, in this book). Finally the *cost-effective rationale* implies that IT will reduce the costs for education. Although all these rationales could be recognized in many IT-related policies of governments (see Plomp et al., 2008), two rationales were very prominent in the introduction of IT in the primary and secondary school curriculum: the pedagogical and the social rationales. The introduction of IT in the primary and secondary school curriculum often started with an emphasis on the social rationale – students had to learn about IT (*learning to use IT*). Currently, the policies in many countries highlight the pedagogical rationale. IT is used as a medium for teaching and learning (*using IT to learn*). However, in the rhetoric of policy makers, *using IT to learn* not only has a pedagogical background, but often also reflects a vision that IT is a means to transform education (e.g., European Commission, 2002). Hence, a reflection of Hawkridge's catalytic rationale is often also part of the public debate about IT in education.

Learning to Use IT

Because desktop personal computers (PCs) entered offices, households, and education in the early 1980s the question was raised whether every citizen needed to have basic IT knowledge and skills. In North America and Western Europe this resulted in the call for a new subject in the curriculum, computer literacy. Computer literacy, later also referred to as information literacy, was meant for all students and often part of the junior secondary school curriculum. Twenty years later the acquisition of basic

IT knowledge and skills – covered in information literacy – does not seem sufficient for coping with the changes in the society. Anderson (2008), in this book, extensively reviews the competencies needed in the twenty-first century. Nevertheless, information literacy is part of the curriculum in many countries (Plomp et al. 2008). Information literacy is aimed at developing a basic understanding of information technology and some proficiency in using IT applications. From the very beginning, the scope of the subject was disputed by scholars (e.g., Plomp and Janssen Reinen, 1996; Watson, 2001). Some advocates of the new subject favored a comprehensive approach. Students were not only introduced to IT applications (e.g., word processing and later also e-mail and the Internet in the mid-1990s), but they also studied concepts as "information" and "data," reflected on societal and ethical implications of IT and, particularly in the early days, simple programming skills. Others focused on an instrumental approach, where the emphasis was on learning basic IT applications. Related to the debate about the scope of information literacy was the location of the new subject in the curriculum. Collis (1988) argued that information literacy as a separate subject in the curriculum would hamper the integration of IT in the curriculum. Collis referred to the potential of IT for teaching and learning and particularly supported the pedagogical rationale for computer use in education. The debate resulted in a variety of approaches for information literacy in the curriculum. For instance, in 1993 The Netherlands adopted a mixed approach. Information literacy was developed as a small, but separate course for the junior secondary curriculum. In this subject new concepts related to information handling as well as basic IT applications, such as word processors and spreadsheets, were introduced. In addition to information literacy as a separate subject, the goals for information literacy had to be realized in all subjects as was stated in subject-specific curriculum objectives. However, the Dutch Inspectorate concluded that the integration of IT in subjects was hardly realized (Inspectie van het Onderwijs, 1999). Moreover, a national monitoring study reported that scores from 5th and 8th graders on a test in basic IT knowledge and skills overlapped for 70% (ten Brummelhuis, 1997–1998). This implied that in primary education the majority of the students already mastered many of the targeted goals for junior secondary education. As a result, the current IT policy in the Netherlands emphasizes the pedagogical rationale (*using IT to learn*) (Ministerie van Onderwijs, Cultuur en Wetenschappen [MOCW], 2002, 2006). For the senior secondary curriculum, computer science as a separate subject was developed, but only few schools offer information technology as an optional subject to their students.

In England and Wales a varied picture emerged, see also Table 1 (Hammond and Mumtaz, 2001). Hammond and Mumtaz noticed that IT taught as a separate subject often resulted in a decontextualized approach, in which the purposes for learning various IT applications were hardly communicated to the students. This implied that transfer of what was learned in IT as a separate subject to other subjects was often problematic. In addition, Cox (in Plomp et al., 2008) argues that when IT is taught across the curriculum, IT as a subject preparing for professions in the IT industry, is taught at a standard that is too low.

Watson (2001) stated that when IT is taught across the curriculum, teachers have to cope with the social, the pedagogical, and often the catalytic rationale. She argues

Table 1 Approaches to teaching IT in secondary schools in England and Wales, 1999 (source, Hammond and Mumtaz, 2001)

Percentage of schools for clustered grade levels	Grades 7,8,9	Grades 10,11	Grades 12,13
IT is taught across the curriculum	25	35	40
IT is taught as a separate subject	29	23	21
IT is taught as a separate subject and across the curriculum	45	42	39

that these rationales do not match. They cause conflicting demands for teachers. On one hand teachers have to meet requirements related to specific IT knowledge and skills. On the other hand teachers are expected to use the potential of IT to facilitate teaching and learning of their subject. Many teachers are not well prepared for these two demands.

Using IT to Learn

Dede (2008), in this book, describes how IT was understood by different theories of learning and how IT was applied to enhance teaching and learning according to these different theories. In the behaviorist perspective IT was used to better attune to the individual characteristics of the learner. Drill and practice IT applications as well as simple tutorials were developed, which allowed the learner to master knowledge and (routine) skills at his or her own pace. Cognitive theories focus on cognitive understanding of complex concepts and skills. In this approach intelligent tutorials were developed, which helped the learner in developing reasoning and problem-solving skills for well-defined content and skills in specific subject matter domains. Constructivist theories assume that the learner has to construct new knowledge and understanding through active participation in the learning process. In this approach learning environments are created, which allow for authentic learning and learner-centered education (Bransford et al., 2000). Various IT applications – productivity tools (e.g., word processor, spreadsheets, Internet) as well as specific IT applications (e.g., simulations, data-logging, multimedia cases) – are available to help the learner construct knowledge. IT may contribute to

- Realize a curriculum that is centered on real-world problems
- Have students involved in virtual communities of practice
- Use advanced tools similar to those in today's high-tech workplaces
- Facilitate guided, reflective inquiry through extended projects
- Utilize modeling and visualization as powerful means of bridging between experience and abstraction
- Enhance students' collaborative construction of meaning via different perspectives on shared experiences
- Include pupils as partners in developing learning experiences and generating knowledge
- Foster success for disabled and disenfranchised students (Dede, 2000)

Table 2 Overview of pedagogy in the industrial vs. the information society

Aspect	Less ("traditional pedagogy")	More ("emerging pedagogy" for the information society)
Active	Activities prescribed by teacher	Activities determined by learners
	Whole-class instruction	Small groups
	Little variation in activities	Many different activities
	Pace determined by the program	Pace determined by learners
Collaborative	Individual	Working in teams
	Homogeneous groups	Heterogeneous groups
	Everyone for him/herself	Supporting each other
Creative	Reproductive learning	Productive learning
	Apply known solutions to problems	Find new solutions to problems
Integrative	No link between theory and practice	Integrating theory and practice
	Separate subjects	Relations between subjects
	Discipline-based	Thematic
	Individual teachers	Teams of teachers
Evaluative	Teacher-directed	Student-directed
	Summative	Diagnostic

Although constructivist approaches to teaching and learning are popular among today's scholars, one must realize that mainstream schooling often reflects a more traditional approach to education.

It is often argued (e.g., Anderson, 2008; Kozma, 2003; Voogt and Pelgrum, 2005) that constructive theories of learning fit the challenges put to education in the information or knowledge society. Voogt (2003), based on an extensive literature review, distinguished educational elements that foster the learning of competencies needed in the information society. In Table 2 these elements are organized in such a way that they show the characteristics of a pedagogical approach that is expected to be relevant for the information society vs. a pedagogical approach that suits an industrial society. By using the words "less" and "more" the table indicates that education nowadays should search for a new balance in pedagogical approaches. The table also shows that change is a process involving many dimensions, with room for variation. Similarly, Dede (2008) also advocates variation in theoretical approaches, given the diversity of people, subjects, and contexts involved in education.

Current Use of IT in the Curriculum

National and international studies on the use of IT in education show at a general level how IT is implemented in the curriculum. These studies often serve as input for the policy makers on assessing the effects of their investments of IT in education.

In the late 1990s a worldwide survey on computers in education (Pelgrum and Anderson, 1999) showed a rapid improvement of student–computer ratios in all levels of education. Despite this fact, the actual integration of computers in schools stayed confined. Except for the use of computers in computer literacy and computer science courses, the use of IT in other subjects was limited. Figures from the USA (Becker et al., 1999) showed the same trend. At the end of the twentieth century only about one third of the US teachers used computers on a regular basis, although the majority of US teachers had computers in their classroom. Similar results were found in surveys in the Netherlands (ten Brummelhuis and Slotman, 1998–1999) and England and Wales (Department for Education and Employment, 1998). Word processing was the most popular IT application in schools (Pelgrum and Anderson, 1999) and the use of the World Wide Web was rapidly increasing (Becker et al., 1999). In elementary education, drill and practice software was used frequently. More sophisticated software, such as simulations, data logging, and the like, were used only in a very small number of schools (Pelgrum and Anderson, 1999). Becker (2000) found that in the USA these kinds of applications were more likely used by those few teachers with a constructivist teaching approach. However, also among this group of teachers generic software tools were still used considerably more than applications specifically designed for education. By the end of the 1990s many countries in Europe and North America had policies on IT in education in place for more than 15 years. However, despite these policies the integration of IT in the curriculum was hardly realized.

More recent studies do not show fast changes in the integration of IT in educational practice. In almost all countries participating in the Program of International Student Assessment (PISA) more than 90% of the students have access to computers at school (Organisation for Economic Co-operation and Development [OECD], 2006). However, the same study also showed that of the 32 countries participating in the study, in only ten countries students use computers frequently (a few times per week or more) in school. Monitoring studies in the Netherlands between 1997 and 2005 reported that IT use in schools was limited to word processing, the World Wide Web, and e-mail (van Kessel et al., 2005).

Realizing the Potential of IT in the Curriculum

The large-scale studies reported in the previous section present only a partial picture on how IT is implemented in schools. Many teachers and other professionals experience in specific projects how the potential of IT could impact curriculum. For example, Beazley et al. (2008), in this book, reported lessons learned from the Computer Pals Across the World project. In a number of projects, scholars, in close collaboration with teachers and subject-matter specialists, carefully designed learning environments in which IT was substantially integrated. They evaluated the impact of these environments in real, but selected classrooms. The Jasper project (Cognition and Technology Group at Vanderbilt, 1997), carried out between 1989 and 1997, is one of the first examples of such a study. With the help of videodisc technology, complex learning environments were designed for use in mathematics teaching from grade 5 and above. Each environment contained an adventure of Jasper Woodbury, in which a complex mathematical problem had to be solved (see also Dede, 2008). The Computer as a Learning Partner project (Linn and Hsi, 2000) and the Web-based Inquiry Science Environment (WISE) project (Linn et al., 2003) are outstanding examples of the potential of IT for science education. Over a period of more than 15 years Linn and her colleagues developed, extended, and refined an IT-rich science curriculum focusing on understanding of complex science concepts for middle-school students. The Apple Classroom of Tomorrow (ACOT) project (Sandholz et al., 1997) was a first example of what is now called "ubiquitous computing." Research in this project found that teachers needed enough hardware and software, just-in-time support and enough time for creatively integrating IT in their curriculum. Other chapters in this book provide accounts of in-depth research on design and integration of IT-rich learning environments (e.g., Tan et al., 2008).

Despite that these exemplary projects indeed realized a different, more constructive approach to teaching and learning, their impact on ordinary classroom practice is marginal and often limited to enthusiast teachers who became involved in the project from the start. A main problem with projects such as Jasper and Computer as a Learning Partner has to do with *scalability*. Often it appeared to be very difficult to transfer the designed curricula to regular classrooms (Dede, 2000), where the actual use of IT is still modest and often embedded in traditional pedagogical approaches (Cuban, 2001).

Next to the *classic* examples presented above, many more studies reported the impact of IT use in specific subject areas. Cox et al. (2004a) reviewed the literature and reported about the way teachers use IT in mathematics, science, language arts, and social studies and the pedagogical changes that teachers experience when using IT. Their reviews were mainly used to summarize teachers' pedagogical use of IT in these subject matter domains. When appropriate other studies were also referenced.

Mathematics. Much research has been done on IT in mathematics education. According to Cox et al. these studies show that effective use of IT in the primary school mathematics classroom was found when IT facilitated mathematics reasoning and helped to connect mathematical ideas with the real world. Frequent use of IT was often related with less whole-class instruction. One of the most widely researched areas is the use of Logo and microworlds. This research indicates that such environments contribute to students' geometrical thinking and problem-solving skills. The results also suggest that effects are larger when the teacher applies collaborative learning techniques.

The use of IT in the secondary mathematics classroom is largely determined by the pedagogical beliefs of the teacher. Findings suggest that secondary mathematics classrooms with learning environments allowing for discussions and group work, and teachers acting as a guide, yield better results in students' performance.

Science. The use of IT in science education has always been justified by the fact that IT makes it possible to visualize phenomena and processes, which could not be demonstrated to students in other ways. For this reason a long-standing tradition of research and development projects in the domain of science education have been carried out. Much research has been done on the potential of IT to support students' understanding of complex science concepts as well as science process skills. In general the vital role of the teacher in creating collaborative learning opportunities as well as in guiding students were found to be important. In this book an extensive review of the impact of IT on science education is provided by Webb (2008).

Language arts. Cox et al. report teachers' using a range of software (they are not specific about the type of software), including word processing in primary schools and secondary schools. Particularly the use of word processing to improve students' writing skills is widely researched (e.g., Goldberg et al., 2003; Kulik, 2003). Teachers' use of word processing in primary schools was aimed at improving student writing skills; however, because of limited access to classroom computers, students use computers to type hand-written stories instead of using the computer to compose. Cox et al. also report about the use of talking book software to support early readers. Van Scoter (2008), in this book, reports about the use of IT for early literacy development, including research on talking book software, in more detail. Secondary school teachers experienced a change in pedagogy when using IT in language arts. An example of change in pedagogy was experienced by teachers who applied a non-linear and collaborative approach to writing by using hypertext.

Social Studies. Cox et al. found relatively few studies about the use of IT in social studies. The studies that were found show the important role of the teacher in realizing successful use of IT. Increased interactions between teachers and students were also found, particularly by the use of simulations and multimedia environments in geography.

Foreign Languages. The literature review of Cox et al. did not contain studies about foreign languages (or second languages). Many studies can be found on IT and foreign language learning, but most of them deal with higher and adult education. The journal *Language, Learning and Technology* (2005) had a special issue about technology and young children. The studies presented in this issue reported about the effect of peer-to-peer feedback in chat environments (Morris, 2005), the need for careful orchestration of instruction in an IT-supported foreign language class (Meskill, 2005), the implications of IT in the foreign language class for teacher learning (Richards, 2005), and the potential of entertainment software for foreign language learning (Purushotma, 2005). The overall conclusion of the editors of the special issue was that more research is needed to fully understand the pedagogical implications of IT in the foreign language classroom.

Innovative IT-Supported Pedagogical Practices

The previous sections of this chapter offer a positive view on the potential of IT for the curriculum but a rather pessimistic view on the implemented curriculum, that is the realization of this potential in educational practice. However, increasingly, examples also emerge, which show how expectations about IT in education are becoming a reality in ordinary classrooms.

Voogt reports findings of an exploratory study of IT-supported use in educational practice as part of module 1 of the Second International Information Technology in Education Study (SITES) (Pelgrum and Anderson, 1999). Randomly sampled school principals from 26 countries were asked to describe briefly "the most satisfying pedagogical practice in their school in which students use computer-related technology and which gives students the most useful and advanced learning experiences with IT" (Voogt, 1999, p. 199). More than 6,000 examples were provided, of which 535 were analyzed. The overall results showed a great deal of similarity for primary and secondary education. The majority of experiences were not focusing on single subjects but on a combination. The subjects most mentioned were social studies, science, and language arts. Students' activities focused on information processing, production activities, and communication, for which they used word processors, retrieved information from the Internet, and communication technology (e-mail). School principals reported that students' knowledge and skills improved, and that their motivation and self esteem increased. Most mentioned changes for teachers related to pedagogical practice and increased IT knowledge and skills.

A follow-up study, SITES module 2, was an international case study (see also Nachmias et al., 2008) on 174 IT-supported pedagogical practices from 28 countries (Kozma, 2003). Although these practices were selected because of their innovativeness, most of them were not so-called "lighthouse cases," but took place in ordinary schools. Initial coding of the cases showed that in almost all practices IT affected changes in pedagogy, but in only a limited number (18%) of the collected practices, IT influenced curriculum content and goals. Voogt and Pelgrum (2005) analyzed those practices in which curriculum content or goals (or both content and goals) were affected. Table 3 provides an overview of how these practices differed from the other practices in the study.

Table 3 Comparison of cases that reported change in curriculum content and/or goals vs. cases that did not report change

Change in curriculum content and/or goals	Percentage of cases ($N = 142$) that reported no change	Percentage of cases ($N = 32$) that reported change
Changes related to curriculum		
Content	19.7	59.1
Goals	29.6	71.9
Organization	67.6	71.9
Time	35.2	40.6
Assessment	42.3	71.9
Impact on teachers in terms of		
New pedagogical skills	54.9	65.6
IT skills	63.4	62.5
Collaborative skills	30.3	56.3
Positive attitudes	19.0	31.3
Negative outcome	5.6	15.6
Impact on students in terms of		
Subject matter knowledge	63.4	59.4
IT skills	73.2	84.4
Communication skills	37.3	50.0
Problem-solving skills	16.2	31.3
Information-handling skills	26.1	40.6
Team/collaborative skills	59.9	75.0
Metacognitive skills	38.0	40.6
Positive attitudes	68.3	68.8

An in-depth analysis of the cases that reported change in content and/or goals revealed that the curriculum content offered was not new, but rather the content was delivered in a different way. Curriculum changes were often limited by the national policy, which determined what content should be taught and examined. From the analysis, it appeared that often national policies were not yet in place to mobilize IT in support of significant curriculum change and education reform. Many of the IT-supported practices aimed at the realization of new goals that were related to skills that were considered important for lifelong learning in an information society. An important finding of the study was that IT skills were not taught in isolation but were part of more complex skills, such as information handling, collaboration, and communication. These more complex skills were seen by teachers and parents as important competencies that students gained from the innovative practice. In addition assessment practices were starting to change in many of the IT-supported practices. In particular, formative assessment was considered important. However, changes in IT-supported assessment were rarely found. Erstad (2008), in this book, elaborates further on the potential of IT for changing assessment practices. Often curriculum content was not organized in 45-min lessons, but took place in the form of projects, crossing the traditional boundaries of academic subjects. These projects varied in scope. Some took only one single school day, while others were integrated throughout the school year. In many of the cases students worked on topics that were meaningful to them, because they were related to real life, including the students' own experiences. Besides gaining IT skills, new pedagogical and collaborative skills were positive teacher outcomes.

SITES module 2 was followed by SITES2006 (Law, Pelgrum and Plomp, 2008). In SITES2006 randomly sampled mathematics and science teachers from 21 countries were asked how extensively they used IT in their educational practice (Voogt, 2008). Teachers who used IT extensively (that is once a week or extensively during a specific period in the school year) were asked to provide a brief description of one most satisfying pedagogical practice in which they used IT. The description was followed by questions about the way the pedagogical practice contributed to change in student outcomes and teaching practice. Findings showed that 50% of the teachers used IT extensively. More than 70% of these teachers reported increased student outcomes with respect to motivation to learn, IT skills, information-handling skills, and subject matter knowledge. In addition more than 70% of these teachers reported that the use of IT in their teaching had increased the availability of new content and varied learning activities and resources. More than half of the teachers mentioned increased collaboration among students, increased quality of instruction and coaching, increased adaptation of their teaching to individual students, and increased self confidence. However, also more than half of the teachers reported an increase in the time they needed for lesson preparation. On most of these aspects more teachers using IT on a weekly basis reported changes than did the teachers using IT during a specific period in the school year. The latter observation suggests that frequent use of IT contributes to change in educational practice, which confirms the findings of the ACOT project (Sandholz et al., 1997).

The Attained Curriculum: Student Outcomes from Learning with IT

The previous sections of this chapter showed that the expectations for IT in education are high, but that the implementation of IT in educational practice is still modest. One reason for its modest use might be the difficulty researchers have in providing convincing evidence of the impact of IT on student attainments, particularly because attainment is often limited to the impact of IT on student performance. The results of SITES (see above) however showed that teachers also see positive affective outcomes from learning with IT, such as an increase in motivation to learn. Regarding the impact of IT on student performance in subject matter areas several studies summarize findings. Kulik (2003) carried out a meta analysis about the impact of IT on reading, writing, mathematics, and science. Cox et al. (2004b) conducted an extensive literature review about the impact of IT on student performance in subject areas, and Dynarski et al. (2007) presented a report to the US Congress about the impact of commercial software for reading and mathematics on student performance on standardized tests. Teachers who participated in the latter study were trained by the company, but used the products for the first time. These studies will be used to summarize recent findings on the use of IT in two subject areas: mathematics and English (language arts).

Kulik found a positive effect of the use of word processors on student writing skills (cf. Goldberg et al., 2003). Kulik did not find positive results of Integrated Learning Systems on student reading skills, but he found a positive effect of reading management programs (e.g., Accelerated Reader) on students' reading development. Dynarski et al. did not find significant effects of reading software on the reading scores of 1st and 4th grade students. However, they reported correlations between student performance and teacher–student ratios and the amount of time the software was used. Cox et al. concluded from their literature review a moderate improvement in achievement in English, but also noticed that results are often inconsistent and depend on access to IT and the amount of IT use.

Cox et al. reported a positive relationship between the use of IT and students' learning of specific mathematics concepts and skills. But she also concludes that these findings are particularly found in small-scale and focused studies. Kulik found that Integrated Learning Systems for mathematics slightly improved student's mathematics score. Yet, Dynarski et al. did not find significant effects of mathematics software on the performance of 6th and 9th graders. They reported that in classrooms where teachers used the software, students were more likely to work on their own and that teachers lectured less and acted more as a guide. Results from the international PISA study (OECD, 2006) showed a relationship between mathematics performance of 15-year-old students and access to and use of computers. Students with limited access to computers (at home or at school) performed lower than did students who had easy access. The relationship between mathematics performance and frequency of computer use was less clear, because students with a high and a low level of computer use scored lower than did students who had a medium level of computer use.

The findings of the studies reported above vary about the impact of IT on student performance. Several factors were mentioned that may account for these results, e.g., access to computers, frequency of computer use, student–teacher ratio, teacher routine in using IT, teaching style, and scope of the study. Taking into account these factors it is necessary to get a clearer picture on conditions for the impact of IT on student performance.

A major problem in establishing the impact of IT on cognitive attainments for students is that the use of IT often aims to contribute to the mastery of complex cognitive skills, such as the perceived impact on students reported as a result of the SITES module 2 study (see Table 3). These skills cannot easily be determined by means of simple, standardized tests. The complexity of the problem is illustrated in the Computer as a Learning Partner project (Linn and Hsi, 2000). Students involved in that project did not score better on multiple-choice items in standardized tests that required recall, but they outperformed students on items that required interpretation. Yet, the outcomes of the project had much more impact on student learning than could be determined in standardized tests. The project could demonstrate that comparing subsequent versions of an IT-rich curriculum for science education resulted in a 400% increase – over eight versions of the curriculum – in student understanding of the complex science concepts that were dealt with in the curriculum.

Conclusions

Despite the rhetoric of policy makers about the potential of IT to facilitate education to change toward the needs of the information society, much of the intentions proposed have not yet been implemented in the ordinary classroom. IT as a subject domain has not yet found its proper place in the curriculum. In addition, scholars and professionals have been able to show the potential impact of IT on teaching and learning, but their efforts have been implemented only on a small scale. This chapter shows the dilemmas that policy and practice face.

Many obstacles hinder full implementation of IT. Curriculum-related problems impeding the integration of IT deal with the integration of IT in national standards and student textbooks and with the organization and content of the curriculum. In 1992 van den Akker et al. argued that educational software packages were not clearly linked to national standards or student textbooks. Currently many student textbooks have integrated software packages or links to websites. However, innovative IT environments (such as WISE) are still not integrated in textbooks or other support guides for teachers, which implies that teachers have to go beyond their immediate means when they want to integrate these environments in their lessons. Hinostroza (2008), in this book, argues that teachers are hardly guided by evidence from research on what IT applications to select and when, given new pedagogical approaches, changing curriculum demands, and emerging IT applications. In addition, for functional use of many IT applications more time is needed than is available in a curriculum organized in lesson periods (Cuban, 2001). The reason is that these applications aim to contribute to the acquisition of complex and productive skills and a thorough understanding of subject-related concepts, which usually needs more time. A curriculum that fosters in-depth understanding should also not be overloaded with content (e.g., Linn and Songer, 1988; Teng and Yeo, 1999).

In spite of these obstacles the SITES studies show that on a world-wide scale education is responding to the challenges of the twenty-first century. Many schools and teachers are creatively applying IT in their educational practice. It is true that in the examples of satisfying IT use provided by teachers and principals, only limited use is made of all the possibilities IT offers, but clearly the basic possibilities (information retrieval and communication) are made use of.

The integration of the full potential of IT in the curriculum will often imply that curriculum content and goals need to be reviewed and examination programs revised. For many teachers this is beyond the scope of their possibilities. The pressure to cover the prescribed curriculum content and to prepare students for examinations therefore often limits the teacher's flexibility to make creative use of IT. Policy makers challenge education to change and to prepare students for the competencies needed in the information society. They emphasize the important role for IT in this respect. At the same time however they require evidence about the impact of IT on student performance based on current curriculum requirements (Dynarski et al., 2007), which only partly agree with the content, goals, pedagogy, and assessment requirements for the twenty-first century. In IT-supported teaching and learning content, goals pedagogy and assessment need to be attuned to bridge the current gap between the intended, the implemented, and the attained curriculum.

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2.2

IMPACT OF IT ON SCIENCE EDUCATION

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Introduction

Since the early days of computer technology expectations for technology-enhanced science learning have been high. The potential for supporting and enabling learning through exploring simulations of scientific phenomena, modelling scientific processes, capturing and analysing data automatically and being able to access and communicate scientific information and expertise is high. Case studies across the globe have shown that IT can enable innovative classroom practices in science learning (Kozma, 2003). However, while science research has been transformed by computer technology, including the establishment of the new field of bioinformatics, the use of IT in science education has been patchy and limited. Major reasons for this include the nature of the science curriculum, availability of appropriate hardware and software and understanding of the pedagogical potential of the various types of IT and how to integrate their use effectively to support learning and teaching.

There is no basis for complacency in science education. Trends across the developed world show a drop in interest and take-up of science subjects (European Union, 2004; National Science Board, 2004; Osborne and Collins, 2001). Evidence suggests that children are interested in school science but to a lesser extent than in other subjects (Jenkins and Nelson, 2005). In recent research students complained that school science consisted of too much repetition, copying and note taking, with no time to discuss scientific ideas or their implications (Teaching and Learning Research Programme, 2006). This is of concern to science educators and governments and consequently several countries have recently undertaken radical rethinking of their science curricula. These developments have focused on the needs for science learning in the twenty-first century and have acknowledged a role, albeit not yet clearly defined, for IT.

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The Use and Impact of IT on Science Learning in Schools

Research into the impact of IT use on learning has produced varying results (e.g. see the review by Kulik, 2003). Some studies have suggested that high levels of IT use may be linked to improved attainment in science (Becta, 2001; Harrison et al., 2002; Christmann et al., 1997). Furthermore the impact of IT use on attainment in science may be greater than that on other subjects (Christmann et al., 1997). Other studies have reported no clear differences in science attainment or achievement between classes making more use of IT and those using less (Alspaugh, 1999; Baggott La Velle et al., 2003). These analyses and surveys suggest that IT use could promote learning in science but provide no insight into how this may happen.

Evidence for *How* IT Enables Science Learning

Evidence for what might lie behind gains in attainment associated with IT use comes mainly from detailed studies of specific types of IT use often studied in experimental situations. Types of IT use that have been shown to promote science learning include simulations, modelling and data logging. Evidence for how these applications may enhance learning is discussed in the following sections. Other types of IT use such as multimedia and video authoring, web-searching and online project work have been less well-researched but their potential for supporting science learning will also be explored.

Learning with Simulations

Obvious benefits of using computer simulations in school science are to enable exploration of phenomena that are too difficult or dangerous to investigate experimentally, things too small or too large to be seen and things that happen too fast or too slow for direct observation. This broadens opportunities for science learning but also invites questions such as what range of phenomena should be explored in school science and in what level of detail?, to what extent should simulations replace experiments and fieldwork? and what additional learning affordances do simulations provide?

A first step in exploring these questions is to investigate how students learn from simulations. Some studies of the use of IT-based simulations have focused on one of the most difficult aspects of science teaching: promoting conceptual change and confronting specific alternative conceptions. It is well-established through extensive studies that children develop their own “naive theories” to explain the natural phenomena that they observe in the world around them and these alternative conceptions tend to persist despite schooling (Driver et al., 1985).

Research on children’s alternative conceptions provided part of the impetus for a movement, towards a constructivist approach to science pedagogy (e.g. Driver and Easley, 1978). More recently socio-cultural theories based on those of Vygotsky and others have been applied to science learning, and other pedagogical approaches have been explored based on constructivist theories of learning (e.g. Scott et al., 1991; Duit and Treagust, 2003).

However despite the development of constructivist pedagogical practices since the 1980s and of extensive research into conceptual change there is no clear evidence of how constructivist theories of learning relate to actual learning and to teachers' practices (Harlen, 1999; Duit and Treagust, 2003).

IT-based resources can enable students to construct and explore their ideas and hence may increase pedagogical opportunities within a constructivist framework. Simulations in particular provide such opportunities. Earlier research showed that through using simulations students gained understanding of physical phenomena involving interacting variables (e.g. Whitelock et al., 1991). Where computer simulations of experiments were developed specifically to confront students' alternative conceptions in mechanics students' conversational interactions showed that these interventions led to conceptual change (Tao and Gunstone, 1999; Monaghan and Clement, 1999).

Simulations of processes that cannot easily be observed permit pupils to visualise and investigate these phenomena. For example, Ardac and Akaygun (2004) carried out a controlled experiment with 13–14-year-olds using the Vischem software (http://vischem.cadre.com.au/) developed by Tasker and found a significantly higher performance of students who received multimedia instruction that integrated the macroscopic, symbolic and molecular representations of chemical phenomena. Results relating to the long-term effects also indicated that students may benefit from additional prompting and guidance when processing distinct representations of the same phenomena. These studies highlight the complexity of the learning situation in which not all scaffolding has a positive effect on learning, and the nature of such experimental studies precludes the ongoing pedagogical reasoning of the teacher, which is crucial and is discussed later.

Some studies of computer simulations of experiments (Tao and Gunstone, 1999; Monaghan and Clement, 1999) were analysed to identify affordances, learning outcomes, and associated pedagogical practices that lead to conceptual change (Webb, 2005). For example, in a study by Tao and Gunstone (1999) a Force and Motion Microworld (FMM) was integrated into a 10-week physics course for 15-year-olds in a Melbourne high school. The simulations were developed specifically to confront students' alternative conceptions in mechanics. The teacher had taught other parts of the course but was not involved in this part so that the students working in pairs were dependent on the worksheets, the microworld and on each other. During the process, students complemented and built on each other's ideas and incrementally reached shared understanding. Affordances were provided by various combined effects of the software, worksheets and interactions with other students (see Table 1).

To enable pupils to make good use of simulations some specific instruction may also be needed because some students lack the necessary skills of visualisation (Piburn et al., 2005).

In summary there is evidence presented here and elsewhere (Webb, 2005) that focusing on specific areas of difficulty and addressing this with carefully designed tasks with IT-based simulations can lead to productive learning. Most of the evidence is concerned with students aged 11–18 and little use is made of simulations in

Table 1 Analysis of affordances for conceptual change in the Force and Motion Microworlds activities (Webb, 2005)

Affordance for students	Elements that provide affordance	Elements that may increase degree of affordance	Elements that provide information about affordance
Investigating the consequences of making changes to objects in the microworld, e.g. effects on a spaceship of shutting down all the rockets.	Force and Motion Microworld of a spaceship.	Ease of use of the software. Worksheets with specific tasks.	Worksheets with specific instructions, e.g. "Do not fire any rockets."
Explaining their predictions.	Prompts and questions on the worksheets. Prompts from other students.	Clear focus of questions, e.g. "Is there a net force on the spaceship?" Other students exchanging ideas.	Worksheets with clear structured prompts. Other students' explanations.
Checking a prediction.	Feedback from the microworld.	Ease of use of the software. Graphical or animated feedback.	Worksheets with instructions to run the simulation with specific values. Other students' explanations.
Reconciling any discrepancy between their prediction and the observation in the microworld.	Prompt from the worksheet to explain in writing. Questions, comments and prompts from other students.	Prompts from other students.	Worksheets with specific prompts for students to think.

primary schools where real practical investigations perhaps supported by data logging and spreadsheets are felt by teachers to be more useful (Murphy, 2003).

The extent to which simulations should be used depends on decisions about the curriculum content, which will be discussed later, and the comparative value of practical investigations and simulations, which depends on the nature of the topic and the age of the students and needs further research. For the present we can be cautiously optimistic about the increasing use of simulations benefiting learning in science.

Learning by Modelling

While simulation software enables exploration of pre-built models by changing the values of their variables, modelling software supports learners in constructing their own models or adding to part-built models. Thus whereas a simulation program of a predator–prey relationship would allow students to change the birth rate, death rate and starting population a modelling program would enable them to model the relationships and add new variables such as cover for the prey. Depending on the modelling environment this may involve specifying formulae, writing a program in Logo-like language or manipulating a graphical or pictorial modelling language.

Understanding the use of models and modelling in science is important for developing scientific understanding (Brodie et al., 1994). However Duit and Treagust (2003) reviewed research into students' development of modelling ability and reported that students "find the diverse models that are used to explain science challenging and confusing" (p. 678).

There is evidence of the contribution of computer-based modelling to pupils' learning in science. Earlier work in physics was reviewed by Niedderer et al. (1991), who concluded that computer-aided modelling at the upper-secondary level (students aged 16–19) does work in normal classroom settings and provides more complex and realistic examples of a larger number of phenomena. Primary pupils building qualitative models with educational modelling software learnt logical strategies for categorising science processes and could construct relevant and reliable models (Webb, 1993). Students in three 10th-grade classes in Israel who used three-dimensional modelling software (Barnea and Dori, 1999) showed considerable gains in understanding of molecular geometry and bonding.

Recent studies have begun to examine in detail pupils' reasoning while collaborating with a modelling environment, e.g. while modelling plant growth pupils were able to reason at several different levels of abstraction (Ergazaki et al., 2005). Other studies, e.g. examining modelling of one-dimensional collisions between moving objects based on programming in ToonTalk (Simpson et al., 2005), revealed the importance of providing a modelling environment with an appropriate level of complexity that enables pupils to focus on the scientific problem rather than the challenge of learning the software.

The use of computerised molecular modelling can enable students to achieve higher grades (Dori et al., 2003). For example, Dori and Barak (2001) conducted an experimental study with 276 pupils from nine high schools in Israel using a new teaching method in which pupils built physical and virtual three-dimensional molecular models. The pupils in the experimental group gained a better understanding of the concepts illustrated by the model and were more capable of defining and implementing new concepts. Specifically they were more capable of mentally traversing across four levels of understanding in chemistry: symbol, macroscopic, microscopic and process.

The studies discussed here suggest that when provided with suitable software and scaffolding students can develop their understanding of concepts and interrelationships between ideas through building models. Generally the use of computer-based modelling in school science is quite rare and certainly much less common than simulation mainly because it requires more planning and understanding by the teacher.

Using IT to Support Practical Work

Devices for recording and analysing data automatically are now readily available and easy to use for field and laboratory investigations. These methods are referred to as data logging or microcomputer-based laboratories (MBL). Research into their value for learning over many years has produced varying results (Kulik, 2003). Barton (1997), in a review of research on data logging, concluded that the main benefit is time saving. However Linn and Hsi (2000) found that pupils are much better at interpreting the findings of their experiments when they use real-time data collection than when they use conventional techniques for graphing their data, and that this greater understanding is carried over to topics where they have not collected the data. Russell et al. (2004) found that interactions with MBL and associated student–student interactions were supporting deep learning.

Other benefits for students' learning may derive from greater opportunities for meaningful interaction with teachers. For example, where students worked in groups using data-loggers to record experimental results this freed up the teachers to circulate and stimulate discussion and thinking about the results (Rogers and Finlayson, 2004).

Learning Through Authoring Multimedia and Video

Less research has been done into the use of video editing and multimedia authoring as an aid to science learning than into other types of IT use. Michel et al.(1999) suggested that allowing pupils to make video clips could develop their powers of observation and encourage pupils to think about exactly what should be recorded in order to explain a concept and hence develop understanding of scientific concepts. In one example from this study, a high-school biology teacher produced a CD-ROM of short clips from tapes made by pupils during a long-term experiment to grow plants. The pupils later incorporated the clips into scientific presentations. In another study teachers found that filming and editing a video about forces helped pupils to assimilate scientific concepts more effectively, quickly and substantially than would have been achieved with handouts or textbooks (Reid et al., 2002).

Other studies have begun to provide evidence of benefits of pupils authoring animations. For example, an experimental study of students developing their own animations of molecular processes in heating and cooling suggested that those who made animations had gained a better understanding than did the control group (Vermaat et al., 2003).

Using Online Resources and Information

Studies in the UK and US found that students can benefit from access to online resources when extensive support and scaffolding are provided by the teacher (Rogers and Finlayson, 2004; Hoffman et al., 2003; Linn et al., 2005). Effective scaffolding made use of electronic worksheets with salient hyperlinks, intranets with bounded databases and time-limited tasks to achieve focused work.

One approach developed in the US is that of the web-based inquiry science environment (WISE) whose website (http://wise.berkeley.edu/) provides projects to support students in examining evidence and analysing scientific controversies, e.g. GM-foods, global warming and antibiotics. The projects can be customised by teachers.

Student Research Projects Supported by IT

It has long been recognised that student research projects enable students to gain insight into how real science investigations may be conducted. For example, use of the internet and remote access telescopes allows students to undertake challenging research projects in optical and radio astronomy and make worthwhile contributions to professional programmes (Hollow, 2000). Projects are difficult for teachers to manage because students and teachers need access to a wide range of information, but web-based resources can support a range of student research projects, including simple ones planned by individual teachers.

Computer Types and Display Technologies

The nature of the hardware devices that enable interaction with the software and learning resources also affect learning opportunities within and beyond the classroom as well as classroom management. For example, large screens can support whole-class teaching and interactive whiteboards (IWBs) or mobile devices wirelessly linked to a data projector can support various types of interaction between students, computers and the teacher within the classroom. Many studies have been and are currently being undertaken to investigate the use and impact of IWBs, and a review of the literature (Smith et al., 2005) reveals that teachers and pupils are overwhelmingly positive about their impact and potential. Case studies of six science teachers who were known to be using IT effectively to support attainment (Cox and Webb, 2004) showed that these teachers did make extensive use of the display technologies available for both teacher and pupils to present and explain ideas and information to the class. Where they had regular access to display technology teachers developed banks of multimedia-based resources. Science teachers identified the main additional advantages of display technologies as the ability to display educational software, or web pages, or store their board notes and diagrams and revisit them later in the same lesson or in a subsequent lesson (Cox and Webb, 2004; Hennessy et al., 2007). Teachers also felt that IWBs engaged the pupils more actively in class discussions, stimulated by the material displayed on the whiteboard and the possibility of entering new text, pictures, etc. Developing pedagogical skills by using IWBs requires time and effort by teachers and detailed planning of teaching and learning sequences (Miller et al., 2005).

Harden (2005) described how a data projector wirelessly linked to laptops was used to enable science teaching in her school. Pedagogical techniques included the use of opening questions or quizzes as starters; Internet links to news clips to provide relevance to the outside world; the presentation of step-by-step instructions incorporating visual prompts for lower ability groups so that they could easily be viewed by the whole class; entering of group experimental results on a class spreadsheet and subsequent graphing and the passing of a “gyro” mouse around the class so that pupils could draw answers on to a PowerPoint presentation. “Big questions” of the type found to be useful for formative assessment (Black and Harrison, 2004) were used and supported by images designed to stimulate interest and thought.

Evaluations by learners and teachers suggested that use of hand-held devices together with wireless networking enhanced learners' experiences and their motivation for learning science in a range of settings, including fieldwork and museum visits (Scanlon et al., 2005).

Pedagogies with IT in Science

Studies of science teachers who were engaged in developing the use of IT for learning (Cox and Webb, 2004; Ruthven et al., 2004; John and Baggott La Velle, 2004; Rogers and Finlayson, 2004) found that the teachers perceived the ability for pupils to explore simulations and to see animations of processes that are difficult to visualise as particularly valuable for science learning. Most of the successful examples of IT use in science cited in these studies were of demonstrations where, for example, teachers used the features of a simulation as a basis for questioning pupils, thus requiring them to discuss and reflect on the processes in some depth. Although teachers believed that group-work would be beneficial for students' learning their main reasons for using only demonstrations were logistical constraints relating to access to computers (Rogers and Finlayson, 2004). Where teachers did organise group-work with computers, e.g. using a circus of practical activities, they reported using the time made available to them to give additional help to weaker pupils, share results, prompt analysis and discussion and emphasise thinking.

Collaboration has been shown to have positive effects on achievement but enabling effective collaboration is not straightforward (Bennett et al., 2004; Crook, 1998; Johnson et al., 2000). For example, Bennett et al. (2004) in a review of studies of small group-work in science found evidence of significant improvement of students' understanding where group discussions were based on a combination of internal conflict (i.e. where a diversity of views and/or understanding are represented within a group) and external conflict (where an external stimulus presents a group with conflicting views).

In the Technology-Enhanced Secondary Science Instruction (TESSI) project and in some other studies collaboration between pupils was a key element for clarifying understanding and supporting deeper learning (Pedretti et al., 1998). The self-pacing aspect of the TESSI course required pupils to monitor their own learning, and contributed to their time-management and organisational skills, fostering a kind of self-regulation and direction extending beyond the immediate use of technology. In these studies the use of IT was associated with a decrease in direction from and exposition by the teacher, a corresponding increase in pupil self-regulation, and more collaboration between pupils. However, a small minority of pupils reported that they preferred to learn in a more teacher-centered environment, with detailed directions and firm deadlines.

In the Computer as Learning Partner (CLP) collaboration (Linn and Hsi, 2000) the teacher's role was explored in depth. In this programme simulations and other types of IT were used to provide new affordances for developing understanding of science within a course designed specifically to incorporate the use of IT. This project built on the developing understanding of students' naïve theories and misconceptions to identify "pivotal cases." Linn and Hsi (2000) found that each student drew on different pivotal cases to clarify their thinking. For each class the teacher needed to research students' understanding, analyse their thinking and identify pivotal cases that would build on students' ideas and inspire them to reflect and restructure their views. The teachers then used these pivotal cases at appropriate times in discussion with the students. For example, a student who believed that metals have the capacity to impart cold would be asked: How do metals feel in a hot or cold car? The students would conduct either practical investigations with real-time graphing or computer-simulated investigations where the teacher's role in questioning and enabling student interaction was crucial.

Following an analysis of these and other studies of IT use in science a framework (Figure 1) was developed for examining pedagogical practices that involve IT use (Cox and Webb, 2004; Webb, 2005).

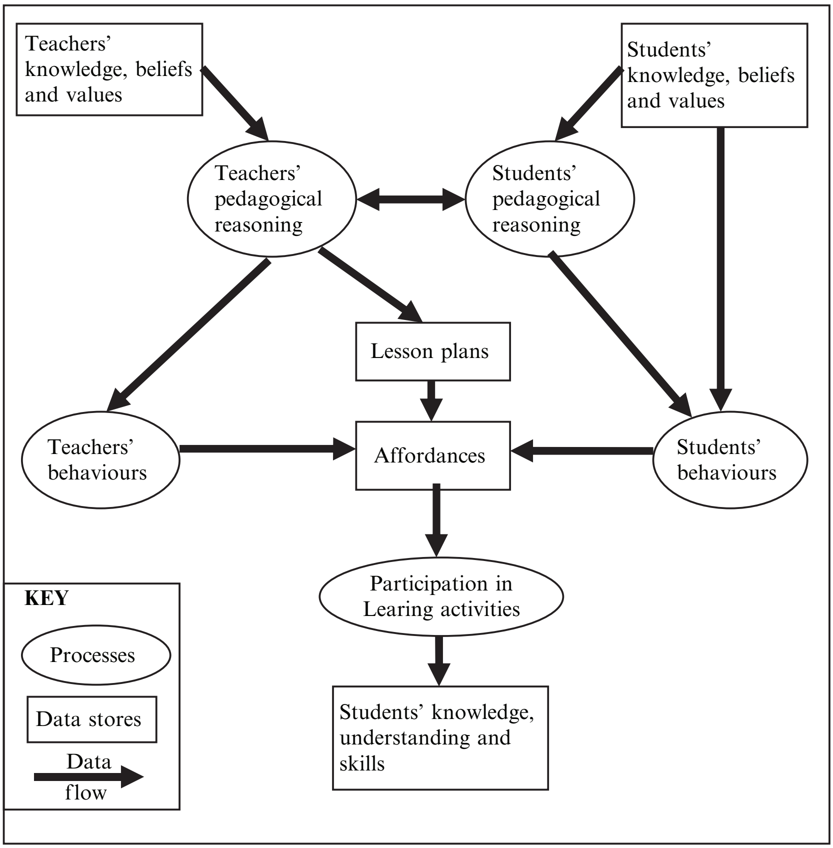

Fig. 1 Revised framework for pedagogical practices relating to IT use (Webb, 2005, p. 730)

The framework incorporates the pedagogical reasoning of the teacher (Shulman, 1987) who uses knowledge, beliefs and values, including those about the importance of IT for learning. Pedagogical reasoning leads to the following: (a) teachers producing lesson plans and schemes of work that incorporate affordances for learning and (b) teachers' behaviours during lessons, which enable students to benefit from these affordances. To plan lessons and to intervene effectively during lessons science teachers need to understand the possible range of alternative conceptions among students, be able to determine the conceptions of their particular students, identify the affordances provided by IT resources such as simulations and to evaluate these in relation to affordances provided by other science-related activities such as practical experiments supported by data logging devices. They need to decide how to deploy these resources in whole class, individual and small-group teaching so that appropriate affordances are provided and students perceive and understand the affordances and are motivated to make use of them. Research such as that discussed in the previous section, which investigates the use of a particular software in controlled conditions is gradually building our understanding of how specific affordances of learning environments incorporating IT can enable students to learn particular concepts and skills.

Analyses of affordances from studies of learning in IT-rich environments (Webb, 2005) showed benefits in learning science through four main effects:

1. Promoting cognitive development.
2. Enabling a wider range of experience so that students can relate science to their own and other real-world experiences.
3. Increasing students' self-management and enabling them to track their progress so that teachers' time is freed to focus on supporting and enabling students' learning.
4. Facilitating data collection and presentation of data, which helps students to understand and interpret the data and additionally frees students' time so that they have more time to focus on developing conceptual understanding.

These effects are generally not achieved by the use of IT alone but by careful integration of specific IT use into the learning environment. Recent research into formative assessment (Black et al., 2003) and the use of dialogue (Alexander, 2004) and argumentation (Newton et al., 1999) suggests that the benefits of these pedagogical innovations may complement those provided by the use of IT.

The development of formative assessment pedagogy has enabled students themselves to identify their needs and hence play a larger role in planning for their learning (Black et al., 2003). These authors suggest that this change in role is facilitated by changes in students' values towards a *learning orientation* from a *performance orientation* (see Dweck, 2000), in which their main motivation is to learn rather than to get a higher grade. Students can become aware not only of what they do not understand but also of how they learn and what kind of materials they prefer to use. Thus students are undertaking a pedagogical reasoning process in which they use knowledge of their own learning abilities and styles and their achievements to make decisions. This has the potential to make learning more effective but tends to increase the complexity of the planning process as students negotiate the planning of their own learning.

IT can support the planning and provision of affordances for learning and for self management, but the ability of students to assess and plan for their own learning is more likely to come through teachers focusing on formative assessment. The main pedagogical practices associated with formative assessment in science education are challenging activities, peer discussion, feedback from teachers, which focuses on how to improve, rich questions that demand thinking and discussion, e.g. if plants need sunlight to grow, why are not the largest plants found in the desert? and self-assessment (Black and Harrison, 2004). Enabling the kinds of classroom discussion that support formative assessment and learning in science is an important challenge that requires teachers to have knowledge of students' conceptual understanding and relevant pivotal cases (Linn and Hsi, 2000) to be able to set up suitable conditions for argumentation (Newton et al., 1999), dialogic learning (Alexander, 2004) or exploratory talk (Mercer et al., 2004).

IT Use and the Nature of the Science Curriculum

Some types of IT, particularly computer simulations, have been used successfully in short episodes in the existing curricula and lead to conceptual change with little or no modifications to existing pedagogy. However the more extensive enhancements to learning discussed in previous sections require changes to science curricula. Secondary science teachers in the UK for example perceived the curriculum as a barrier to their use of IT, owing to the heavy content loading (Ruthven, 2005). Longer term studies show that IT can also play a larger role when its use is fully integrated into the curriculum (Linn and Hsi, 2000; Mayer-Smith, 1998). For example the CLP collaboration (Linn and Hsi, 2000) was designed to promote lifelong learning, to enable students to make connections between the problems they face in their lives and the material they study in class and to help them to understand the nature of science so that this guides their future learning. Similar aims are found in proposals for the future of the science curriculum (Millar and Osborne, 1998). This is exemplified by new courses in England (see for example "Science for Public Understanding" at http://www.scpub.org/ and "21st Century Science" at http://www.21stcenturyscience.org/).

Implications for Teachers and Curriculum Developers

The new affordances for learning science provided by IT-rich environments require significant additions to the knowledge-base used in teachers' pedagogical reasoning and pedagogical practices as well as possible changes to teachers' values and beliefs. For pedagogical reasoning in the context of these new approaches teachers need to understand the wide range of different affordances provided by IT and the rest of the learning environment for students' learning, as well as knowing how IT can free the teacher from basic organisational tasks. This together with our increasing understanding of the potential of formative assessments (Black et al., 2003), the value of knowledge of the conceptual difficulties that students are likely to experience, the new science curriculum and the possibilities of promoting cognitive development in science creates a more complex range of types of knowledge needed for pedagogical reasoning. Teachers need to know about these affordances and how to provide sufficient information about them to enable learners to use them. Teachers then need to use this knowledge of affordances together with a wide range of other types of knowledge (Shulman, 1987) to plan activities that will lead to learning and will motivate their students.

The pedagogical reasoning process has always involved teachers using their knowledge of students, but in future with the use of better formative assessment techniques teachers may have richer evidence of students' understanding. Furthermore there could be a greater emphasis on joint planning as students themselves begin to employ pedagogical reasoning. For example, teachers who were using formative assessment gave students more control in lessons over what they needed to learn, how long they spent on a topic and what activities they did (Black et al., 2003).

These pedagogical innovations, including the integration of IT, formative assessment and the use of dialogue and argumentation techniques, could enable significant improvements in science teaching but they present a considerable challenge for teachers, teacher educators and curriculum developers. Historically science teachers planned and taught their classes autonomously usually following a syllabus agreed by the school or government but making their own pedagogical decisions. More recently teachers have planned schemes of work jointly and shared their pedagogical reasoning within their schools. Teachers have always developed their own resources to some extent, but now technology is enabling them to produce a wider range of types of material and to share them more easily. Thus a large amount of learning and teaching materials are becoming available. However powerful authoring tools do not ensure well-designed materials. Design skills and pedagogical knowledge are also crucial. A model for many curriculum development projects has been to bring together innovative teachers, researchers, designers and developers to explore new approaches to learning and to develop materials. Wider sharing and integration of research findings, pedagogical ideas and resources is now being enabled by Web portals such as that provided by Xplora (www.xplora.org/), which aims to be the European Gateway to science education.

Conclusions: Ways Forward for Science Education with IT

Research suggests that IT use could significantly promote and enhance learning in science but its potential has yet to be fulfilled. Well-designed learning activities focusing on specific areas of difficulty and incorporating carefully selected IT resources, particularly simulations, can lead to productive learning. More general use of IT resources can provide a more stimulating and motivating experience for students. IT can support collaborative learning but to be effective this requires careful orchestration. Use of IT can enable more self-management by students. However, for this to be effective it is argued here that other pedagogical innovations such as formative assessment and the use of dialogue need to be incorporated into planning and teaching. A major problem in this respect is that innovations in science education tend to be conducted without considering the use of IT. For example, a recent report titled "Science education in schools: issues, evidence and proposals" from the Teaching and Learning Programme in the UK (Teaching and Learning Research Programme, 2006) made no mention of IT. Conversely many programmes focused on development of IT use fail to take account of other pedagogical innovations. For IT to fulfil its potential to enhance science education four areas need to be addressed. First the process of reviewing and redesigning the science curriculum for the twenty-first century needs to continue and to take full account of new technology. Second science resource developers and educators need to be aware of benefits of IT use and incorporate it as an important aspect of any curriculum or pedagogical innovations. Third research needs to focus on developing pedagogy in science education incorporating IT together with other pedagogical innovations. Most importantly teachers need to be supported and enabled to collaborate and to explore and evaluate new uses of IT so that they can contribute to curriculum and resource development.

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2.3

THE POTENTIAL OF IT TO FOSTER LITERACY DEVELOPMENT IN KINDERGARTEN

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Introduction

Controversy has always been part of the discussion surrounding young children's use of computers and other forms of technology. Critics such as Healy (1999) express concern that children's time spent at a computer puts their physical and emotional health at risk, and even threatens the loss of childhood itself (Cordes and Miller, 2000). At the same time, computers are increasingly part of preschoolers' lives (Vernadakis et al., 2005). While some continue to raise concerns, a consensus has formed that technology can be used appropriately in ways that support meaningful learning for children (Plowman and Stephen, 2003). Research over three decades refutes the claims of harmful effects and provides evidence of IT's potential to benefit young children (see for example Clements and Sarama, 2003; Plowman and Stephen 2003). The evidence is clear that computers can help young children learn; the task now is to understand how best to assist children's learning, and which types of learning will benefit from computer facilitation (Clements and Swaminathan, 1995).

This chapter examines the uses of IT within the classroom and curriculum that have demonstrated impact or the potential to foster literacy skills. Information technology is generally referred largely to computers. With rapid changes taking place in technology, newer tools from digital cameras to "smart toys" are increasingly common in early childhood settings. While some suggest the need for a broader definition of IT and recognition of the access young children now have to a range of devices with their potential impact (Labbo, 2005; Plowman and Stephen, 2003), the main body of research continues to focus on computer-based technology (Plowman and Stephen, 2003).

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Literacy Development

Literacy has its beginnings in a child's earliest interactions with others, hearing and absorbing language, and responding to the tone of the parent or caregiver. Literacy develops over time through these countless social interactions and everyday experiences with language. Children's language takes place in a social environment, prompted by their involvement, communicating for a purpose. Language development is closely tied to relationships and to the child's early experiences – the social aspects of reading and writing activities are interesting and meaningful to young children. Positive experiences with literacy from an early age, such as singing nursery rhymes or being read to, provide a basis for successful literacy development (Snow et al., 1998).

Pretend play is a valuable part of early literacy and provides important opportunities to practice and experiment with language and thus acquire skills. Young children first write by drawing; their ability to draw and to represent actions symbolically in dramatic play are part of early literacy development (Bowman et al., 2000). In addition, the physical environment influences children's opportunities to interact and to engage in literacy-rich play (Shilling, 1997). Oral language, representational play, and experimentation with written language are all part of developing literacy. Interactive activities such as storybook reading, language games, and communicative writing can also have significant influence on children's oral and written language (Segers and Verhoeven, 2002).

Written and oral language skills develop over time, and are interwoven with learning to read (Fasting and Halaas Lyster, 2005). To support this development, there is a consensus that the environment of young children should be rich in language, with a wide variety of words used in extended conversations, interesting stories, and explanations (Snow et al., 1998). Similarly, just as children learn oral language by using it for authentic purposes, they learn about written language in an environment rich with meaningful messages and functional print, surrounding children with words (Warash et al., 1999).

Playful exploration of reading and writing fosters communication in all forms. Early childhood settings promote literacy by offering frequent opportunities for children to engage in pretend play incorporating the tools of literacy; to experiment with language, using non-conventional forms of writing at first; and to express themselves through writing in many kinds of texts for a variety of purposes (International Reading Association [IRA] and National Association for the Education of Young Children [NAEYC], 1998). In such an environment children encounter literacy as they pursue expression and communication for their own purposes (Labbo, 2005).

IT and Literacy Development

Technology offers new, additional opportunities for language use and development. A long history shows computers to be beneficial for encouraging language, interaction, and conversations. Indeed, language development and emerging literacy are the most frequently studied areas with young children (Plowman and Stephen, 2003; Shilling, 1997). Contrary to initial concerns that computers would isolate children, computers and software can serve as catalysts for social interaction and enhance language development. Children share leadership roles and initiate interactions more frequently when using computers (Haugland and Wright, 1997). They have more and different types of social interactions than during more traditional activities such as play with blocks or puzzles, and researchers have consistently observed high levels of verbal communication and cooperation as young children interact at computers (e.g. Clements et al., 1993).

Technology can take a positive role during children's play. Computer play elicits language, encourages longer, more complex speech, and can increase language fluency (Davidson and Wright, 1994). Graphics software allows children to draw pictures or geometric shapes to represent their stories with greater ease (Davis and Shade, 1999) and to revise as desired. As when drawing on paper, children tend to narrate what they are doing as they draw on the computer, or move characters around on the screen (Davidson and Wright, 1994). With computer graphics children often write and tell more detailed, elaborate stories than they do about static pictures (Clements and Nastasi, 1993).

In kindergarten considerable attention is devoted to children's emergent literacy to provide a sound base for reading and writing (Segers and Verhoeven, 2005). There is increasing interest in emergent reading and writing skills, along with the awareness that performance in these areas is an important determinant of later academic success (Voogt and McKenney, 2007). Reading and writing are important skills learned in school, with problems in these areas accounting for a large number of students requiring special education services (Fasting and Halaas Lyster, 2005). Use of computers can help to teach young children about symbol systems and communicative tools (Segers and Verhoeven, 2002), while children at high risk for learning difficulties may benefit from intervention with computer materials, making significant improvement in phonological awareness, word recognition, and letter-naming skills (Mioduser et al., 2000). Van Daal and Reitsma (2000) suggest that use of computer-assisted learning activities may provide an alternative to intensive one-to-one intervention with struggling students, which may also be more cost effective.

Word Processing

Research in the 1980s found that talking word processors provide a different and effective approach for children to learn to write. Especially important with young children and emergent readers, the tool can be used naturally in play and experimentation. Beginning writers with access to support through synthesized speech feedback for their early efforts show increases in risk taking, hypothesis testing, focused participation, and persistence as they explore written language (Rosegrant, 1988). As they become more skilled as writers, children reduce their use of the support they request. Research also suggests that computers, with and without speech-synthesized feedback, contribute to learning about functions and features of print, when placed in an environment that fosters written language exploration (Segers and Verhoeven, 2002; Shilling, 1997).

Children benefit from the guidance of adults and more able peers, making it possible for them to accomplish what they could not otherwise do on their own (Vygotsky, 1978). In a similar manner computers and appropriate software can provide scaffolding that supports children and allows them to perform in their zone of proximal development. Word processors provide critical support that let young writers experiment more easily with the process of writing, allowing them to focus on ideas and content rather than on the mechanics of still-developing small motor skills (Silvern, 1988). Children write more, revise more, and are less concerned about making mistakes when using these tools (Hoot and Silvern, 1988). Word processing facilitates positive attitudes toward writing, increases children's confidence in their writing, and can be used with preschool-aged children to explore written language and successfully integrated into process-oriented writing programs as early as kindergarten (Clements and Nastasi, 1993).

Hypertext and Reading Potential in the Classroom

Hypertext, highlighted text that links to support materials, illustrates how IT can respond to the needs and interests of the individual readers as they interact with text (Labbo, 2000; Reinking and Bridwell-Bowles, 1991). Linked materials, which may include digitized text, video, or other media forms, provide support for beginning or struggling readers, or those with little background knowledge to bring to the text (Anderson-Inman and Horney, 1998; Labbo, 2000). These features allow for differentiation through offering the child the ability to select needed support, such as word pronunciation, and thus some control of the presentation of the text as the reader selects the path to navigate (Hasselbring and Williams Glaser, 2000). Talking books, or interactive storybooks on CD-ROM, are a form of hypertext familiar in many classrooms. These hypermedia texts offer digitized pronunciation of words and larger sections of text, and may also include such features as illustrations and animations (Leu, 2000). Use of these tools can help reinforce skills and contribute to comprehension.

While most of the research on multimedia software involves students aged 8 or above, results with younger readers with access to support from digitized speech generally show increases in comprehension (Leu, 2000; McKenna, 1998). Kindergarten and grade 1 children (5–6-year olds) using electronic books show increases on sight words (McKenna, 1998; Lewin, 2000), though younger students may not make significant gains. A minimal level of literacy skill may be needed to lead to the increase (McKenna, 1998). Different types of support may also be appropriate for different levels of readers (Lewin, 2000). While electronic books increase word recognition in context and students' ability to make meaning of the text, a combination of reading both the electronic and the print version of the text appears to provide the greatest benefit to students (Grant, 2004).

Research further suggests that computer-assisted software can be valuable for both those experiencing difficulties with reading, and those who are progressing normally. Talking book software can support an integrated-literacy approach by providing the text in an alternative format, but research also notes the potential of possible reliance on the computer for unknown words, with the child not developing alternative strategies (Lewin, 2000).

The educational value of interactive storybooks depends on the relevance of the interactive features to the storyline. Similar stories matched for number of "pages" or screens, and number of linked features per page lead to differing results when used with children. Children's experiences reflect the relationship between the linked hypertext materials and the story being presented. Hypermedia links that are congruent, that supplement and are relevant to the story line, support involvement and understanding for the child, while access to linked features that are predominantly illogical or incidental detract from the text, impede student comprehension, and result in more passive viewing (Labbo, 2005; Leu, 2000; Trushell and Maitland, 2005), particularly for children at an early stage of understanding stories (de Jong and Bus, 2004). Current research shows value in the use of hypertext in reading, and sounds a caution that the materials used be well-designed, and used along with other resources to ensure development of the variety of strategies necessary for skilled readers.

Given the impact of learning difficulties, it is not surprising that the needs of children with disabilities are a continuing area of interest in the research on IT and literacy. Indeed, this area accounts for a significant portion of the recent research relating to young children and technology (see also the section Technology in the inclusion classroom). A review of recent studies on literacy and technology found a scarcity of studies identified in the areas of literacy and technology. Of the studies identified, only a small fraction dealt with children from 0–8 years of age (Lankshear and Knobel, 2003). Moreover, the early childhood studies revealed that a large majority of the small body of studies related to decoding and encoding skills. While the authors note that a portion of the studies focus on learners with mild to moderate disabilities, they and others question whether new technologies are being used to full advantage. New technologies have the potential to go beyond the current definition of literacy, focused on text in print, and consider a future quite different from the past.

Interactive storybooks may offer significant changes in the way young children experience reading. Before children are able to read and decode fluently, they have a large vocabulary, as well as familiarity with print conventions, and working knowledge of the structure of language; they may, however, recognize only a small number of words in print. With support from digital text, electronic books may offer children the potential to read independently long before they reach automaticity (McKenna, 1998). And while electronic books may not be a satisfactory replacement for adults reading aloud to children, they can provide another way to listen to stories, allowing children with the ability to understand stories to engage in independent reading before they are able to read conventional text (de Jong and Bus, 2004). As electronic forms of literature become more commonplace, new definitions and understandings of what literacy means will need to be developed.

Integrated Learning Systems and Drill and Practice

Integrated learning systems (ILS) or computer-assisted instruction (CAI), available for many years, are receiving increased attention. The appeal of a software package that may improve academic performance, together with the availability of affordable, high-speed computers, has raised new interest in the use of computerized instruction. Research on ILS has produced mixed results, however, and does not provide compelling evidence of positive outcomes (Cassady and Smith, 2004; Leu, 2000; Van Daal and Reitsma, 2000).

Although ILS may be moderately successful in improving basic skills (Davis and Shade 1999), this type of software is less likely to include the characteristics identified by NAEYC (1998) as developmentally appropriate, such as open-ended, active learning, with children in control of the pacing and the path of the action. Some express concern that ILS, with its sequence of lessons based on prior performance, diminishes teacher and child control over young children's development (Clements, 1994). Newer programs allow some control to teachers and children through authoring options, an important feature if teachers wish to adapt the program to address the needs of students (Bauserman et al., 2005). This feature offers the potential to individualize instruction, and to allow various modes of presentation, such as text, audio, and graphics, to support the curriculum.

While research is limited on the effective use of ILS for increasing emergent literacy skills, ILS is found to be most effective when the program can be adapted to meet individual needs, and is integrated into and consistent with the curriculum (Bauserman et al., 2005; Davis and Shade, 1999). ILS should not be used to replace teacher-led instruction, but may be used as a supplement in the classroom (Davis and Shade, 1999; Ferguson, 2001). To receive the greatest benefits, the software must align with the literacy goals and with students' individual instructional needs (Labbo, et al., 2003). As with any computer program, learning with computers can be effective only with the teacher's attention to the critical features of quality of the software, the amount of time children work with the software, and the way in which they use it (Clements, 1994).

Integrating IT in the Kindergarten Classroom

Having a variety of literacy tools available in the classroom encourages developing skills as children practice and experiment with language. Center areas can provide literacy props for dramatic play, such as office play, grocery store, or restaurant, and offer frequent opportunities for children to read and write for their own purposes. Working in collaboration with others increases a child's understanding and success, and builds language skills as they talk together about their activities. Children might use paper, pencils, and crayons for writing and drawing, along with computers and software, pursuing their pretend play. With ready access, children reap the benefits of IT as an integral part of the curriculum, supporting and enhancing the literacy program. Computer-based technologies embedded in the learning environment are perceived to be available for children to use in accomplishing their own goals (Clements et al., 1993). Research (e.g. Roschelle et al., 2000) confirms that computer-based technologies offer four key characteristics of effective learning environments: active engagement, collaborative learning, frequent and immediate feedback, and connections to real world contexts. In this section we discuss how IT might be integrated in the kindergarten classroom and which conditions are necessary to facilitate IT integration.

Print-Rich Environment

Children's words displayed in the classroom encourage reading of meaningful text. Technology can serve as an excellent exposure to print by offering other ways to record and display text. Banners, posters, or charts that students create reinforce language skills, and surround them with words. Children may choose to write with paper and crayons, or use software programs that let them experiment with languages. They may type words to accompany photos, or create stories. IT makes it easy for children to tell their stories in a variety of ways, responding to individual needs and preferences. Emergent writers might tell a story in pictures through paper and pencil drawings, drawings on a computer, or capturing images with a camera. They may then choose to add a caption, or to record their own words as they relate the story that goes along with the pictures.

Technology Center

A technology center can be arranged to have children work together, and to encourage students to experiment and explore language. Word processing provides opportunities for child-directed exploration and experiences with written language. The talking word processor with digitized speech allows children to hear the sounds of letters or words as they are entered on the keyboard. Children working together may type in a word, then perhaps change a letter to make rhyming words as they play with the sound and rhythm of language. They receive immediate spoken feedback that can lead to further attempts, or refinement of the text to more closely match what was intended. Digital or synthesized speech can also provide independent learning experiences for young readers as they listen to text read aloud – their own or that of others – while viewing it on the screen. The reading–writing connection is strong, and children benefit in each area as they read and revise their own words. Word processing encourages writing, increases motivation, and improves writing skills. Writing for an audience engages students and gives authenticity to the work. With computers and printers commonly available, publishing within the school or classroom is an option.

IT and the Classroom Reading Corner

A classroom reading corner may have interactive story books nestled alongside print books, both a regular part of reading activities. In addition to children reading for their own pleasure, interactive story books can also be easily integrated into the interactive reading commonly practiced in the classroom and blend into existing literacy practices with little disruption (Trushell and Maitland, 2005).

Connection with Real Worlds

Children learn a language best, whether first language or second, by using it to communicate. Sending home photographs of classroom activities enhances communication and home–school connections, and fosters oral language as children and families talk about the activities. With digital cameras it is easy to print and send home photos the same day. No captions are needed, so when children share pictures with their families they can be discussed in the home language. Alternatively, including children's captions provides opportunities for children to practice reading meaningful text.

For young authors another option is to write as a group. Using a large monitor for display, a teacher can record children's words, and then guide them through revising for the finished product. The record of class activities, stories, and projects can be shared and enjoyed by families and the community.

Products and Presentations

Visual representations offer rich opportunities for learners at all levels and speaking a variety of languages. Practitioners find that digital cameras motivate and engage students, thus encouraging language skills, with even young children able and eager to be the photographer. Their experiences echo the finding of Roschelle et al. (2000) of the power of involvement. Children love to take photos that record and document activities. Photos keep the activity fresh as children revisit the learning. Pictures become a springboard for language as small groups of children combine images and words into a slide show. Software allows for revision of images and recordings at any time, and the creator receives immediate feedback when viewing the revised version. The ease of revision encourages students to return and improve on their original efforts (Duling 1999).

Presentation software is a useful tool for children to elaborate on a topic and show their learning in words and pictures. With a child-friendly program – Kid Pix (http://www.learningcompany.com/jump.jsp?itemID=87&itemType=CATEGORY) is one well-known example – children can combine pictures with written text or oral language. The result may be a single screen, with a title or description of what is happening in the picture. With the student in control, the slide show may contain any number of slides, adapting to the ability of the child, with narration, captions, and text growing as the child's oral and written language skills develop.

Technology and Literacy in the Inclusion Classroom

In addition to the opportunities for differentiation afforded to students by technology, applications can be of particular value in the inclusion classroom. Computers and other technologies can provide critical support to students with special needs. Children who struggle with difficulties comprehending text can benefit from supported text, electronic modifications that give the reader access to support materials that may include additional text, sound, or graphics as well as synthesized speech (Anderson-Inman and Horney, 1998). Children can access the type of support they need, thus providing autonomy and individualized learning.

The characteristics and features of word processing that make it an effective tool for all students also make it a valuable tool for students with special needs (Hasselbring and Williams Glaser, 2000). By giving children more control over their work, word processors can improve confidence, motivation, and writing ability, and may enhance self-esteem of children with learning disabilities (Clements et al., 1993).

Computer use can also contribute to social interaction for young children with disabilities, enhance interpersonal interactions, and lead to significant gains in communication and other emergent literacy behavior. The use of involving, interactive software programs encourages communication, even for children who tend not to communicate (Hutinger, 1996).

Children learning a second language engage in language learning and linguistic practice in response to software that provides support through visual clues and animations (Brooker and Siraj-Blatchford, 2002). Children learning a second language can have access to reading materials in both languages, with or without audio versions, or spoken text, thus supporting both the home and the second language. (Anderson-Inman and Horney, 1998; Labbo, 2000).

When composing on word processors students read and re-read their words on the screen as they make changes to improve their text, providing valuable practice. Students with limited English tend to experiment more with language when using word processors due to the ease of revision, particularly important for students learning a language who may be hesitant to put words on paper (Johnson, 1988). Johnson quotes a first grader on the appeal of technology: "I love to write on the computer cuz the eraser (delete key) doesn't make holes in my paper."

Implementation Concerns

Of course, learning is not solely a matter of software and hardware. To implement technology in the kindergarten classroom one needs to be aware of the following:

- As with all instructional materials, software should be consistent with best practice in literacy instruction and with classroom curriculum goals, complementing rather than supplanting effective teaching or curriculum (Snow et al., 1998).
- Children are more interested and less frustrated when an adult is present, and computer use, especially at first, may be facilitated or mediated by the teacher, consistent with best practice at this age (Clements and Nastasi, 1993; Voogt and McKenney, 2007).
- Modelling technology in real life activities – printing digital photographs or making labels – shows children the value of the tools and how they are used (Plowman and Stephen, 2007).

– Despite there being a large selection of edutainment software available for the home market, high quality educational software for emergent and beginning readers is in short supply (Segers and Verhoeven, 2002).
– To be effective, the kindergarten program must provide a balance of open-ended and more closed learning activities (Segers and Verhoeven, 2002).
– Computer interaction can be helpful in supporting young children's early reading skills (Segers and Verhoeven, 2002); regular and frequent use of technology can have a positive effect on the literacy development of 4- and 5-year olds (Voogt and McKenney, 2007).
– Technology is used within a social environment, and mediated by interaction with teachers and peers. The teacher plays a critical role in determining the manner in which the tools are used, indeed, whether they are used at all (Segers and Verhoeven, 2002; Clements and Nastasi, 1993). Teaching through computers is an interactive process requiring teacher involvement. The teacher is key in integrating technology, encouraging collaboration among students and student independence in activities.

While a number of factors contribute to the growth of IT use in early childhood, including increased awareness of what IT can offer, and greater familiarity and comfort with technology among adults, evidence suggests that teachers are more likely to adopt technologies that fit their current practices or can be easily adapted. Leu (2000) posits that teachers with constructive beliefs, in which students actively construct their understandings rather than passively absorb information, may be more comfortable with hypermedia, and therefore less resistant to the technology because it aligns with teachers' beliefs.

Technology as a Benign Addition

The presence of technology in early childhood education is becoming more and more a physical reality, with hardware available and in place. The next step, beyond the necessary infrastructure, is to create the robust pedagogical solutions to learning problems (Mioduser et al., 2000; Plowman and Stephen (2003). Plowman and Stephen note that, at present, the widespread use of technology with children of this age is as a supplement to classroom practice, rather than fundamentally transforming the environment. Others point out that most teachers continue to use technology in traditional ways, such as drill on basic skills, and instructional games (Clements, 1994; Haugland 1999). Technology used for its own sake, or as an add-on, does not take advantage of the potential for IT to contribute to student involvement and deep learning. For children to actively engage in learning, software and contexts for learning must support and encourage authentic, creative, and meaningful opportunities for children (Yelland, 1999).

Although many questions are still to be answered as to the most promising approaches, clearly IT offers additional and valuable means to engage in learning. While technology is too frequently used as an add-on it can have significant impacts on language and literacy development. Research over decades records the benefits that computers and appropriate software afford young readers and authors. Computers encourage social interactions and language as children work together. Graphics software provides beginning writers with additional ways to tell their stories in pictures. Word processors support early efforts at writing and, with synthesized speech, provide immediate feedback to children experimenting with language. Hypertext gives the reader access to support, responding to the needs of the individual at that time. Talking books allow children to read independently with the support of electronic text, and to read text in two different formats. IT offers students more control over their work and provides critical support for struggling readers and students with special needs.

The number of educators incorporating technology into their literacy curriculum continues to increase with awareness of the new forms of support it offers children. Access to the many tools of literacy, including technology, can foster reading and writing skills and increase opportunities for success for all students.

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2.4

INNOVATIVE PEDAGOGICAL PRACTICES USING TECHNOLOGY: THE CURRICULUM PERSPECTIVE

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Introduction

Curriculum Rationales

The publication of Tyler's seminal book on *Basic principles of curriculum and instruction* (1949) was contemporaneous with the birth of the first electronic digital computers (e.g., Electronic Numerical Integrator And Computer (ENIAC), the first general hi-speed electronic computer, in 1946). About six decades later, the context (at all its possible levels – social, cultural, economical, educational, political, technological, etc.) in which we situate our current elaboration on curriculum-related issues has changed drastically. Yet, the basic questions raised by Tyler still offer a solid framework for our discussion: What educational purposes should the school seek to attain? What knowledge about the learners' needs, society's needs and subject-areas-based needs helps in defining these educational purposes and how should it do so? What curricular and pedagogical solutions, and learning experiences, should be devised to attain these educational purposes? How can the extent of attainment of the defined educational purposes be evaluated?

Undoubtedly, the rapid and multi-faceted development of Information and Communication Technologies (ICTs) has played a crucial role in changing the way we learn, work, communicate, create, spend leisure time – in short, the way we live. Within this new context, the attempt to answer the above questions represents a complex endeavour leading to the design of novel and unique models of curricular solutions (Watson, 2001),

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based on an updated elaboration on social needs, learner needs, the integration of ICT in all subjects and disciplines, and new pedagogical perspectives.

The definition of educational purposes based on a *social needs* point of view should take into account, among other things, issues such as the drastic transformations in work and workplaces; the rise of new occupational areas and decay of others; economical weight of ICT-based endeavours; perception of the rising status of ICT-based professions; philosophical, moral and ethical issues arising from ICT's wide-ranging entry into all venues of life and society and inter-societal processes such as the tension between globalization and local-contextualization.

Educational purposes focusing on the *learners'* needs should obviously build on the demands – in terms of knowledge and skills – derived from the ICT-saturated environments within which these learners act and live. But less obviously, the definition of learners' needs requires special attention to the fact that increasingly, learning is no longer confined to the traditional school setting, but takes place in several kinds of settings and from several kinds of resources. In 1949, Tyler claimed that "It is unnecessary for the school to duplicate educational experiences already adequately provided outside school. The school's efforts should be focused particularly upon serious gaps in the present development of students" (p. 8). These words, written at times when the school still enjoyed the status of main educational agency and information provider present a strong challenge to today's school, whose potential contribution to the learners' preparation to function in the knowledge society is perceived as minimal. Learners appear to acquire the knowledge and skills they perceive as essential by informal means, a mode of learning characterized by high personal motivation and noninstructional interaction with ICT tools and knowledge systems. The question is: Will the school be able to identify the current *serious gaps in the present development* and offer the learners appropriate bridging between their inside and outside school knowledge worlds?

New Curricular Needs

Integration of emerging ICT *content, subjects and disciplines* into the school curricula leads to new curricular needs. Research supplies comprehensive mapping of the knowledge and skills comprising new disciplines and inter-disciplines, requiring the resolution of specific curricular issues, e.g., definition of multi-layer content, from the conceptual to the practical; thematic re-organization; or novel ways to integrate between ICT content and other disciplines. In addition, new epistemological and knowledge-organizational perspectives that form the basis of hypertext and hypermedia systems (and ultimately the Web) challenge traditional representational templates of the school curricula (e.g., books) and open the scene to new solutions.

Concerning *pedagogy* and *learning experiences*, integration of the results of decades of research on learning and on the development of ICT-based instructional environments allows the formulation of a novel repertoire of pedagogical solutions. Learners have stepped into the centre of the scene (as individuals or groups), and have been supplied with powerful learning tools (e.g., tools for information searching, retrieval or processing; for modelling and exploring natural, social and artificial phenomena; for digital-products creation). The fusion between ICT and learning modalities deriving from current theoretical frameworks (e.g., constructivism, collaborative learning, learning by design, learning by modelling) has already resulted in innovative pedagogical and curricular solutions.

Second Information Technology in Education Study – Module 2

Overall, looking for original and appropriate answers to current essential questions is a necessary stage in the process aiming to devise new ICT-based curricular models for the knowledge society. This chapter's main goal is to present these answers, which are embedded in a large set of examples of successful ICT implementation across curricular areas and instructional models, from 28 countries. This database of cases of successful implementation of ICT-rich pedagogical practices resulted from an international study conducted by the IEA (International Association for the Evaluation of Educational Achievement) as the Second Information Technology in Education Study, Module 2 (SITESm2) (for a full report see Kozma, 2003; see also Voogt, 2008).

The chapter comprises four main sections: (1) the *background*, which includes *theoretical issues* concerning ICT, innovations and the curriculum, (2) a general description of the *SITESm2 analysis framework*; (3) SITESm2-specific curriculum-related *questions* and *findings* from secondary analysis of the data; (4) *discussion, conclusions and implications*, shedding light on how ICT may facilitate or even encourage different ways for organizing curriculum content, goals, pedagogical solutions and assessment methods.

ICT, Curriculum and Innovation

ICT and Educational Innovation

In the digital era (i.e., information or knowledge era), in which endless information is available at the push of a button, and learning is ubiquitous, theoretical and empirical aspects have been examined regarding the impact of ICT on educational processes (Becker, 1994; Mioduser and Nachmias, 2002; Pelgrum and Anderson, 1999).

ICT integration in education might affect schools irreversibly, contributing to transformation of teaching and learning processes and outcomes at different levels, e.g., meeting students' individual needs; providing rich instructional environments; affording the delivery of educational materials in ways that stimulate meaningful learning and motivates students (Abbot, 2001; Norton and Wilburg, 2002). The extent to which this potential is actually being realized needs to be explored, since evidence collected so far is still controversial (Becker, 1998; Marsh, 2004). Several frameworks have been developed and offered, aiming to characterize the ways ICT might promote and support educational change (Fullan, 2000).

According to Means et al. (1993) technology may support transition from conventional to reform approaches to instruction in several dimensions, e.g., the curriculum, time configuration, teacher and student practices and roles, grouping and collaboration. Kozma (2000) characterizes ICT-based innovations in four main dimensions:

curriculum content and goals, student practices, teacher practices and the ways of ICT use in schools.

At the most general level, an innovation can be regarded as a shift in educational paradigm, which in this case would move to viewing school as a fundamental agent for the preparation of students to function in an information society (Fullan, 2000; Pelgrum et al., 1997). This paradigm change does not have to be comprehensive; rather, it can be a *first-order innovation*, one that involves changing one or more aspects of the school milieu, e.g., a curriculum change in one or more disciplines, change in time or space definitions (i.e., lesson units or location of the teaching–learning process), or novel pedagogic solutions. To conclude, innovation is a change that conveys new ideas and an aspiration for improvement of an existing situation or resolution of a problem (Chen, 2006).

The school's main goal is to supply the skills required to live and work in a world of continuous change (Fisher, 2000). Therefore, ICT, as a driving force behind the creation and evolvement of the information society, plays a vital role in this change, affecting both content (new technology-related concepts and skills included in the curriculum, re-arranging the curriculum) and general skills (e.g., learning how to learn, acquiring generic knowledge-manipulation skills, teamwork skills). At this level, innovations can be defined in operational terms as the wide range of activities and means (e.g., curricular decisions, learning materials, learning configurations, lesson plans, tools and resources) that reflect the school's educational and philosophical orientation towards lifelong learning.

ICT and Curricular Innovation

The concept of curriculum is as old as education itself; however, the way we theorize and define it has changed over the years, raising considerable controversy as to its meaning and implications. The core definition of *curriculum*, derived from the Latin term *racehorse*, refers to an anthology of disciplines or subject matters to be taught and passed on. However, the scope of the term is extremely wide nowadays, ranging from well-defined disciplines with clear taxonomies and methodology, to all planned instruction that the school is responsible for and the whole set of learning experiences supplied to the students (Marsh, 2004).

This breadth of scope is mainly due to the fact that curriculum is one of the pillars of the entire education system. It ranges from objective disciplinary definitions to meanings that entail subjective aspects such as whole learning experiences; from narrow definitions that include analysis by subject matters to complex ones that deal with multi-disciplinary projects (Goodson and Marsh, 1996; Marsh, 2004; Marsh and Willis, 2003).

Some definitions refer to phases in the curriculum development and implementation process, leading to different perspectives regarding its nature: planned curriculum, enacted curriculum and experienced curriculum (Marsh and Willis, 2003). Other definitions refer to scope and span, i.e., single-subject curricular focus, thematic focus and school-wide focus (Voogt and Pelgrum, 2003).

In this chapter we will adopt the following premises when we address the concept of curriculum: (a) the notion of curriculum includes theory as well as practice; (b) it refers to both the academic disciplines and their pedagogy; (c) our referential context is that of formal schooling, i.e., education within the school milieu; (d) school learning processes are assumed to be planned and guided, in terms of goals, means and processes, and assessment. From this perspective we approach our discussion of ICT-based innovations at the curricular level.

ICT, when implemented in a school, is perceived as innovative by itself, regardless of the content addressed in its use (e.g., a skill or a concept), its function (e.g., part of a learning task or a communication tool), or its application scope (e.g., school-wide or limited to a discipline within a class). In the SITESm2 study, the following definition was adopted: *ICT-supported pedagogical innovations* are pedagogical solutions and means supporting a shift from traditional educational paradigms towards emerging pedagogical approaches based on our current understanding of learning, such as fostering learner-centred and constructivist processes, and the acquisition of lifelong learning skills (Pelgrum et al. 1997; Mioduser et al., 2002). These skills may include the planning of one's own learning, self-assessment of learning processes and outcomes, making decisions as to whether and when to act as an active or passive learner, adapting to changes in learning settings, applying collaborative skills, or integrating knowledge from different disciplines using different learning strategies for different situations (Knapper and Cropley, 2000).

The new curriculum, reflecting changes in education as a mirror to changes in society at large, includes characteristics such as new goals, restructuring of information resources, infringement of boundaries between traditional disciplines, and gradual closure of the gap between school and its environment, and as a consequence, between the curriculum and real-life situations (Voogt and Pelgrum, 2003).

To conclude, an innovative curriculum is much more than a technical development: it is a qualitative educational shift towards a new paradigm as a result of an ongoing process (Dede, 2000; Mioduser, 2005). Consequently, the innovative curriculum is a never-completed product, including new content, and novel and creative didactic processes and assessment solutions.

As to the character of the process by which innovations are generated and implemented, Rogers (2003) refers to three main types of innovations: *continuous innovation* reflects a gradual and continuing change or improvement of an existing product, in spite of its usage in the same manner as before; *dynamically continuous innovation* involves creation of a new product or alternatively a radical change to an existing one, which in turn modifies its diffusion patterns; and *discontinuous innovation* features a novel and innovative product, which brings change to consumers' acquisition and usage practices. This typology is compatible with the framework we have developed for studying innovative ICT-based pedagogies in Israeli schools participating in SITESm2 (Forkosh-Baruch, Mioduser, Nachmias and Tubin, 2005; Mioduser et al., 2003; Tubin et al., 2003).

Curricular Issues in ICT-Based Innovations: Secondary analysis of SITESm2 cases

Introduction

Educational innovation is usually not a one-shot episode, but rather a complex, multi-faceted and evolving process. Therefore, the three-level scale of innovation we defined, in correspondence with Rogers' classification, for studying innovative

ICT-based pedagogies, included *assimilation*, *transition* and *transformation* (Rogers, 2003). At the assimilation level, specific pedagogical conditions go through qualitative change, but the school curriculum as a whole (e.g., content and goals), the instructional means (e.g., textbooks), the learning environment (e.g., classrooms, labs) and the learning organisation (e.g., timetable) remain unchanged. At the transition level, ICT supports the incorporation, within the school's everyday functioning, of new content, didactic solutions, and organizational solutions alongside the traditional ones. At the transformation level, substantive and fundamental changes take place in the school system as a whole. Traditional processes still exist, but the school identity is mainly defined by the rationale and goals of new approaches and lines of operation; student and teacher roles are enriched with new dimensions; new contents are introduced into the curriculum; new teaching methods are developed and implemented; and, for particular activities, the traditional time and space configurations are transformed (Mioduser et al., 2003).

Method of Analysis

The need for further systematic analysis of ICT-based pedagogical innovations led us to develop the following analysis schema (for a detailed description see Mioduser et al., 2003). The schema's dimensions are located within a grid defined by two axes. The horizontal axis represents the levels of innovation, from minor modification of the school's schedule as a result of ICT assimilation, to comprehensive transformations of pedagogical practices and learning processes. The vertical axis details domains of innovation, focusing on four main components of the school's milieu: time–space configurations, students, teachers and the curriculum. Three of the four components were divided into sub-components, constituting altogether nine sub-components. Table 1 illustrates these domains and sub-domains and describes the indicators for each level within each domain.

First, two independent evaluators analyzed the case study data from ten innovative practices using ICT in Israel, using the innovation analysis schema, in order to validate the grading. Each evaluator came up with a scaling for each school in each domain on a 5-point scale (1 – *basic assimilation level*, 2 – *beginning of the transition*, 3 – *transition level*, 4 – *beginning of the transformation level* and 5 – *full transformation level*). Matching judgment was reached for 83% of the grading in the first evaluation round. The remaining 17% were discussed and elucidated by the evaluators until full agreement was reached (for additional information see Tubin et al., 2003). In a second phase, the whole international case-base (174 cases) was analyzed. Matching judgment of the international database was reached for 94% of the grading. In this chapter we use this analysis schema to further understand changes in the nature and scope of the curriculum as a result of ICT-implementation.

We also included in our analysis an additional categorization that surfaced from the data of the SITESm2 study. This grouping is also consistent with the literature that deals with change in the curriculum as a result of ICT integration, namely discipline-specific vs. multi-disciplinary approach. In the traditional curriculum, we identified three major disciplinary groups of subjects: science and technology, languages (mother tongue

Table 1 Levels and domains of pedagogical innovation using ICT

	Levels	Assimilation	Transition	Transformation
Domains				
Time and space configuration	Physical space	Public spaces	Public and personal spaces	Personal and community spaces in school and beyond
	Digital space	Desktop and Internet applications usage	Flexible Internet use and content creation	Virtual learning spaces and organizations
	Time	Mainly embedded in the school schedule and timetable	Flexible access for individuals within constraints of school schedule	Any time for all in school hours and beyond
Student role	Main roles	Using ICT for accomplishing curricular assignments	Development of ICT generic expertise – for usage, maintenance and creation	Personal assimilation of ICT as learning, creation and working means
Teacher role	With students	Main source of leadership, information and knowledge	Pedagogic authority, mentor, supporter, coordinator	Expert colleague, partner in the process of discovery
	With teachers	Acting individually, functional peer interaction	Team work, collaboration, mutual help	Acting cooperatively, organic solidarity
	Content	Traditional subjects enriched with ICT	Expanded subjects incorporating new knowledge resources; thematic approaches	New subjects; design and development using ICT; multi-theme approaches
Curriculum	Didactic solutions	Tutorial packages, constrained use of generic tools and Internet	Open assignments and projects using generic tools and Internet	Virtual environments, development of personal digital spaces
	Assessment methods	Digital versions of standard assessment means	Criteria development for assessing igital products	Digital alternative assessment: projects, portfolio, etc.

Table 1 is a modification of an earlier schema published in Mioduser et al., 2003

and foreign languages) and humanistic disciplines. This information was available to us via cover sheets, which were filled out for each of the 174 innovative pedagogical practices that were included in the SITESm2 study (for the online cover sheet, see http://www.sitesm2.org). These were constructed on the basis of a coding scheme based on the conceptual framework of the study (Kozma, 2003).

In previous analyses we found that the tendency to adopt multi-disciplinary (related to several disciplines from different categories) innovative pedagogical practices is evident in initiatives that reflect a shift from traditional pedagogical practices to a novel educational paradigm. ICT plays a major role in the implementation of this paradigmatic change in the teaching and learning processes (Mioduser et al., 2006). Learning according to this new paradigm attains the shape of a constructivist process, in which authentic problem-based learning is sought. Often, in these cases, there is project-based learning, as well as self and peer assessment. ICT serves as a lever for these changes, for example, as a resource, an assessment tool, or a means to cope with complex multi-faceted tasks (Venezky and Davis, 2002). Furthermore, the smaller the innovation is in scope, its innovativeness seems to grow in terms of content, towards new and perhaps unorthodox compositions of content (Mioduser et al., 2006).

Subject Domains

In the coding sheet of the SITESm2 study, a list was drawn for subjects included in the school curriculum. The original list consisted of 14 separate subjects, which we clustered into three categories: *science and technology*, including mathematics, physics, chemistry, biology or life sciences, earth sciences, vocational subjects and computer education and informatics; *languages*, including mother tongue and foreign languages; and *humanities*, including creative arts, history, civics, economics and geography. Of the 174 cases, a majority of 93 cases (53.4%) crossed the curricular themes, including subjects from more than one of them, as well as multi-disciplinary projects or activities as defined in the cover sheets filled by the participating countries (see http://www.sitesm2.org – advanced search, 9. Subject Matter Areas: Multi-disciplinary projects or activities); these cases included disciplines that crossed the basic classification of science–foreign languages–humanities categories. Of the remaining 81 cases, 22 (12.6%) focused on languages, 26 (14.9%) had a humanities subject and 33 (19%) fell under the science and technology subjects. Multi-disciplinary innovations included disciplines that crossed our category classification.

It light of the major theoretical issues concerning curriculum, our research questions address a quantitative account of the data, in which we examine levels of innovations in different school domains according to content themes and scopes followed by a discussion of themes within the curriculum domain.

Results: Subject Domains vs. Multi-disciplinarity

The difference between the amount of multi-disciplinary innovations (93) and the remaining thematic innovations (81) reflects an evident paradigm shift in the curriculum domain, specifically in the content sub-domain. In light of this, we were intrigued by possible differences between the categories of disciplines, and between them and multi-disciplinary innovations, in the extent of their "innovativeness". Table 2 displays the results.

In general, means displayed in Table 2 range between 2.30 (between the assimilation and the transition levels) and 3.55 (between the transition and transformation levels, leaning towards the transition level). This information is of great value with respect to the fact that these 174 pedagogic initiatives were chosen because of their innovative nature. However, we noted that the average level of innovation for didactic

Table 2 Comparison of domain means by categories vs. multi-disciplinary innovations ($N = 174$)

Theme	Sub-domain	Sciences ($n = 33$)	Languages ($n = 22$)	Humanistic ($n = 26$)	Multi-disciplinary ($n = 93$)
Domain					
Time and space configuration	Physical space	2.39 (1.50)	2.55 (1.53)	2.65 (1.47)	2.84 (1.35)
	Digital space	3.12 (1.45)	3.41 (1.10)	2.85 (1.16)	3.20 (1.15)
	Time	2.30 (1.42)	2.82 (1.65)	2.69 (1.49)	2.97 (1.39)
Student role	Main roles	2.48 (1.33)	3.50 (1.34)	3.62 (1.33)	3.32 (1.16)
Teacher role	With students	3.12 (0.99)	3.23 (1.02)	3.42 (1.14)	3.39 (0.87)
	With teachers	2.61 (1.32)	2.73 (1.32)	2.92 (1.52)	3.27 (1.31)
Curriculum	Content	2.33 (0.89)	3.27 (1.16)	3.15 (1.16)	3.27 (1.16)
	Didactic solutions	3.15 (1.20)	3.55 (1.01)	3.12 (0.65)	3.37 (1.00)
	Assessment methods	2.61 (1.30)	2.91 (1.48)	3.04 (1.45)	3.00 (1.50)
Total average		2.68 (0.80)	3.11 (0.84)	3.05 (0.85)	3.18 (0.75)

SD values are given in parentheses

1 = assimilation level; 2 = towards transition; 3 = transition level; 4 = towards transformation; 5 = transformation level

solutions is slightly higher than that of the other average values. This may demonstrate the potential of this curricular sub-domain to boost a change in ICT-based educational processes, and maybe to project on other aspects of the school milieu as well.

The sciences category exhibits the lowest means of the category groups for almost all sub-domains (2.68 total domain average, i.e., below the transitional level), with 6 of the 9 sub-domains scoring below the transitional level. The relationship between science curriculum and the potential of ICT in science education is twofold: on one hand, mathematics, science and technology curricula are relatively conservative and overloaded, with ICT tools being assimilated into existing teaching and learning processes; on the other hand, ICT may assume a role that enables emphasis on scientific reasoning rather than on mere empirical scientific practice. While ICT can be used to enhance scientific reasoning and theoretical understanding, we suggest it is actually used mostly for scientific drill and practice (McFarlane and Sakellariou, 2002). A major obstacle in implementing change in the science curriculum is the failure of teachers to prepare students for future scientific practice and to create an intriguing experience. In the academic science community, the use of computer-based technologies has become a built-in and vital part of work in scientific research, whereas in K-12 education, it is only a supplementary component (Baggott La Velle et al., 2003).

The highest total domain average (3.18) was found in the multi-disciplinary innovations. Innovations within the languages category display a relatively high domain average as well (3.11). To establish significance, we performed an analysis of variance procedure between the category groups with relation to the total domains average.

Results reveal significant differences in their level of innovativeness ($F = 3.305$, $p < 0.05$). This is mostly due to the significant difference evident from mean differences in pair-wise comparisons between the science theme and the multi-disciplinary innovations ($r = -0.50$, $p < 0.05$).

There are similarities between means of multi-disciplinary innovations and innovations belonging to the language category in most sub-domains, especially in the curriculum sub-domains. These two groupings of innovation are apparently the ones that involve the highest levels of change in almost all domains. Mastering a language is considered a social process that involves effective and productive interaction (Lantolf, 2000). Emerging technologies and new network options, or novel use of existing technologies, provide exclusive opportunities for language learning, whether oral or written language practice. The data suggests that the mean for students' roles was highest in the language category innovations. It appears that ICT serves as a powerful tool not only for enhancing language studies, i.e., mother tongue or foreign language, but also for implementing novel teaching solutions. In fact, the highest mean value, 3.55, was found for didactic solutions in the innovations focusing on the languages category. Language studies, being interactive in nature, are well-suited for ICT integration, bringing telecommunication possibilities into the curriculum and altering the ways students act and react during the learning process.

Results: Curriculum Components and Levels of Innovation

Further examination of the data disclosed details concerning components of the curriculum that were previously defined: content, didactic solutions and assessment methods. These findings are exhibited in Table 3.

For the three sub-domains, frequencies are displayed for each of the five levels of innovation. Table 3 shows that the mean innovation level for didactic solutions is the highest of all three sub-domains. However, all three sub-domain means reflect the transitional level of innovation and slightly beyond that. This is consistent with prior findings according to which most initiatives were located in the transitional level (Tubin et al., 2003). However, on further examination of the data, it seems that the patterns of frequencies within each sub-domain differ somewhat.

The relative innovativeness of the didactic solution sub-domain stands out. Both didactic solutions and content sub-domains display a one-peak curve located in the transitional level of innovation. However, the assessment methods sub-domain shows two peaks. The highest amount of innovations is located in the assimilation level, which reflects the use of digital versions of standard and traditional assessment resources, low participation of students in the evaluation of their work and low repertoire of new ICT-based assessment procedures and tools. The second peak is the frequency value of 40, which is common to the two other sub-domains and located between the transitional and transformation level (4). It seems that though novel didactic solutions are attempted, assessment is still conservative. This may also explain claims about the failure of computers to change education: as long as assessment is conducted in conformity with traditional educational paradigms, a fundamental change in achievements may not be evident. This also strengthens our claim

Table 3 Frequencies of levels of innovation in the sub-domains of the curriculum domain (% in brackets) and sub-domain means (SD in brackets) ($N = 174$)

Levels of Innovation	1	2	3	4	5	Sub-domain average
Curriculum sub-domains						
Content	18 (10.3)	34 (19.5)	62 (35.6)	37 (21.3%	23 (13.2)	3.07 (1.16)
Didactic solutions	7 (4.0)	23 (13.2)	77 (44.3)	43 (24.7)	24 (13.8)	3.31 (1.00)
Assessment methods	45 (25.9)	24 (13.8)	35 (20.1)	40 (23.0)	30 (17.2)	3.10 (0.98)

1 = assimilation level; 2 = towards transition; 3 = transition level; 4 = towards transformation; 5 = transformation level

that educational initiative should not be thought of as dichotomous – i.e., either innovative or traditional – in general, and in the curricular domain in particular. Rather, it is a complex enterprise that demonstrates the complexity of teaching and learning in the information era.

Results: Diffusion Patterns

In earlier analysis of the Israeli ICT-based innovations we found that changes in and implementation of new didactic solutions is correlated significantly with other domains of innovation, i.e., time and space configuration sub-domains, student role and teacher–student interactions, as well as the content sub-domain (Mioduser et al., 2002). This led us to observe data in yet another perspective: the scope of content-areas as a reflection of the diffusion pattern of the innovation, i.e., the scope of the innovation, and its bearing on the level of innovation. Data show that 51 (29.3%) innovative pedagogical practices of the 174 examined included only one subject matter; 37 (21.3%) innovations were thematic, i.e., were ascribed to sciences, language studies or humanities, while the remaining 86 (49.4%) innovations, which include almost half of the total amount of initiatives, were multi-disciplinary in nature, crossing the boundaries of the traditional disciplinary curriculum (Voogt and Pelgrum, 2003). These included only innovations that were in nature unbound to the traditional classification into disciplines, and excluded innovations that exhibited minor additions to the traditional curriculum. This exclusion explains the difference between the number of multi-disciplinary innovations in Table 2 and the number of cross-disciplinary innovations in Table 4. Table 4 sums up our findings on this issue.

On examining the data in the table, a minority of the emerging differences are noteworthy. To establish significance, we performed analysis of variance between the diffusion patterns in all nine sub-domains. Results revealed significant difference relating to the level of innovation in teachers' interaction with fellow teachers, i.e., teacher role with teachers ($F = 3.870, p < 0.05$); this is due to the difference between two of the three pattern groups: disciplinary and cross-disciplinary innovations. This in turn can be explained by the fact that in cross-disciplinary innovations teachers of

Table 4 Mean levels of innovation in the school sub-domains by content scope: disciplinary, category-based and cross-disciplinary diffusion pattern ($N = 174$)

Domain	Diffusion pattern	Disciplinary ($n = 51$)	Category-based ($n = 37$)	Cross-disciplinary ($n = 86$)
Sub-domain				
Time and space configuration	Physical space	2.67 (1.54)	2.49 (1.46)	2.79 (1.33)
	Digital space	3.10 (1.22)	3.32 (1.33)	3.13 (1.14)
	Time	2.71 (1.55)	2.59 (1.50)	2.91 (1.39)
Student role	Main roles	3.10 (1.46)	3.27 (1.37)	3.29 (1.15)
Teacher role	With students	3.25 (1.02)	3.35 (1.06)	3.35 (0.88)
	With teachers	2.61 (1.46)	3.03 (1.25)	3.27 (1.30)
Curriculum	Content	2.90 (1.17)	3.03 (1.17)	3.20 (1.16)
	Didactic solutions	3.29 (1.00)	3.30 (1.02)	3.33 (1.00)
	Assessment methods	2.90 (1.39)	2.86 (1.46)	2.95 (1.49)
Total average		2.95 (0.88)	3.03 (0.84)	3.14 (0.73)

SD values are given in parentheses

1 = assimilation level; 2 = towards transition; 3 = transition level; 4 = towards transformation; 5 = transformation level

versatile curricular disciplines must cooperate as a result of the innovation framework; in addition, cross curricular initiatives may be school-wide in nature, thereby laying the foundation for collaboration between teachers as a prerequisite for implementation.

Data also show that the innovative practices using ICT from the SITESm2 study are situated at the transitional level, with a relatively constant level of innovation for each sub-domain, across diffusion patterns. High levels of innovation are detected in student roles, teachers' relation with students and didactic solutions. This adds emphasis to conclusions from former studies, according to which the students are the main beneficiaries of an ICT-based innovation; this is regardless of the scope of the diffusion pattern within the curriculum (Mioduser et al., 2006). One of the teachers participating in an Israeli innovation using ICT said … *we learned things through students' eyes, which are in fact the learner's eyes, and it was important for me to see things the way they do…*; however, there is a noticeable pattern, in some sub-domains, by which the wider the innovation scope is, the higher the level of innovation, as detailed in the scheme of analysis in Table 1. This tendency, though significant only for the teacher–teacher interaction sub-domain, supports the role of ICT as a facilitator of change and innovation within the school setting.

The standard deviations noted in brackets are also a valuable source of information, shedding light on some of the sub-domains. These emphasise that teacher–student interaction, while being the sub-domain with the highest average level of innovation, is also the one with the lowest standard deviation for all three scopes of implementation: disciplinary, category-based and cross-disciplinary. This enables us to state clearly that the main actors within any innovation, be it a disciplinary one or including a wide range of content from diverse subject-matters, have considerable bearing on the course of an

ICT-based initiative. Another interesting fact includes the combination between relatively low levels of innovation, but the relatively high level of standard deviation for the physical space and time sub-domain. This implies that there are differences within each diffusion pattern group in the nature and levels of innovation in these sub-domains. In addition, the lowest standard deviation values for almost all sub-domains are included in the cross-disciplinary pattern, which indicates low variations between initiatives; this, together with relatively high levels of innovation for almost all sub-domains indicates that the cross-disciplinary ICT-based innovation is a robust initiative pattern, that affects all school domains, thereby striving towards sustainable and scalable improvement of teaching and learning (Mioduser et al., 2004).

Conclusions and Implications

The rapidly changing environment forces schools to challenges involving preparation of students for a global economy (Dede et al., 2005); sometimes this is far beyond their scope.

One major constituent of the curriculum, which is evolving constantly due to change in the organization of knowledge in the information age, is content, which can be considered in terms of: (a) structure of content, disciplinary issues and relationships among disciplines, as reflected in the former section; and (b) who determines the content being taught. Our analysis deals largely with the former.

Content and disciplinary issues involve mapping a landscape comprising various options. The first involves *ICT assimilation into traditional disciplines*, as a means of broadening the possibilities for learning processes and involving updated and hypermedia information, which alters the mapping and connections between existing content components. In the Chilean initiative, for instance, in which students compose with a virtual orchestra, the role of the software is to provide a wider variety of musical instruments than would otherwise be possible, as well as to assist students in exploring the process of composition. The second changes the strict and uncompromising structure of disciplines, allowing *multi-disciplinary learning topics*. In the Danish innovation titled "Springtime in Our Part of the World," the main goal was to explore the varying conceptualizations of "spring time" in two separate Danish environments, displaying different geographic, climatic and cultural contexts using ICT. In this activity, the students performed scientific as well as social inquiry.

Fundamental curriculum transformation however, is not within the boundaries of existing content but involves incorporation of novel content and the formation of new disciplines or multi-theme enterprises, whether by means of creating a conglomerate of two or more disciplines, thus generating new inter-disciplines, e.g., biotechnology, or initiating new disciplines altogether, e.g., info science, study of complex systems. The Israeli Center for Leadership and Excellence in Technology began developing a new curriculum for computer science, which was subsequently adopted on a nationwide level by the Ministry of Education. In a French initiative, making use of satellite images in biology–geology, geography and physics, the pedagogical goals were to develop interdisciplinary work by gathering information from three disciplines into one thematic entity.

Revision of curricula into a network of content, didactic solutions and assessment methods is bound to be a process taking place within and beyond school boundaries, and posing a challenge to theorists, policymakers and practitioners. Hence, one of the debates concentrates on whether this change should be a centralized top–down initiative, or a unique-local enterprise, facilitating change gradually, in an evolving scalable process.

The implementation of ICT-based pedagogical innovations may be best analyzed in terms of a continuous line of development, rather than in terms of a series of discrete and independent events. The implementation and diffusion of an ICT-based innovation as an integral and vital component of the curriculum in general and pedagogical practice in particular is by definition a process requiring time and proceeding through various phases. The versatile character of ICT technology allows for a wide range of educational uses as well as multiple levels of implementation within a networked curriculum, or hyper-curriculum. Its multi-faceted character requires gradual diffusion within the teaching and learning processes, either way. Technological shifts in organizations are gradual developments rather than drastic transformations, and they are in direct relation to the disparity between existent and new technologies.

However, change must begin first by the understanding that schools of the twenty-first century must adjust their practice to the information rather than the industrial age (McFarlane, 2003). Maintaining educational institutes built on traditional teaching as well as assessment methods that focus on rote learning, which is inappropriate in an age of ubiquitous information, may delay the implementation of novel educational paradigms in general. It may also hinder efficient use of ICT as a lever for reaching high levels of innovativeness in the various school domains. With regards to curricular educational shift, instead of focusing on the management and organization of endlessly accumulating knowledge that continuously changes our body of knowledge, ICT will serve as an additional means of information management and organization.

Epilogue

The new curriculum is at this point a fusion of practical knowledge, a result of trial-and-error processes aiming to come to terms with the multiple challenges that the information era poses. Curriculum structure should not evolve in a predetermined canned-content mode. Rather, ICT in general, and Web 2.0 applications in particular, have generated the need for theory referring to curricula as a dynamic component of the educational process.

Presently, there are various practical developments of ICT implementation offering novel online learning environments. Some of these are *multiple curricular templates*, which are teaching and learning patterns crossing the curriculum, sometimes overlapping and creating multi-layer learning environments. These patterns are drawing growing interest as a research objective from a technological point of view (Gibson et al., 2005). Understanding complex and challenging topics is a growing and critical component of the learning process, and is fundamental for solving real-world problems. The educational potential of hypermedia has spawned a growing number of studies examining its effectiveness in facilitating students' learning. Research addresses several cognitive issues, among them the roles of basic cognitive structures (e.g., multi-modal short-term-memory stores) and multiple representations (e.g., text, diagrams and video) (Azevedo, 2005).

In terms of content, there are numerous resources, and a growing number of databases based on sharing and collaboration in the Web 2.0 spirit i.e., second-generation Web-based services and platforms, for example, via wiki and communication applications, as well as social networking sites emphasizing collaboration and sharing among users. These can also comprise repositories or banks of *learning objects* (McKenney et al., 2008) and *learning experiences* (Downes, 2004): digital storage areas for self-contained reusable units of learning that may be used in multiple contexts for multiple purposes are constantly updated and can be aggregated. Web 2.0 applications allow learning objects to be tagged with metadata, for efficient retrieval (Alexander, 2006). This changes the overall configuration of learning experiences: from individual learning to close-group collaboration (class, school), and subsequently – open-group collaboration (ranging from a defined community to the whole of the Internet users population).

The usage of the Internet not only broadens content and learning modes or configuration, but also creates multiple space and time of learning: within school, outside school and in nontraditional learning settings. In actual fact, we practice learning in all endeavours of life, almost everywhere, hence the term *ubiquitous learning* or *u-learning* (Dede, 2005). Every student is also a teacher, merging content from several disciplines, and conveying these content units from anywhere to everywhere. This can be achieved greatly by a user-friendly open source software, available online for the creation of dynamic digital repositories. Examples are numerous, one of the salient being wiki technology, which permits enrichment of curricula by the learners themselves, via collaborative creation. Moreover, possibilities relating to real-time data and real-time phenomena (audio, video) acquisition, assimilation and prediction allow reality-enriched curricula. This is in congruence with the growing implementation of personal digital assistants (PDAs) and the novel multimedia and hypermedia possibilities they display for the enrichment and reorganization of content, for the improvement of teaching and learning processes, for posing *alternative assessment methods* (Erstad, 2008) and for allowing this to occur anytime and at anyplace.

The establishment, consolidation and implementation of a theoretical as well as an empirical research framework for exploring the new curriculum, i.e., the *hyper-curriculum*, may contribute to the formation of new pedagogical models for teaching and learning.

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2.5

CHANGING ASSESSMENT PRACTICES AND THE ROLE OF IT

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Introduction

Assessment lies at the heart of education (Little and Wolf, 1996; Ridgway et al., 2004). Assessment practices both reflect and influence the way we conceive and organize learning and teaching. Such practices have evolved to be an integrated mechanism that largely determines how the curriculum and education works (van den Akker, 2003). By using the metaphor of the curriculum spiderweb (see also Voogt, 2008, in this book), Van den Akker argues the need for coherence and balance between curriculum components, such as content, goals, learning activities, and assessment. Therefore, it is highly important to examine assessment and how it is related to changes in education.

It is common to distinguish between summative and formative ways of assessment, or what is also described as assessment of learning and assessment for learning. The former is characterized as occurring at the end of a learning process, evaluating what the student has learned and can perform on certain test procedures, while the latter is done during a learning process to support progress of learning among students. The role of formative and summative assessment and differences between the two have been the subject of much debate in recent years, which has also surfaced in debates about IT in education in the way new technologies might support assessment practices in different ways (Ridgway et al., 2004). Major assessment strategies include standardized testing, adaptive testing, and peer-and self-assessment. Multiple choice, classroom assessment, and portfolio are among the most often used assessment formats today. In this chapter assessment is used as a general term incorporating a wide range of methods for evaluating student performance and attainment.

The increased implementation of new digital technologies in school settings not only makes us view traditional ways of assessment in new ways but also raises new issues of assessment. This chapter focuses on the impact of increased educational use

J. Voogt, G. Knezek (eds.) *International Handbook of Information Technology in Primary and Secondary Education, 181–194.*

of IT on assessment by synthesizing research on assessment and IT. For this end, a search through online databases and key journals from the mid-1990s until today has been made. Books on assessment in general and assessment in relation to the use of new technologies have also been consulted.

This chapter reports about research on assessment; it has been structured in two sections. The first section highlights assessment as part of educational change and is linked to different perspectives on learning. The second section, which is the main section of this chapter, reviews relevant literature on assessment and IT, and has been structured according to assessing "what" and "how" related to the role of IT. The purpose of this chapter is to question to what extent and in which ways the use of new technologies represent changing assessment practices in school-based settings.

Teaching, Learning, and Assessment

The dominating assessment system over the last century, with an emphasis on standardized tests, reflects the development of mass education. The factory metaphor has been used (Olson, 2003) to show how students were required to master, largely through memorization, specific contents defined by textbooks and teachers. Examinations were developed for the purpose of getting feedback about students' performance so as to stratify and certify them accordingly. Even though there have been changes in the way learning is done in schools, our assessment system has not changed accordingly. A question often raised in recent years is whether the introduction of IT and the challenges of the information society will change existing assessment practices.

Assessment indicates what is rewarded in a culture, and thereby how learning and knowledge is defined. There has been an increased understanding of the relationship between assessment and learning (Broadfoot and Black, 2004; Gipps, 2002), which is defined differently in different schools of learning theories.

In *the behaviourist tradition*, where the learner is seen as a passive receiver of knowledge delivered within specific subject areas, assessment is directed toward checking whether students can perform according to certain predefined measurements of appropriate responses. Examples are multiple choice and standardized achievement tests, which focus on facts and predefined fragments of content. Technologies, such as *teaching machines* in the 1960s and the use of CD-ROMs in the 1990s, have been seen as part of assessment in this perspective, with specified procedures and feedback possibilities on responses made by students.

In *the constructivist tradition* of learning, where the learner is seen as a more cognitively active participant in the learning process than the learner in the former tradition, assessment focuses on more complex processes of learning by the individual. These processes require diverse approaches to assessment of learning, such as assessment of essays or projects, and performance assessment. Performance assessment, also known as alternative or authentic assessment, is a form of testing that requires students to perform a task rather than select an answer from a ready-made list. For example, a student may be asked to explain historical events, generate scientific hypotheses, solve math problems, converse in a foreign language, or conduct research on an assigned topic. In the past decade there have been several projects that have attempted to develop technologies as tools for assessment within a constructivist tradition, for example, tracking students reasoning by using simulations in science education or by playing educational games (Kafai and Resnick, 1996). This is partly due to the fact that technological developments have made it possible to develop interactive tools to assess complex cognitive skills, which can include different modalities of expressions, combining written text, pictures, video, simulations, and so forth.

The sociocultural tradition of learning (Wertsch et al., 1995), with an emphasis on learning as social practice, has become increasingly influential in the last 15 years, although probably more in theory than in school practice. The major difference from the constructivist tradition is the emphasis on collaboration and communication between people (inter-psychological) rather than the individual cognitive processes (intra-psychological) per se. In this way it has some common approach to learning with a socio-cognitive perspective arguing for interaction as a unit of analysis. Describing assessment building on a sociocultural tradition, Gipps (2002) states that "the requirements are that process should be assessed as well as product, that the conception be dynamic rather than static, and that attention must be paid to the social and cultural context of both learning and assessment" (p. 74). Compared with the two other traditions mentioned above, this perspective links learning and assessment more to the world around, and thus to how our culture is changing. In this way it also relates to what is called authentic assessment and performance assessment, as mentioned above. This indicates a form of assessment where students are asked to perform real-world tasks that demonstrate meaningful application of essential knowledge and skills. In school settings this also implies that assessment methods focus more on interpersonal ways of learning than the intrapersonal and how teaching challenges students' learning processes in different ways. Regarding new digital technologies, this perspective sees tools and technologies as embedded in the ways we learn, for example, by the use of digital portfolios. Given the competencies needed for the information society (Anderson, 2008), it is clear that the broader and more complex approaches to assessment represented by this perspective are becoming more relevant.

Assessment Practices, IT, and Change

IT and educational change has proved to be more complex than initial expectations (Cuban, 2001). Most of the research in this field has been on curriculum changes, learning environments, students' learning, and the organization of schooling as a consequence of the implementation of IT. To a lesser extent, research has focused on assessment and IT. Although assessment in education is a substantial research field, it is only during the last decade that IT-based assessment has been growing as a research field (McFarlane, 2003), partly due to an increase in developments of IT infrastructure in schools and access to hardware, software, and broadband Internet connection for students and teachers.

How to introduce substantial educational change and improve quality in education has been the concern of educational planners, in recent years shifting from input to outcomes in terms of learning achievement (Kellaghan and Greaney 2001).

The introduction of IT in our educational system has to relate to overall issues of educational change and be seen as embedded in the context of curriculum issues such as goals, content, and methods of learning (van den Akker, 2003). New digital technologies in schools can partly be seen as a way of improving students, learning, and partly be seen as a catalyst for systemic change in schools (Erstad, 2004).

Existing research has examined both the impact of IT on traditional assessment methods and how IT raises new issues of assessment. As part of the Second International Technology in Education Study (see also Nachmias et al., 2008; Voogt, 2008), innovative IT-supported pedagogical practices were analyzed. In several countries some of the involved pedagogical practices showed a shift toward more use of formative ways of assessment when IT is introduced (Voogt and Pelgrum, 2003). However, in most practices, often old and new assessment methods coexisted, because schools had to relate to national standards and systems over which they have no control, while at the same time they are developing alternative assessment methods for their own purposes.

Different Conceptions of IT and Assessment

Overview

In the following three subsections, relevant research both on how IT might change assessment practices and how different aspects of student learning can be assessed are presented. The three subsections are defined by the way IT is conceived in the assessment of student learning. See also Table 1 for an overview of this section.

Traditional Goals and Objectives

At a time when concerns are being raised about the workload on teachers and costs of education, methods aimed at reducing the weight of assessment demands in the classroom are to be welcomed. In addition, the question can be raised as to what extent and in which ways IT could contribute to the improvement of assessment practices and make assessment more adaptive to serve various needs. The potential of item banking for assessment practices is one example providing a solution to measuring items and categories across different domains of computer use in schools (Rudner, 1998; Van der Linden and Glas, 2000). Ways in which IT can improve assessment has also been triggered by developments in online learning where courses and assessments are done online.

Many countries and states have adopted a "dual" program of both computer-based and paper-and-pencil tests. Raikes and Harding (2003) mention examples of such dual programs from some states in the US where students switch between answering computer-based and paper-and-pencil tests. They argue that the need to be fair to

Table 1 Overview of the section

What	How (role of IT)
Traditional goals and objectives	IT for processing large numbers of tests
	IT for new approaches, e.g., adaptive testing
New goals	Digital portfolios
Higher order thinking skills	For example, technological tools in science education (www.futurelab.org.uk/projects)
Lifelong learning skills	Multimodal products made by students, for example, as part of "digital storytelling" (http://oaklanddusty.org/)
IT literacy skills	Performance assessment tasks measuring competencies in using and reasoning with IT-tools
	Using IT assessment framework like "UNESCO's ICT Competency Standards for Teachers" (ICT-CST)

students regardless of their schools' technological capabilities and the requirement to avoid sudden discontinuities so that standards may be compared may require a transitional period during which computer and paper versions of conventional external examinations run in parallel. They sketch some of the issues (costs, equivalence of test forms, security, diversity of school cultures and environments, and technical reliability) that must be solved before conventional examinations can be computerized.

Based on their own research on the state of Kansas' large-scale assessment program limited to middle-level mathematics, Poggio et al. (2005) argue that change can be enacted in schools that are ready to implement computer-based testing without upholding the paper-and-pencil modality. In a meta-evaluation of initiatives in different states in the US, Bennett (2002) shows that the majority of these states have begun the transition from paper-and-pencil tests to computer-based testing with simple assessment tasks. He concludes, "If all we do is put multiple-choice tests on computer, we will not have done enough to align assessment with how technology is coming to be used for classroom instruction" (pp. 14–15).

Recent developments in assessment practices can be seen as a more direct response to the potential of IT for assessment. An example of such developments is the effort to use computers in standardized national exams in the Netherlands. This goes beyond simple multiple choice tests. It has so far been tried out in science education where exams contain 40% physics assignments which have to be solved with computer tools like modelling, data video, data processing and automated control technique (Boeijen and Uijlings, 2004).

A major concern in much of the research on IT and assessment has been on the transition from paper-and-pencil-based to computer-based assessment. Several studies trying to compare specific paper-and-pencil testing with computer-based testing have described the latter as highly problematic, especially concerning issues of test validity (Russell et al., 2003). Findings from these studies, however, show little difference in student performance (Poggio et al., 2005), even though there are indications of enough differences in performance at individual question level to warrant further investigation (Johnson and Green, 2004). There are differences in prior computer experience among students and items from different content areas can be presented and performed on the computer in many different ways, which have different impacts on the validity of test scores (Russell et al., 2003). While some studies provide evidence of score equivalence across the two modes, computerized assessments tend to be more difficult than paper-and-pencil versions of the same test. Pommerich (2004) concludes that the more difficult it is to present a paper-and-pencil test on a computer, the greater the likelihood of mode effects to occur. Previous literature (Russell, 1999; Pommerich, 2004) seems to indicate that mode differences typically result from the extent to which the presentation of the test and the process of taking the test differ across modes, rather than from differences in content. This may imply a need to try to minimize differences between modes. A major concern is whether computer-based testing meets the needs of all students equally and whether some are advantaged while others are disadvantaged by the methodology. In short, there have been an increasing number of initiatives in studying how computer-based assessment can be compared to, and ultimately might replace paper-based assessment. However, as reported, there are several concerns of test validity and mode effects that restrict such transitions, resulting in the parallel use of both procedures. What is needed is not less quality criteria for alternative ways of assessing student performance, such as portfolios, but to look for new ways of making student attainment visible in a valid and reliable way (Gipps and Stobart, 2003).

New Goals

New technologies have created a new interest in what some describe as "assessing the inaccessible" (Nunes et al., 2003), that is, metacognition, learning strategies, attitudes, and lifelong learning skills (Anderson, 2008; Deakin Crick et al., 2004). The introduction of IT in education has further developed an interest in formative ways of assessment in order to better monitor and assess student progress. The handling of files and the possibility to use different modes of expression (multimodality) support an increased interest for methods like project work (Kozma, 2003), also indicating an increased focus on formative assessment.

The increased use of digital portfolios in many countries (McFarlane, 2003) is an example of how formative assessment is gaining importance. The use of portfolio assessments is not new and has been used for some time without IT (see e.g., special issue in *Assessment in Education*, 1998, on "Portfolios and Records of Achievement"). However, in recent years, the use of digital tools seems to have developed this type of assessment further by bringing in some new qualitative dimensions such as possibilities for sending files electronically, hypertexts with links to other documents, and multimodality with written text, animations, simulations, moving images, and so forth. The focus in the design of digital portfolios is on developing structures for organizing and saving documents in a digital form. As a tool for formative assessment, and compared with paper-based portfolios, digital portfolios make it easier for teachers to follow students' progress and comment on students' assignments and keep track of documents. In addition digital portfolios are used for summative assessment as documentation of the product students have developed and the reporting of their progress. This offers greater choice and variety to the reporting and presenting of student learning (Woodward and Nanlohy, 2004).

An important point is also the way digital tools can support collaborative work. Students can send documents and files to each other and in this way work on tasks together. Within the field of computer-supported collaborative learning (CSCL), there are many examples of how computer-based learning environments for collaboration can work to stimulate student learning and the process of inquiry (Wasson et al., 2003). Collaborative problem-solving skills are considered necessary for success in today's world of work and school. Online collaborative problem-solving tasks offer new measurement opportunities when information on what individuals and teams are doing is synthesised along the cognitive dimension. This raises issues both on interface design features that can support online measurement and how to evaluate collaborative problem-solving processes in an online context (O'Neil et al., 2003).

There are also examples of web-based peer assessment strategies (Lee et al., 2006). Peer assessment has been defined by some as an innovative assessment method since students themselves are put in the position of evaluators as well as learners (Lin et al., 2001). It has been used with success in different fields such as writing, business, science, engineering, and medicine.

A truly innovative example of IT and assessment, which takes into consideration the affordances that new technologies might give, is the eVIVA-project developed at Ultralab in the United Kingdom. The intention was to create a more flexible way of assessment, taking advantage of the possibilities given by new technologies such as a mobile phone and web-based formative assessment tools. By using such tools Ultralab promoted self- and peer-assessment as well as dialogue between teachers and students. In this project the students had access to the eVIVA website where they could set up an individual profile of system preferences and recording an introductory sound file, on their mobile or land phone. After this students' could then carry out a simple self-assessment activity by selecting a series of simple "I Can" statements designed to start them thinking about what they are able to do in IT. The website consisted of a question bank from which the pupils were asked to select 4 or 5 questions for their telephone viva or assessment carried out toward the end of their course, but at a time of their own choice. Students were guided in their choice by the system and their teacher. They had their own e-portfolio web-space in which they were asked to record significant *milestone* moments of learning, and to upload supporting files as evidence. Each milestone were then annotated or described by the pupil to explain what they had learned or why they were proud of a particular piece of work. Once milestones had been published, teachers and pupils could use the annotation and the messaging features to engage in dialogue with each other about the learning. Students were encouraged to add comments to their own and each other's work and the annotations could be sent via phone using SMS or voice messages. When ready, students would dial into eVIVA, either by mobile or land phone, and record their answers to their selected questions. This gave students the opportunity to explain what they had done and reflect further on their work. Their answers were recorded and sent to the website as separate sound files. The teacher made an holistic assessment of the pupil's IT capabilities based on the milestones and work submitted in the e-portfolio, student reflections or annotations, the recorded eVIVA answers and any written answers attached to the questions, and classroom observations (see Walton, 2005).

The research findings from this project showed that both teachers and students experienced this as a new form of assessment procedure stimulating the students' learning process. As mentioned earlier, one important aspect of how IT brings something new into the field of assessment is multimodality. Jewitt (2003) argues that unlike other media, computers bring different modes together. Computer applications and educational software introduce new kinds of texts into the classroom and these demand different practices of students (McFarlane, 2001). These developments pose new challenges for assessment, which traditionally is mainly written. For example, related to the assessment of writing, how do we evaluate the coherence of a hypertextual essay or the clarity of a visual argument?

One area of research with great implications for how IT challenges assessment concerns higher-order thinking skills. Ridgway and McCusker (2003) show how computers can make a unique contribution to assessment in the sense that they can present new sorts of tasks, whereby dynamic displays show changes in several variables over time. The authors cite examples from the World Class Arena (www.worldclassarena.org) to demonstrate how these tasks and tools support problem-solving for different age groups. They show how computers can facilitate the creation of microworlds for students to explore in order to discover hidden rules or relationships, like virtual laboratories for doing experiments or games to explore problem-solving strategies. Computers allow students to work with complex data sets of a sort that would be very difficult to work with on paper. Tools like computer-based simulations can in this way give a more nuanced understanding of what students know and can do than traditional testing methods (Bennett et al., 2003).

Findings such as those reported by Ridgway and McCusker (2003) are positive in the way students relate to computer-based tasks and the increased performances they do. However, they also find that students have problems in adjusting their strategies and skills since the result shows that they are still tuned into the old test situation with correct answers rather than explanations and reasoning skills.

In a systematic review of the impact of the use of IT on students and teachers for the assessment of creative and critical thinking skills (Harlen and Deakin Crick, 2003), it is argued that the neglect of creative and critical thinking in assessment methods is a cause for concern, given the importance of these skills in the preparation for life in a rapidly changing society and for lifelong learning. The review shows a lack of substantial research on these issues and argues for more strategic research.

The use of new digital media in education has been linked to assessment of creative thinking as different from analytic thinking (Ridgway et al., 2004). Digital camera and different software tools make it easier for students to show their work and reflect on it. A number of subjects in the school curriculum ask students to make various kinds of practices and arts-based productions (Sefton-Green and Sinker, 2000). These might include paintings in art, creative writing in English, performance in drama, recording in music, videos in media studies, and multimedia "digital creations" in different subjects. There are so far not many examples of how IT influences assessment in this way (Sefton-Green and Sinker, 2000). However, these aspects of students' knowledge and competencies as well as how IT is an integrated part of student learning and creative practices are important dimensions to keep in mind in conceptualizing IT and assessment.

In this section we have seen how IT represents some new possibilities for developing assessment practices, especially formative assessment, and how the complexity of these tools can be used to assess higher order thinking skills, such as problem solving, that are difficult to assess by paper and pencil. As McFarlane (2001) notes, "It seems that use of ICT can impact favourably on a range of attributes considered desirable in an effective learner: problem-solving capability; critical thinking skill; information-handling ability" (p. 230). Such competencies can be said to be more relevant to the needs in the information society and the emphasis on lifelong learning than those which traditional tests and paper-based assessments tend to measure.

IT Literacy Skills

This section deals more directly with IT in schools as an area of competence in itself. IT literacy is analogous to reading literacy, that is, it is both an end and a means. At school young people learn to read and read to learn. They also learn to use IT and use IT to learn.

The *ImpaCT2* concept mapping data from the UK strongly suggests that there is a mismatch between conventional national tests, which focus on prespecified knowledge and concepts, and the wider range of knowledge that students are acquiring by carrying out new kinds of activities with IT at home (Somekh and Mavers, 2003). By using concept maps and children's drawings of computers in their everyday environments, the research generates strong indication of children's rich conceptualization of technology and its role in their world, for purposes of communication, entertainment, or accessing information. It shows that most children acquire practical skills in using computers that are not part of the assessment processes that they meet in schools. Some research has shown that students who are active computer users consistently under-perform on paper-based tests (Russell and Haney, 2000).

EU countries, both on a regional and national level, and other countries around the world, are in the process of developing a framework and indicators to better grasp the impact of technology in education and what we should be looking for in assessing students' learning using IT. (For example, see for EU, http://www.digeulit.ec/, for Norway, Erstad (2006), and for Australia, Ainley et al. (2006)). According to the Summit of Twenty-first Century Literacy in Berlin in 2002 (Clift, 2002), new approaches stress the abilities to use information and knowledge that extend beyond the traditional base of reading, writing, and math, which has been termed *digital literacy* or *IT literacy*.

In January 2001, the Educational Testing Service (ETS) in the US assembled a panel for the purpose of developing a workable framework for IT literacy. The outcome was the report *Digital transformation. A framework for ICT literacy* (International ICT Literacy Panel, 2002). Based on this framework, one can define IT literacy as "the ability of individuals to use ICT appropriately to access, manage and evaluate information, develop new understandings, and communicate with others in order to participate effectively in society" (Ainley et al., 2006).

In line with this perspective, some agencies have developed performance assessment tasks of "IT Literacy," indicating that IT is changing our view on what is being assessed and how tasks are developed using different digital tools. One example is the tasks developed by the International Society for Technology in Education (ISTE) called *National Educational Technology Standards* (NETS, http://cnets.iste.org/), which are designed to assess how skillful students, teachers, and administrators are in using IT.

In Australia, a tool has been developed with a sample of students from grade 6 and grade 10 to validate and refine a progress map that identifies a progression of IT literacy. The IT literacy construct is described using three "strands": working with information, creating and sharing information, and using IT responsibly. Students carrying out authentic tasks in authentic contexts is seen as fundamental to the design of the Australian National IT Literacy Assessment Instrument (Ainley et al., 2006). The instrument evaluates six key processes: accessing information (identifying information requirements and knowing how to find and retrieve information); managing information (organizing and storing information for retrieval and reuse); evaluating (reflecting on the processes used to design and construct IT solutions and judgements regarding the integrity, relevance, and usefulness of information); developing new understandings (creating information and knowledge by synthesizing, adapting, applying, designing, inventing, or authoring); communicating (exchanging information by sharing knowledge and creating information products to suit the audience, the context, and the medium); and using IT appropriately (critical, reflective and strategic IT decisions, and considering social, legal, and ethical issues) (Ainley et al., 2006). Preliminary results of the use of the instrument show highly reliable estimates of IT ability.

There are also cases where an IT assessment framework is linked to specific frameworks for subject domains in schools. Reporting on the initial outline of a US project aiming at designing a Coordinated ICT Assessment Framework, Quellmalz and Kozma (2003) have developed a strategy to study IT tools and skills as an integrated part of science and mathematics. The objective is to design innovative IT performance assessments that could gather evidence of use of IT strategies in science and mathematics.

The earlier-mentioned projects and perspectives represent attempts at linking IT and assessment that are in the making. There are not many substantial research results to build on yet, but this will probably be a field of research that will grow in the years to come in relation to developing the twenty-first century skills.

Conclusion: Are We Changing Practices?

The aim of this chapter has been to look closely at the assessment and the development of new information technologies and the extent to which we can see examples of changing assessment practices as a consequence of these developments. The use of IT as part of assessment is still marginal in most countries, which is also reflected in the lack of research in this field.

The influence of IT on students' attainment and learning has also been linked closely to studies of assessment (McFarlane, 2003), even though studying this link has not been a major objective in this chapter. It seems that asking "What is the impact of IT on attainment?" is the wrong question, both as a basis for research and for justification of policy. Rather, what is required is to analyze the changes in *what* has to be assessed and discuss how IT can support all relevant types of assessments.

In this chapter the presentation of research on assessment practices and IT has been structured into three areas, defined by the way IT is conceived as part of assessment of student learning. The first section shows that many initiatives of IT and assessment have not been about changing assessment practices, but to further develop traditional ways of assessment using the same set of criteria for what is being assessed, mostly summative ways of assessment. Studies trying to compare paper-and-pencil testing with computer-based testing are inconclusive. At the same time, there are initiatives aiming to replace paper-based assessment made possible by increased access to computers in schools, better security and developments in test-procedures adjusted to computer-based assessment. Moreover, there are also some examples explicitly showing developments in traditional assessment methods due to the use of IT, such as scoring essays or using simulations.

The second section refers to research on the use of IT in assessing learning processes that otherwise could have been difficult to assess using traditional methods. These studies show that the use of IT is not only to support more formative ways of assessment, but can also be used to assess higher order thinking skills such as problem solving among students and lifelong learning skills that are difficult to assess by paper and pencil.

The third section deals with research in which assessment is linked to the introduction of IT itself and where digital literacy is seen as a knowledge domain. This is a new area of research with growing attention in many countries. *IT literacy* is being introduced into curricula in some countries, which calls for performance assessments in this area. As shown earlier, there have been a few research initiatives in this respect, exploring how IT is changing assessment practices.

These developments have implications for three different areas:

- *Policy and curriculum development*: In curriculum development, policy-makers and experts need to take into consideration not only the impact of IT on teaching and learning, but just as important, the influence of IT on assessment practices. So far this has been a neglected area. Without changing assessment practices using IT in formal policy documents and curricula, the ways in which IT is used in schools will be limited.
- *Research:* There is a need to develop studies with the affordances of IT more in focus. Most of the research so far has been directed toward the transition from paper-and-pencil to computer-based assessment. These studies do not really document changes in assessment practices. There is, however, some research available that represents a platform to build on. This implies that we need to look

more in-depth into different aspects of IT applications and the new possibilities they might give, and to focus more on the ways these tools provide access to higher order thinking skills among students and their "digital literacy."

– *Teaching:* Assessment practices have a direct influence on teaching in schools. There is a need to be clearer about the link between student learning, teaching practices, and assessment. Changes in assessment practices have to be seen in connection with developments in the usage of IT, developments of different methods such as project-based learning, teacher competences, and learning communities.

Even though there seems to be teacher support for student-oriented assessment, the dominating test culture presses for other priorities (Broadfoot and Black, 2004). The influence of IT on assessment practices might represent a more fundamental break from traditional school practices and student learning, if we manage to grasp the full potential of using IT to enhance student learning for developing the twenty-first century competencies.

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2.6

INFORMATION TECHNOLOGY TOOLS FOR CURRICULUM DEVELOPMENT

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Curriculum Development Aided by Technology

Before discussing specific information technology tools for curriculum development, it is useful to first examine the two main fields involved. This chapter therefore begins with a brief discussion of curriculum development as a complex task, and those aspects that lend themselves most naturally to being supported by technology. Thereafter, recent advances of IT in supporting complex tasks are addressed.

Curriculum Development: A Complex Endeavor

In this chapter, the term *curriculum* is used in accordance with Taba's (1962) broad definition: "a plan for learning." A well-considered plan specifies how learning will take place and considers its central rationale, the aims and objectives, content, organization, and evaluation of learning (Walker, 2003). Curricular concerns may be addressed at several levels: supra (society), macro (system), meso (school), micro (classroom), or nano (learner). Among other characteristics, a robustly designed curriculum will evidence consistency among curricular components and across curricular levels (McKenney et al., 2006). Depending on the level the curriculum addresses, different groups of people are involved in the process of creating this plan for learning. At the supra and macro level these are (among others) subject-matter experts, pedagogical content experts, and educational policy makers, whereas at meso, micro, and nano level, teachers, teacher teams, school leaders, and learners are commonly involved. As far as

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the design of lesson materials (micro level) is concerned, particularly educational publishers, subject-matter experts, pedagogical content experts, IT-experts, and teachers are engaged. When taking all factors and actors into consideration, curriculum development may be viewed as a complex task.

In the last 15 years, many computer-based tools have been developed to support designers during the complex endeavor of instructional and curriculum development, especially at the micro level (Gustafson and Reeves, 1990; van den Akker et al., 1999; van Merriënboer and Martens, 2002; Zhongmin and Merrill, 1991). These developments have been influenced by the growing possibilities of information technology and evolving insights in the potentials of computer-based tools in this domain. The following section provides an historical perspective on the field of IT tools that support the performance of complex tasks in general and of educational design tasks in particular.

IT Tools for Supporting Complex Tasks

Amidst an explosion of technological innovation, several types of IT tools emerged that also have been applied to the context of curriculum design. In this section, we distinguish three types of these IT tools: Electronic Performance Support Systems (EPSSs), Knowledge Management Systems (KMSs), and Repositories for Reuse. As depicted in Figure 1, an example will be given for each type of tool in the following section.

Electronic Performance Support Systems

The concept of EPSSs was born in the late 1980s and took a foothold in the early 1990s. An EPSS is a computer-based system that provides integrated support in the format of any or all of the following: job aids (including conceptual and procedural

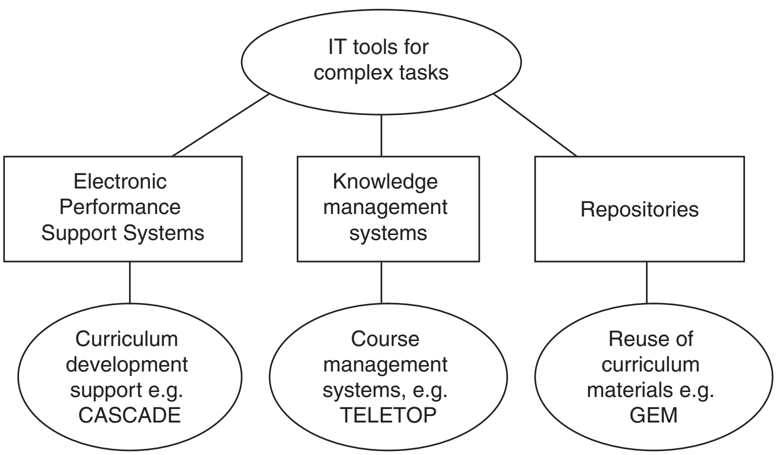

Fig. 1 ICT tool types used to support the complex task of curriculum development

information and advice), communication aids and learning opportunities (such as Computer-Based Training (CBT), in order to improve user performance.

Earlier work in this area demonstrated a clear orientation toward "proof of concept" thinking, as evidenced by the literature that populated journals at that time (for an overview of EPSS-related literature from 1989 to 1995, please refer to Hudzina et al., 1996). Emphasis was given to defining the innovative concept of EPSS, to demonstrating its potential feasibility, and to verifying the likelihood of its usefulness (cf. Gery, 1995) as well as to discussing ways of exploring the potential further (Stevens and Stevens, 1995). The widely accepted goal of EPSS is to provide whatever is necessary to generate performance and learning *at the moment of need*. An EPSS can be distinguished from other types of interactive resources by the degree to which it integrates *information, tools and methodology* for the user. It should be noted that, while high quality performance support is likely to contain learning opportunities, experts lament the misconception that CBT – by itself – constitutes performance support; they call for CBT utilities to be more easily integrated in larger systems (Dickelman, 2003a). In other words, consensus has not been reached on the ideal balance of support elements in systems, with many variations being offered in literature (e.g., Collis and Verwijs, 1995; McKenney, 2008; Nieveen and van den Akker, 1999; Raybould, 1990; Stevens and Stevens, 1995). Whereas earlier research and development efforts seemed more inspired by the idea of exploring what electronic *systems* could offer, a trend rapidly emerged in which *user performance* became central, with the supporting systems on the periphery (Rosenberg, 1995; Winslow and Bramer, 1994); hence the concept of Performance-Centered Design (PCD) was born. This gave rise to articulation of fundamental forms of support (Gery, 1995; Marion, 2002), and attributes and behaviors of performance-centered systems (Gery, 1997; McGraw, 1997) as well as methodologies for conducting PCD (Raybould, 2000) and guidelines for designing tools to support specific learning-behaviors (Gery, 2002). At the same time, advances in the field of human performance technology (HPT), with its emphasis on systematically bridging the gap between what is and what should be in human performance, have provided useful concepts and tools for conceptualizing performance problems (e.g., see Wilmoth et al., 2002, for an overview of HPT models).

A variety of EPSSs have been developed to support designers during the complex endeavor of curriculum development. These tools tend to be created for instructional designers, preservice teachers, inservice teachers, teacher educators, and educational consultants. Tools in this classification assist in the design and development tasks that might also be described as *desk work*. These tasks include planning needs analysis (but not the actual data collection), drafting and designing curriculum materials, creating formative evaluation instruments, and analyzing work flows. Task-specific tools within this classification include those designed to aid in personal course or lesson planning (Gervedink Nijhuis and Collis, 2005; Wild, 2000), creating teacher guides for use by others (McKenney, 2005), and formative evaluation (Nieveen and van den Akker, 1999). Outputs from systems within this classification may be conceptual (e.g., formulating an approach for conducting a context analysis) or concrete (e.g., an interview scheme to be used with headmasters during context analysis).

For comprehensive accounts of tools for instructional and curriculum design, please refer to Nieveen and Gustafson (1999), van Merriënboer and Martens (2002), or Spector and Ohrazda (2003). Studies have demonstrated that support tools can aid both design experts (de Croock et al., 2002; Merrill and Thompson, 1999; Rowley, 2005; Spector, 1999) and nondesign experts, such as teachers and subject-matter experts (McKenney et al., 2002; Mooij, 2002). In Section 2.1 an example of an EPSS for curriculum developers will be more fully described.

Knowledge Management Systems

A KMS is a system for managing knowledge within an organization. A KMS may support the creation, capture, storage, and/or dissemination of knowledge and/or expertise. Although realizing their potential is often difficult (cf. Rosenberg, 2002), KMSs support the performance of complex tasks by offering aids for communication, coordination, collaboration, and control (Spector, 2002).

While KMSs have been used in education, tools more tailored to the job of planning instruction or teaching most often fulfill these functions: Course Management Systems (CMSs). Common forms of (teacher) support in CMSs include administration tools (e.g., grading tools, assignment tracking, testing); course delivery tools (e.g., discussions, messages, shared work space); and content development tools (e.g., templates for course design, content reuse, instructional design aids). For comparison of CMS products most commonly used by K-12 schools and in higher education, visit http://www.edutools.info. For an early overview of Web-based course support, see the special issue of the *International Journal of Educational Telecommunication*, 5(4), 1999, which examines relevant technical, pedagogical, and institutional issues. Section 2.2 elaborates on an example of a CMS. Instructional Knowledge Management Systems (IKMSs) bear resemblance to CMSs, but also offer additional functionalities, such as the management of paper-based documents and knowledge management across multiple courses (e.g., across subjects and disciplines); for additional information on IKMSs and their core features, please refer to Edmonds and Pusch (2002).

Repositories of Resources for Reuse

The advance of flexible access to digital information supported by World Wide Web browsers in the early 1990s also rang in an era of digital libraries and digital repositories. These are “organized collections of information resources and associated tools for creating, archiving, sharing, searching, and using information that can be accessed electronically” (Reeves, 2005, p. 527). In educational settings, digital libraries particularly focus on the reuse of digital teaching and learning materials (see, for example, the *Journal of Interactive Media in Education*’s special issue in 2003). The term *reusable resources* pertains to the teacher perspective as well as the learner perspective. Several national and international repositories have been established to collect and share digital resources. For example, the Dutch EduRep

(Educational Repositories) initiative (http://edurep.kennisnet.nl) offers a central listing of (digital) learning material that is available through the Internet. Its databases include the collections of materials offered by publishers, educational institutions, and socio-cultural organizations; most participating organizations are active in the K-12 sector. Searches in EduRep yield information about the various resources and links to either (a) download the resource itself or (b) request it from the provider (e.g., in the case of paper-based resources).

Commonly referred to as learning objects (also knowledge objects or sharable content objects), reusable resources from the learner perspective are frequently incorporated into tools that assist with curriculum implementation. Strijker and Collis (2007a) describe differences in curriculum contexts and also the requirements for different approaches for the use of learning objects. Learning objects vary, due to differences in size, granularity, shape, and intended usage, but the following definition by Sosteric and Hesemeier (2002) may be useful, “A learning object is a digital file (image, movie, etc.) intended to be used for pedagogical purposes, which includes either internally or via association, suggestions on the appropriate context within which to utilize the object.” Wiley’s (2000) taxonomy distinguishes five types of learning objects and their various characteristics; this same chapter also emphasizes the need for instructional use to be well-specified. Others, such as Harvey (2005), go on to stress the need to apply instructional design principles to the learning object development process. In fact, he warns that, “If such principles are not heeded, learning repositories will gain a reputation for amateurish content, rather than credibility as worthwhile educational resources.”

From a technical perspective, much of the discussion concerning the reuse of learning objects centers on the need for standardized Learning Object Metadata (LOM) to facilitate interoperability between systems. The Learning Technology Standards Committee (http://ieeeltsc.org/) authored the LOM standard to make this possible. The LOM is based on categories such as lifecycle, technical, educational, rights, relation, annotation, and classification. Within these categories metadata elements such as title, language, keyword, author, version, intended user role, context, age range, and typical learning time can be found. This LOM standard is also incorporated in the Sharable Content Object Reference Model (SCORM), which is a set of specifications for composing Web-based learning objects (diNitto et al., 2006).

However, sustainability and interoperability are fundamentally determined by issues from the human perspective. In terms of design, three factors bear particular mention: (1) technical expertise (skills within a particular team); (2) commercial interests (remember that IBM’s technology was once so proprietary that not even another system’s keyboard could be used!); and (3) planning ahead (having both the perspective and the time to tackle things with reuse in mind). Perhaps even more importantly, reusable materials must be a shared goal, as Spector (2002) argues, “… the key to successful reuse is not a particular tagging scheme or a particular technology – the key to successful reuse is in getting people with relevant interests, expertise and motivation to collaborate in ways that obviously extend and enhance what they might accomplish individually.” Also, Parrish (2004, p. 65) takes a critical look at the proposed benefits of learning objects, and aptly points out that "solutions lie in more effective instructional practice … not simply access to more content."

Large-scale learning object repository initiatives have been undertaken by universities (e.g., Merlot (Malloy and Hanley, 2001; MERLOT, 2007) and MIT (MIT, 2007)) as well as organizations such as the European Union (Ariadne (ARIADNE, 2007)). In Section 2.3 an example of a repository for reuse of resources in K-12 education will be described more extensively.

Three Cases of IT Support for Curriculum Development

This section discusses examples of the three types of IT support tools discussed in the previous section. Each tool is described based on four system characteristics: (a) user profiles; (b) design processes supported; (c) results generated; (d) support formats offered. The *user profiles* for tools for curriculum development vary in terms of the educational design expertise of the user group, the scope of the intended user group, and the computer experience. While some tools are designed for large audiences (commercial production), many are also custom made for smaller ones. Tools further differ in terms of the part(s) of the *design process* for which the support is offered (analysis, design, construction, implementation, evaluation). *Tool results*, or outputs, vary depending on the target group (e.g., learner-based, teacher-based); form (paper-based, computer-based, www-based); and extensiveness of the task being supported (site specific, generic). Finally, while the accents in different tools shift to meet user needs, most tools include some *support form(s)* of advice, tools, learning opportunities, and communication aids.

Example of an EPSS: CASCADE-SEA

CASCADE-SEA stands for Computer ASsisted Curriculum Analysis, Design and Evaluation for Science Education in Africa. It is the name of a computer program that helps resource teachers create exemplary teacher guides.

User Profile

CASCADE-SEA assists facilitator teachers, working at regional teacher resource centers, in making teacher guides that can then be used by other teachers (usually colleagues in the same region). The CASCADE-SEA system has been used by facilitator teachers in Namibia, Tanzania, Zimbabwe, and South Africa in conjunction with broader curriculum development initiatives. In addition, the following other groups have been using the system in recent years: preservice teachers in Zimbabwe (in curriculum methods courses) and professional curriculum developers from the Tanzanian Institute of Education as well as course designers within the Faculty of Education at Eduardo Mondlane University on Mozambique.

Fig. 2 Main menu within CASCADE-SEA

Design Process Supported

As the main menu (Figure 2) illustrates, CASCADE-SEA guides its users through the following key phases in the cyclic process of curriculum development:

- Rationale (Why am I making materials? What do I want to achieve with them?)
- Analysis (What kinds of materials do we need? What are the problem areas?)
- Design (How can I best structure these materials? What kinds of tips do I include?)
- Evaluation (Do they work as I had hoped? How can they be improved?)

Results

Different outputs are produced in each area of the program. These are summarized in Table 1.

Support Formats

CASCADE-SEA was designed to provide four main types of support: advice, tools, learning opportunities, and communication aids. Six illustrations of each type are provided in Table 2.

Table 1 Main outputs from CASCADE-SEA system

Area	Conceptual results	Concrete: Printable, electronic outputs
Rationale	Articulation of aims Clarification of context	Rationale profile Design tips Implementation recommendations Templates
Analysis and evaluation	Generation of questions Selection of methods to answer questions	Analysis/evaluation plan Analysis/evaluation plan checklist Analysis/evaluation instruments (interview schemes, questionnaires, document analysis checklists, etc.) Guidelines for working with respondent groups (headmasters, teachers, learners, classes) Suggestions on (re)shaping materials
Design	Setting goals Choosing assessment Clustering and sequencing content Shaping layout	Table of contents Individual lesson plans Lesson plan checklist

Table 2 Illustrations of support types offered within CASCADE-SEA

		Examples from the CASCADE-SEA program
Advice	Tailor-made	Reminders of choices made previously Consistency checks (illogical options are disabled) Heuristics
	Generic tips	Reference and further reading lists provided for sub-tasks Examples given in explanations Sample/draft text preformatted in text-entry boxes
Tools	Internal	Templates provided for all instrument types Automatic-save/archive/copy Generates (draft) plans
	External	Drawing and concept-mapping software Links to relevant Websites Additional resources available through online database
Learning opportunities	Implicit	Visual appearance suggests a method for doing (sub)tasks

(continued)

Table 2 (continued)

		Examples from the CASCADE-SEA program
		Previews consequences of user actions
		System monitors and responds to user choices
	Explicit	Explanations
		Tutorials
		Illustrations
Communication aids	Written	Shared database
		Website discussion forum
		E-mail links
	Verbal	Checklists for use in design team discussions
		Examples to stimulate dialogue
		Instructions for interacting with respondents

For Further reading on the Cascade system, please refer to the following sources: McKenney, 2008; McKenney et al., 2002; McKenney, 2005

Example of a KMS (CMS): TeleTop

TeleTop is a Web-based course design and delivery environment. It was originally designed to support university faculty in planning and managing their courses, as well as using telematics applications in their teaching.

User Profile

Since the initial development of TeleTop, the tool has been revised and expanded. Nowadays, TeleTop is also used on a large scale in Dutch secondary education as well as adult and vocational education, higher education, and corporate and government organizations.

Design Process Supported

TeleTop is an online CMS, whose functionalities include options to postcourse information (about, e.g., learning goals, assessment, teachers); create and submit assessments (e.g., assignments, quizzes); post e-sources and learning objects (e.g., presentations, multimedia files, simulations); and communication aids (e.g., online discussions, shared workspaces).

Results

The use of TeleTop results in a Web-based course environment. Figure 3 offers an example of one of the resources (leermiddelen) about gravity. The site is in Dutch to support students and teachers in there native language; translations in the text are given in parentheses and refer to this figure.

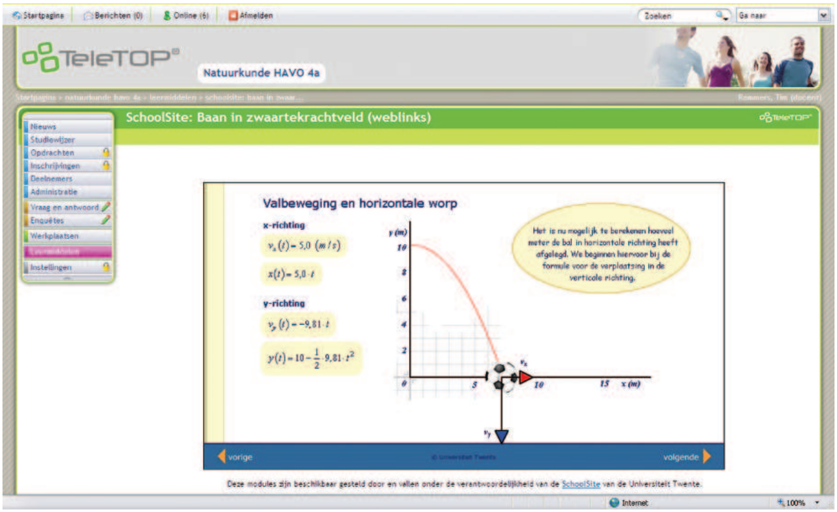

Fig. 3 Resources within a Science TeleTop course environment

Support Formats

The Teletop system is database driven. Support within the TeleTop system is offered in several ways, including the following.

- Template tool: Offering seven course models and support for selecting the most relevant.
- Menu-design tool: Offering different additional functionalities to choose within the course models.
- Roster-design (Studiewijzer) tool: A scheduling framework and possibilities to offer and retrieve assignments.
- A course tutor: Offering recommendations for flexibility, technology and pedagogy.
- A Learning Content Management System: Offering reuse (zoeken) possibilities and connections to digital repositories.

The connection to the digital repositories is made through a search (zoeken) option in the right top of Figure 2. This search option provides direct access to educational repositories and makes it possible to select resources from educational repositories directly. Based on the copyrights copies or links to the course material are provided. Table 3 provides examples of support given in the form of advice, tools, learning opportunities, and communication aids.

Example of Repositories for Reuse: GEM

The U.S. Department of Education's National Library of Education launched the Gateway to Educational Materials (GEMs) project in 1996 to help educators find lesson plans and teacher guides on the Internet (see http://www.thegateway.org).

Table 3 Examples of support offered within TeleTop

	Examples from the TeleTop environment
Advice	Videos with expert comments
	Consistency checks (illogical options are disabled)
	Guidelines for selecting functionalities
Tools	Templates provided for seven course structures
	Reuse previous course through copy/edit function
	Selection from educational repositories (Zoeken)
	Tracking, tracing, and reporting (Administratie)
	Menu designer
Learning opportunities	Explanations
	Simulations
	Tutorials
	Videos
Communication aids	Group work and shared workspaces (Werkplaatsen)
	Question and answer (Vraag en antwoord)
	Questionnaires (Enquetes)
	Online and offline messaging (left top icons)
	E-mail links (Deelnemers)
	Threaded discussions

Further reading on the TeleTop system: Strijker and Collis, 2005, 2007b; Collis and Moonen, 2001

GEM is a consortium of government agencies, educational institutions, nonprofit and commercial organizations offering access to over 40,000 records from over 600 consortium member collections; see Figure 4.

User Profile

GEM was initially designed to help practicing K-12 teachers locate materials and tools for use in their classrooms. While that remains the case, additional user groups now include administrators, preservice teachers and their educators, parents, and the general public.

Design Process Supported

The GEM resources primarily aid in the planning and organization of learning and instruction. Many resources also offer artifacts to use in the classroom with learners. Some items contain tools or tips for assessment. Although in the minority, there are also classes of resources meant to help leaders and managers as well as the establishment of collaborative partnerships (e.g., between businesses and schools).

Results

GEM searches yield access to various types of teaching and learning resources, predominantly lesson and activity plans and instructional units. Additional types of

Fig. 4 Screen shot from the homepage of the GEM Website

resources include images, digital and paper-based tools, data sets, and references. For a comprehensive description of results, please refer to the aforementioned Website.

Support Formats

Trends and tips, with relevant links, are offered on GEM's three themes (teaching and learning, leading and managing, and partnering). The dominant theme is the teaching and learning strand, but for all strands, users can search and browse by subject, type, level, keywords, mediators, or beneficiaries. Help is offered for effective browsing and searching.

Further reading on GEM: Small et al. (1999); Sutton (2003).

Future Directions

The concept of performance support for curriculum development is relatively young. The variety of tools developed implies that the concept's potential has been widely recognized. Advocates of performance support systems cite a variety of potential advantages, the most common of which include improved task performance, transfer of knowledge and skills, organizational learning, and cost-saving.

Naturally however, there are obstacles to realizing all the benefits. When it comes to curriculum development tools, evidence of sustained use is rare. On one hand this could be caused by the fact that this kind of follow-up research is hardly carried out. On the other hand, potential hindrances to EPSS implementation in regular design practices constitute no small hurdles. From the technical perspective, logistics and infrastructure can present huge challenges (e.g., the inertia of legacy systems and the need for network administrators to install non-Web-based environments) and new technologies can be unstable. Even more significant are barriers from the human perspective, which commonly include unfavorable organizational or political climate, philosophical differences (e.g., "a computer shouldn't be able to do my job for me"), and personal resistance (time-consuming, intimidating, confusing). Oftentimes, educational designers are not even aware of relevant, available tools. EPSS design is often a risky business, as it usually requires high investment and yields difficult-to-measure results. Insufficient needs analysis is a common pitfall among EPSS designers, who sometimes base their products on user perceived needs, rather than real ones. Perhaps this is due in part to the fact that, with a few recent exceptions, participatory development of EPSSs has been scarce. Reeves and Raven (2002) offer a useful framework for assessing the feasibility of designing an EPSS.

But what is on the research and development horizon?

Over a decade ago, Gery (1995, p. 48) said, "Few [EPSSs] are guided by a set of integrated and fully articulated design principles. Many innovations are the result of team creativity and iterative design employing rapid prototyping coupled with ongoing usability and performance testing." Since then, steps have been made to strengthen development processes for EPSSs in general (Carliner, 2002; Dickelman, 2003b), but far less so when it comes to designing performance support specifically within the field of education. If progress is to be made toward a much-needed increase in quality and types of performance support tools for K-12 and higher education, then it would seem fitting to consider design principles for this genre of tools. Such principles should be distilled from well-documented, high-quality research and development endeavors.

In terms of future research, it would seem that systematically evaluating the degree to which these tools actually can yield the potential benefits (effectiveness) should be high on the agenda. In fact, Gustafson (2002, p. 65) takes this notion a step further, "Probably the single most important area needing further attention is systematically evaluating the effectiveness and appeal of the education and training that result from using [instructional design] tools."

With regard to the future, the growth of information technology for curriculum development is almost surely to be steered by technological innovation. For example, we could see more integrated use of intelligent technologies (e.g., agents, search engines, filtering) and generic tracking and tracing utilities (cf. Quesenbery, 2002). This can lead, for example, to a more sophisticated personalization of support and learning through portal technology (cf. Strijker and Fisser, 2008). Perhaps systems will be linked to mobile phones that can be used to collect data: pupil location, time of events, and even utterances while performing a new learning task. In all cases, additional examples of system design, flanked by design research during prototyping as well as implementation, are needed to extract insights and advance the field.

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Section 3

IT AND THE LEARNING PROCESS

3

IT AND THE LEARNING PROCESS

Kwok-Wing Lai
Section Editor

The changing conceptions of learning and the rapid advancement of technology have led to the development and expansion of a model of education through which learners are engaged in social construction of knowledge and meaning in learning environments and communities, supported by information and communication technology (ICT) (Pea, 2002; Salomon and Almog, 1998). How, and under what conditions, digital and communications technologies can be successfully adopted to enhance the learning processes in primary and secondary schools thus has become a key focus in educational research in the last three decades (Selwyn, 2000). In this section of the Handbook, several key research areas on ICT and the learning process, which have been extensively studied, are reviewed:

- Design of interactive learning environments and multimedia-networked environments
- Computer-supported collaborative learning
- Online learning communities
- The use of ICT as a cognitive and metacognitive tool to support learning

The chapters included in this section review and synthesize exemplar studies to illustrate how technology can be used to support a variety of learning environments, such as problem-based (Savery and Duffy, 1996), discovery-based (de Jong and van Joolingen, 1998), and knowledge-based (Scardamalia and Bereiter, 2006) learning environments and communities. They also review the use of ICT as a cognitive and metacognitive tool to support students' communication, collaboration, reflection, and knowledge creation. In synthesizing research findings on the outcomes of ICT-supported learning environments, attention has been paid to the learning principles, which underpin the design of these environments, pedagogies employed to facilitate learning, software used to support knowledge inquiry, communication and collaboration, as well as the role of the teachers and learners in the learning environment.

J. Voogt, G. Knezek (eds.) *International Handbook of Information Technology in Primary and Secondary Education, 213–214.*

Chapter 3.1 provides an overview of how ICT has been used to support learning, within the context of the changing conceptions of learning. A range of promising and effective ICT tools embedded in learning environments are reviewed in this chapter. Chapter 3.2 synthesizes research on the design of interactive environments on the basis of the understanding of the learning and teaching process, and provides a framework to conceptualise the key concepts in their design. Chapter 3.3 reviews the concept and boundary of research on online learning communities, identifies the major trends of research, and suggests pertinent issues for future research. An in-depth review on the design principles and characteristics of four online learning communities, namely Knowledge Building communities, Quest Atlantis, Virtual Math Team, and Web-Based Inquiry Science Environment are presented in this chapter. In Chapter 3.4, the concept of collaborative learning and the issues involved in using information and communication technology to support collaborative learning is reviewed. This chapter also discusses the potential of computer-supported collaborative learning (CSCL) environments, and addresses the challenges CSCL environments face. Chapter 3.5 reviews the most frequently documented metacognitive learning outcomes including recall/memory, content learning/problem solving, and social interactions as knowledge acquisition and examines the potential of computer tools in supporting these learning outcomes. Chapter 3.6 reviews the integration of networked multimedia environments into classroom learning, focusing on inquiry, collaboration, and knowledge building, with exemplary environments (including CoVis and Knowledge Forum) discussed. Theoretical changes in learning and how these changes have influenced the design of multimedia-networked environments, as well as theoretical, pedagogical, and methodological implications are also discussed in this chapter.

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3.1

ICT SUPPORTING THE LEARNING PROCESS: THE PREMISE, REALITY, AND PROMISE

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Introduction

How learning occurs has been reconceptualized over the last few decades to recognize the social construction of knowledge and meaning in context. Learning is now perceived not so much as a passive activity with knowledge transmitted from the teacher to the learner, but with the learner actively constructing knowledge and solving problems individually or collaboratively in authentic contexts (Salomon and Almog, 1998). During this same period, there has also been a rapid advance of technology and a concurrent evolution of digital culture. The convergence of socio-technical initiatives has led to the development and expansion of a model of education through which learners are involved in information and communication technology (ICT) supported learning environments, as well as in learning communities (Pea, 2002). We have now amassed a wealth of research findings on the design and implementation of ICT-supported learning environments, as well as its effects on learning. It is evident that although there are exemplar practices and benefits in the use of ICT in the learning process, there is no evidence to support its use in every learning context, in every learning area, or for every learner (International Society of Technology in Education, n.d.). To improve learning, technological applications have to be well designed, on the basis of learning and pedagogical principles, used under appropriate conditions, and be well integrated into the school curriculum. How, and why, ICT can be successfully adopted to further enhance student-centered learning processes in schools has become a key focus in educational research.

The purpose of this overview chapter is not to provide a comprehensive review of the use of ICT and its effects in the learning process, but to give a historical context of ICT use, placing it within an evolving conception of learning, and to discuss ICT-supported learning environments, on the basis of a contemporary understanding of

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learning principles. This chapter thus provides a background for the discussion of the five specific areas of ICT supporting the learning process included in this section of the Handbook. The areas covered are the design of interactive learning environments, multimedia learning environments, metacognition, computer-supported collaborative learning, and learning communities. The examples provided in this chapter also give the reader some ideas regarding how effective computer-supported learning environments can be designed and used.

The Learning Process and ICT Use

The use of technology in the last few decades to a great extent reflects the changing understandings of how learning and teaching are conceptualized. Conventionally, learning has been conceptualized as a passive activity, with knowledge being transmitted from someone who knows it to someone who does not. In this view, learning is primarily understood as reproducing knowledge, and as a commodity that can be delivered to the learner and put into his or her head. Researchers thus use the knowledge acquisition metaphor to describe this learning process where learning is seen as individuals acquiring knowledge, which is a concrete, transferable entity and the mind as a storage vessel (Sfard, 1998). The terms instructionist or transmission models are also used to describe this learning process. More recently, learning has been understood as a constructive process, where the learner actively participates in the construction of knowledge through situated and authentic tasks either as an individual or collaboratively to support deep, rather than surface, learning. Learning is thus more often viewed as a transformative process and metaphors of learning, such as *learning as process*, *learning as participation*, *learning as practice*, and *learning as knowledge creation*, are used to describe the process. This participatory approach is in sharp contrast with the traditional view of *learning as outcome or product* (Wilson, 1995). These different conceptions of learning to a large extent have determined how ICT may be designed to support and foster learning.

Alongside with the changing conceptions of learning, we see *waves* of ICT-supported applications in the classroom in the last 30 years. It began with computer-assisted instruction (CAI), in the late 1970s–1980s, where students were encouraged to learn from drill and practice and tutorial software programs, as well as from simulation programs. In this period, the computer primarily served as a tutor or a "surrogate teacher," to "drill, tutor, and test students and to manage instructional programs [and] to supplement or replace more conventional teaching methods" (Kulik and Kulik, 1991, p. 75). Soon students were asked to learn to program the computer, using programming languages such as Logo™ and BASIC™, and the computer was conceptualized as a tutee. There is an expectation that programming would bring cognitive and metacognitive benefits to the learners, such as an improvement in problem solving and thinking skills (Papert, 1980). From the late 1980s, ICT has been predominantly used as a tool in the classroom, with word processing, database management, and spreadsheet software being used as open-ended applications to support writing, mathematics, and other curricular areas. This is sometimes called computer-enhanced instruction. In Becker's (2000) most recent Teaching, Learning, and Computing Survey, conducted in 1998, word processing was reportedly the only software that had broad (across school subjects) and frequent use. With the advent of the Internet to the classroom, from the mid-1990s, the World Wide Web (Web) has been used as an information resource, as well as a communication, networking, and self-publishing tool. The Web has also facilitated the development of multimedia applications. As well, increasingly ICT has been used to support inquiry-based, problem-based, and knowledge-creating learning environments, during this period. Since the 2000s, e-Learning, social networking, and mobile communication applications have gained popularity. These ICT applications are underpinned by different conceptions of the learning process. As suggested by Koschmann (1996), CAI is underpinned by a behaviourist approach, and the intelligent tutoring system is based on a cognitivist philosophy. The TM programming language is based on a constructivist approach, while the computer-supported collaborative approaches are motivated by social constructivist theories (see also Dede, 2008, in this Handbook).

Research on ICT Effects

As the use of ICT in the classroom has been seen as inevitable in the knowledge society (Anderson, 2008), justified as a reaction to technological developments in the society, and as a preparation for future employment (Selwyn, 2007), the pressure to push the use of ICT in education has resulted in what Maddux (2003) has referred to as the *Everest syndrome*, with a general conception that "computers should be brought into educational settings simply because they are there" (p. 5). As quick add-ons to the classroom, ICT use is often driven by a technology-centered approach where technological innovations are adopted in the classroom to drive pedagogy without adequate research validation (Maddux and Cummings, 2004).

A large number of single and meta-analytic studies have been conducted to investigate the effects of computers on achievement. Most of these studies are media comparison studies, investigating the effects of the use of technology as a medium of instruction, compared with traditional teaching. They are usually conducted with classes divided into experimental and control groups, with the experimental group being *taught* by computer-assisted instruction and the control group by a teacher. The findings of these studies generally show that CAI and CMI have a positive, but modest effect on achievement (e.g., Kulik and Kulik, 1991; Blok et al., 2002). However, it should be noted that findings on the effects of CAI use are not always positive, and the overall results should be considered as inconclusive. For example, an earlier review by Bangert-Drowns et al., (1985) reported that simulation-based learning has no positive effect on achievement. Another example is the effect of Logo on learning. More recent findings on the use of Logo have become more favourable, while earlier studies have shown little cognitive benefits in its use. The more favourable results appear to be due to the attention paid to the teaching surrounded™ use (Cognition and Technology Group at Vanderbilt, 1996). Also, in Dillon and Gabbard's (1998) detailed review of 30 studies focusing on the quantitative effects of hypermedia on learning outcomes, they concluded that as a form of information presentation, the value of hypermedia in pedagogy was limited and the educational benefits of hypermedia were more mythical than real.

In assessing the impact of the use of technology on learning, some researchers (Salomon, 2006) question the validity of separating out the technology from the teaching and learning context, as it is difficult, if impossible, to determine the extent to which the technology, in and of itself, may lead to any improvement in learning. After all, the learning environment is a complex system where the interplay and interactions of a number of factors will impact on the learning process (Salomon, 2006). In the so called "Media Effects Debate," triggered by Clark (1983), and continued well into the 2000s, Clark asserts that instructional methods cannot be separated from the media of instruction, and it is the instructional method that affects learning as media "are mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition. Basically, the choice of vehicle might influence the cost or extent of distributing instruction, but only the content of the vehicle can influence achievement" (p. 445). Clark's position is supported by Mayer (2003), who has conducted a series of multimedia learning studies, using the same instructional method across different media environments to show that it was the instructional method, which promoted active cognitive process that caused learning, not the media environments (i.e., technology). Similarly, research conducted by the Cognition and Technology Group at Vanderbilt (1996) supports the need to investigate the effectiveness of instructional designs rather than the technologies used to transmit content. Taking an opposing stance, Kozma (1994) argues that medium and method should have a more integral relationship and that both are part of the instructional design. Some technology may have certain attributes, which can provide affordances to support instructional strategies that would not be possible without the technology.

With the shift of understanding of learning and the role of technology in the learning process, Mayer (1997) argues that research on media effects is based on an outmoded knowledge acquisition metaphor of learning, and with its replacement by the knowledge construction metaphor, and the shift from a techno-centric to a learner-centered approach to learning, future research on technology and learning should be learner-centered rather than media-centered. It is thus time to shift the focus of research "from media as conveyors of methods to media and methods as facilitators of knowledge-construction and meaning-making on the part of learners" (Kozma, 1994, p. 13).

ICT and Learning Environments

Recent research on technology and learning has paid greater attention to the integration of technology into the learning environment (Salomon, 1998). We now understand that it is the whole culture of the learning environment that will affect learning, rather than a technology or a single activity that involves the use of technology. It is thus more productive and promising to study the effects of ICT within the learning environment where it is embedded. Multiple definitions exist around the term *learning environment*, with researchers having diverse understandings of its scope. The term learning environment can be defined narrowly to refer to the computer software being created to support certain types of learning. A broader definition of a learning environment, as suggested by Sawyer (2006), would include the people (teachers, students, and other people in the environment), the computers and their roles, the architecture and the layout of the room, and other physical objects in the physical environment, as well as the psychological, social, and cultural environment. Similarly, Salomon and Almog (1998) use the term learning environment to refer to the entirety of teaching and learning activities, in a particular context, along with any technology used. Considered as complex systems, Salomon (2006) maintains that there are three characteristics of learning environments. First, there are different components in a learning environment, such as student and teacher characteristics, student–student and student–teacher interactions, learning activities and materials, and rules and regulations. Second, these components interact with each other thus giving meaning to each other. Finally, the learning environment is not static, as the interactions and their consequences are constantly changing. Understanding the characteristics of learning environments will improve the way the technology can be used to support learning in these environments.

A learning environment does not necessarily have a physical space. It can exist online. For example, many online courses have created a virtual environment to facilitate the learning process. These courses sometimes take place in a more formal structure using course management systems such as Blackboard™ or WebCT™. Increasingly research has been conducted to understand the characteristics of virtual learning environments and how they affect learning. Learning environments can be designed and developed as learning communities. The study of learning communities has now become a growing research strand in the literature and is seen as an effective way of supporting both learning and knowledge creation. Tan, Seah, Yeo, and Hung (2008) in this Handbook provide a detailed discussion on the role of learning communities in the learning process.

Although learning environments greatly depends on the technology that can shape, not just enable, the design of these learning environments (Salomon, 1998), to design a student-centered learning environment, attention has to be paid to its five foundations, namely psychological, pedagogical, technological, cultural, and pragmatic foundations, as suggested by Hannafin and Land, 1997. Bielaczyc (2006) also pointed out that in designing a learning environment, within the classroom context, the scope of the design process must not only focus on the learning tool itself (i.e., the computer software) but must also consider "the software; the technical infrastructure and specifications of the hardware; the social infrastructure: the social structures that support learning with the tool; the ways in which learning with the tool fits into the curriculum and relates to standards; and the teacher's knowledge of the functionality of the tool" (p. 316). One important area in the study of learning environment design is how technology can effectively support the social structure and infrastructure to enhance interactivity within the learning environment. Brown (2008) in this Handbook synthesizes the literature on interactive learning environments and provides a framework to conceptualize the key concepts in their design.

Computer-Supported Learning Environments

As noted earlier, to use technology effectively, technological applications must be underpinned by learning theories and pedagogical principles. Without a good understanding of how learning occurs, it would be difficult to determine how technology could be used effectively to support the learning process. In a seminal book, *How People Learn*, Bransford et al., (1999) postulate that learning environments should be student-centered, knowledge-centered, assessment-centered, and community-centered. Used effectively, ICT can play a key role in supporting these learning environments. In the last two decades, increasingly researchers from the learning sciences tradition have been designing computer-supported learning environments, based on the principle that the learner is actively engaged in authentic tasks, both individually and collaboratively in solving problems and constructing knowledge. Research on the use of technology to support learning, based on the research conducted in the field of learning sciences, is promising. As pointed out by Blumenfeld et al., (2006),

> When learning environments are based on learning sciences principles (e.g. project, problem, and design approaches), they are more likely to be motivating for students. The principles – such as authenticity, inquiry, collaboration, and technology – engage the learners so that they will think deeply about the content and construct an understanding that entails integration and application of the key ideas of the discipline (p. 475).

On the basis of learning sciences principles, a myriad of participatory and technology-enhanced, student-centered learning environments have emerged and been implemented, such as project-based learning, problem-based learning, anchored instruction, cognitive apprenticeships, and constructivist learning environments (Land and Hannafin, 2000). Although slightly varied in their scope, and in the technology and instructional method used to construct these learning environments, they are underpinned by similar learning principles and the way it can be facilitated. They are also often validated by design-based methods. In these computer-supported learning environments, there are several ways technology can enhance what students can learn and do. Technology can be used to bring real-world problems into the classroom by providing access to scientific data and information (Roschelle et al., 2000); create computer simulations to model real-world phenomena; provide scaffolds and cognitive and metacognitive tools to support inquiry or discovery learning (de Jong, 2006a; Sawyer, 2006); provide opportunities for feedback, reflection, and revision (Sawyer, 2006); and support collaborative learning and network learners and learning activities to local and global communities (Stahl, 2006). These benefits will be discussed in more detail as follows. The examples described are by and large drawn from research underpinned by learning sciences principles.

Bringing real-world problems to the classroom: Research shows that connecting learning activities to real-world tasks can create an active learning environment for students to explore ideas, which will help transfer learning from one context to another (Roschelle et al., 2000). Supported by technology, students can work in simulated real-world environments to carry out authentic tasks and solve problems as real workers would do (Means and Olson, 1995). Video and computer-based programs are available to involve students in authentic tasks. For example, the Voyage of the Mimi series, developed by the Bank Street College (http://www.bankstreetcorner.com/voyages_of_mimi.shtml), contains video episodes taking students to expeditions, which show scientists and archaeologists at work in a real place. These multimedia packages include computer programs and hands-on activities, which encourage students to use scientific and mathematics concepts and instruments to perform real-world tasks (e.g., to free a trapped whale) in student-directed and collaborative projects. Another example is the Adventures of Jasper Woodbury series developed by the Cognition and Technology Group at Vanderbilt University (http://peabody.vanderbilt.edu/projects/funded/jasper/intro/Jasperintro.html), focusing on mathematical problem finding and problem solving. The video episodes provide a simulated natural environment for students to solve complex, but authentic problems. Other similar projects using technology to support authentic problem solving include Immigrant 1850, Project GALAXY, and Antarctica Project (Means and Olson, 1995).

With the advent of communications technologies, students now have access to the latest scientific data online, as well as to the same tools professionals use to experiment with this data. For example, the Global Learning and Observations to Benefit the Environment (GLOBE) (http://www.globe.gov/globe_flash.html) program uses computer technologies linking schools to scientists to tackle real world problems. Participating schools (more than 3,800) collect local environment data for scientists, via the Internet, to conduct their own research. Supported by the scientists, students also analyze their data and compare their findings with those findings obtained from students worldwide (Roschelle et al., 2000). The CoVis (Collaborative Visualization) project (http://www.covis.northwestern.edu/) is another example where students can access the same data and tools used by scientists (Edelson et al., 1999).

Computer simulation: Computer simulation programs provide the learners with the opportunity to work with real world data in authentic situations and perform experiments in a simulated environment. Although computer simulations have been used for a long time (e.g., *The Oregon Trail* – http://www.isu.edu/ trinmich/Oregontrail.html), contemporary computer simulations are designed to facilitate students' conceptual understanding and the development and construction of knowledge by the learners themselves. In computer simulation programs, real world phenomenon, processes, systems, or apparatuses can be formalized and simplified to mimic the real life experiences and allow the learner to actively manipulate input variables and parameters within the simulation, and thus scaffold specific learning processes such as hypotheses generation, prediction, and model exploration (de Jong, 2006b).

Computer simulations allow students to act like scientists. For example, students can manipulate dynamic models in virtual reality environments in a range of systems that would be too dangerous or time consuming to experiment without the simulation programs, from studying "virtual spill sites to reconfiguring virtual DNA molecules and exploring virtual galaxies" (Bransford et al., 1999, p. 20). Recent examples of computer-based simulation environments include the GenScope project (http:www.//

genscope.concord.org/), the Co-Lab project (http://www.colab.edte.utwente.nl/), and Inquiry Island (http://www.thinkertools.org/Pages/sciwise.html). The GenScope project (Hickey et al., 2003), which uses simulations to teach core topics in high school genetics, has incorporated complex curricular-based discovery learning activities into the learning environment. A series of evaluative studies have been conducted to report substantial gains in genetics reasoning ability of the participants. Research suggests that simulation programs increase students' motivation and retention, exposes misconceptions, assists integrating information, and enhances transfer of learning. The use of simulation programs to give initial exposure to students about a concept and to integrate knowledge and stimulate inquiry and problem solving are the two most promising simulation-based applications (Akpan, 2001).

Inquiry-based learning: In recent years, there has been much research on how technology can provide an exploratory learning environment to support inquiry or discovery learning (or problem-based or project-based learning). According to de Jong (2006b), there is consensus among researchers that inquiry learning involves the cognitive processes of orientation, hypothesis generation, experimentation, the drawing of conclusions, evaluation, and monitoring. Research (de Jong, 2006b) shows that it is difficult for students to undertake inquiry learning as they do not always possess the cognitive skills to generate hypotheses, design experiments, interpret data, and regulate the inquiry process. Scaffolds and cognitive tools have been found to be effective to support students to acquire these skills in the inquiry process. These are computer generated tools which "provide cognitive and social support for people new to a task or knowledge domain…[They] may be questions, prompts, or procedures provided to students that more knowledgeable people have internalized and provide for themselves" (Kozma and Schank, 1998, p. 16). With the support of scaffolds, students are able to perform these cognitive and metacognitive processes at a higher level and extend their ability into the *zone of proximal development* (Vygotsky, 1978). As outlined in de Jong's (2006a) review of scaffolds for scientific discovery learning, there are a number of computer-based tools that can scaffold the learners in the inquiry processes, such as the *inquiry diagram*, a concept mapping tool used in Belvedere (a collaborative learning environment designed to support the inquiry process) (http://www.lilt.ics.hawaii.edu/belvedere/index.html), to link hypotheses and data; the graphical modelling tool provided in the Co-Lab environment; and the *advisors* used in the Inquiry Island project to support the inquiry cycle. Other cognitive and metacognitive tools include *hypothesis scratchpad*, to generate hypotheses, computer-generated prompts to stimulate reflection on the strategies used, and tools such as *investigation journal* to help the learners to organize evidence and tools to support planning and monitoring. These and other metacognitive tools used to support learning are discussed in more detail in Lin and Sullivan (2008) in this Handbook. Another type of tool, scientific visualization tools, has been found to be effective in helping students develop general inquiry abilities, acquire specific investigation skills, and understand science concepts and principles (Edelson et al., 1999). They are developed in a series of technology-supported, inquiry-based projects, called CoVis. These computer-based visualization tools combine the ability to manipulate data with the use of video displays and thus allow the learner to analyze large collections of real world quantitative data generated by the scientific community to examine patterns and relationships (Collins et al., 2000). Cognitive tools such as these allow students to perform more advanced activities and engage in thinking and problem solving in far more complex ways than they could do before (Bransford et al., 1999). The CoVis multimedia-based learning environment is discussed in more detail in Chan and van Aalst (2008) in this Handbook.

Accessing information resources: With the advent of the Internet, students can now access a vast amount of information on the Web, including real-time (e.g., weather information) and real world (e.g., census data) data, original documents, artefacts (historical documents), and expert information (Windschitl, 2000). The Web thus can be used by the learners as an inquiry tool to build ideas and construct knowledge. In fact, already in 1998, Web searching was the third most common use of computers in schools in the US (Becker, 2000). Although gathering information is the most common way for students to use the Web in schools, the learners often do not have the searching skills to locate relevant information, or the evaluation and critical reading skills to determine its accuracy and appropriateness. Kuiper et al., (2005) have identified and summarized four characteristics of the Web, which include (1) huge scope containing up-to-date general and specialized information, (2) easy access by students who are both information consumers and providers, (3) a hypertext structure, which is nonlinear and associative, and (4) having a visual character. They maintain that the nature of the Web requires its users to acquire information literacy skills to handle the Web critically for learning to occur while using it.

The term information literacy is commonly used to describe the skills needed to search, process, and critically evaluate the value of the information sourced from the Web. As most of the students do not possess these skills, they are not able to successfully use the information retrieved from the Web for inquiry or solving a problem (Kuiper et al., 2005). How learning activities should be designed to support the acquisition of these skills is a key question to consider. Simply encouraging students to surf the Web would achieve little, as it may result in information overload, or what Postman (1992) termed as *information chaos*. Postman (1992) maintains that it is more important for learners to reflect on the implications and consequences of the process of information gathering, than simply to acquire the skills to generate, retrieve, gather, and distribute information, in easier and faster ways. Similarly, Kuiper et al. (2005) suggest that searching for information on the Web should not be considered as an end to itself, but must be used as an inquiry tool in the context of inquiry activities to tackle challenging problems, and closely related to the school curriculum. Using a model, such as the resource inquiry model proposed by Nesbit and Winne (2003), may be useful to support self-regulated and inquiry learning, using networked resources. This five-stage model involves the following stages: (1) setting resource inquiry goals, (2) planning for resource study, (3) searching and select resources, (4) studying and assessing new knowledge, and (5) critiquing and recommending resources.

Despite the problems associated with using the Web as an information resource, there are many exemplar uses of the Web to support active construction of knowledge. For example, in the Union City Online project (http://www.ncrel.org/sdrs/areas/issues/

methods/technlgy/te8lk14.htm) (Honey et al., 1998), teachers developed Web-based curricula, using educational resources available on the Web. Students thus would be able to access up to date and authentic information from the Internet. In the CoVis project (Lento et al., 1998), Internet and Web resources were used to support science teaching and the formation of virtual learning communities. In addition, technology-intensive, network-supported curricular activities, called CoVis Interschool Activities, have been designed to enhance students' learning experience. These are long-term projects on geosciences, involving collaboration between students and volunteer mentors, which allow students to pursue research with the latest available data, collaborate with distant collaborators, or address an audience that students do not normally have contact with. Finally, the knowledge integration environment (KIE) (http://www.kie.berkeley.edu/) (Linn et al., 1998) is another example of using Web resources to support a learning environment, which facilitates students' understanding of science. KIE is supported by a variety of cognitive tools, and students are actively engaged in critiquing and questioning evidence gathered from the Internet, and organising evidence to construct arguments to support their theory.

Supporting the Reflective Process: A reflective process involves learners querying the implications of the incoming information, comparing it with their own experience, and creating links to their existing knowledge structures, so that new conceptual knowledge is formed and can be applied in different settings (Laurillard, 1995). In discussing self-regulated learning using networked resources, Nesbit and Winne (2003) suggest that online tools can facilitate reflection and self-monitoring. These tools include goal setting and planning tools, which link learning goals into a goal structure, resource repositories linking goals with resources, annotation tools for indexing, self-questioning, and summarisation, resource evaluation tools enabling learners to rate and comment on resources, and recommendation tools to recommend the resources for others to use. For many learning scientists, learning is a process of transforming novices into experts by developing their ability to reflect on their own thinking (Sawyer, 2006). Reflection takes time and effort, and has to be supported. Computers can be used to support the reflective process by making thinking more visible through prompting learners to articulate the steps they take in their thinking process, thus allowing students to control their learning pace, without which reflection is difficult to take place. Also, computers can create a record of thoughts, so that the learner can use it to reflect on their work and teachers to assess their progress (Sawyer, 2006; Kolodner, 2006). For example, in the KIE, briefly mentioned in the last section, cognitive tools have been developed to help make learners' thinking visible. The KIE cow guide, for example, provides conceptual hints, which guide students in investigating Web evidence in their projects. *SenseMaker* is another tool in KIE to allow students to organize their evidence conceptually and spatially to make their thinking visible (Linn et al., 1998).

There are other tools developed to support students' reflective process. For example, networked communal databases, created in projects such as the Knowledge Forum (Scardamalia and Bereiter, 2003), described later in this chapter, and CoVis (Edelson et al., 1999) can help students reflect on their actions and critique each other's thinking. Another example is learning by design (LBD) (http://www.cc.gatech.edu/

projects/lbd/). On the basis of case-based reasoning, LBD is a project-based inquiry approach where students learn by primarily constructing working physical objects like miniature vehicles (Kolodner, 2006). Authoring software tools such as Supportive Multi-User Interactive Learning Environment (SMILE) have been developed to support LBD students to document their design experience (called case libraries), as well as for others to learn from these cases. When students write up their experiences, they need to reflect on them, making connections, and organising them in a coherent way so that others will be able to understand. SMILE provides prompts and other scaffolding to assist students in this process. Research has shown that using and authoring case libraries such as LBD helps students learn (Kolodner, 2006).

Cognitive Tutoring: One-to-one tutoring has been shown to be more effective than one-to-many classroom teaching. For example, Bloom (1984) reported a general difference in achievement of two standard deviations favouring tutoring. Technology has long been expected to play a tutoring role, as shown in the early CAI applications, where the computer program is used as a tutor to help students acquire discrete facts and skills. As has been discussed, the learning outcomes from using these computer programs are far from satisfactory. The subsequent development of intelligent computer-assisted instruction (ICAI), or intelligent tutoring systems (ITS), while having the potential to deal with more complex domains, have not been widely used (Means and Olson, 1995). So little is known about their effects on learning. The more recent development of cognitive tutoring systems, however, is promising, as it is designed to support the process of problem solving and reasoning. For example, the widely used Cognitive Tutor Algebra (http://www.pact.cs.cmu.edu/index.html) has been designed based on an elaborate cognitive model of the user, and so far has been used by half a million of students for a total of about 20 million student hours. In 2004–2005, this program was used in 2000 high schools in US, and students using the Cognitive Tutor scored "twice as high on end-of-course open-ended problem solving tests and 15% higher on objective tests as students enrolled in a traditional algebra course" (Koedinger and Corbett, 2006, p. 62).

Supporting communication: The study of ICT-supported learning environments is increasingly informed by attention given to the interactive and communicative capabilities of ICT. Since the advent of the Internet, there has been a proliferation of online student exchange projects. Although there is variation in the curriculum focus, number of participants, and length of the project, most of these projects are similar to some aspects of the AT&T Online Learning Circles project. Began in the mid 1980s by Margaret Riel, Learning Circles were initially supported by the AT&T Learning Network, and since 1997, by iEARN (The International Education and Resource Network). A Learning Circle (http://www.iearn.org/circles/) is created for a period of 3–4 months by 6–12 classes, working on projects around a theme related to their curriculum. Students and teachers share ideas and work regularly in a virtual space by email and computer conferences to deepen their understandings of a certain issues or problems. Currently, there are themes including Places and Perspectives, Computer Chronicles, Global Issues, Society's Problems, Energy and the Environment, and Mind Works. At the end of the term, the group collects and publishes their work. The whole process goes through six phases: get ready, open circle, plan projects, share work, publish, and close circle. Learning Circles now connect students all over the world and lead to the development of learning communities (http://www.iearn.org/circles/lcguide/p.intro/a.intro.html). Examples of similar projects that aimed at investigating real world problems and tasks include the TERC network projects (e.g., the Star School project collects weather data and designs solar houses; the National Geographic Kids Network studies acid rain), Earth Lab (to study earth science) (http://www.terc.edu/aboutus/history), and the GLOBE project that we mentioned previously. It is evident from the evaluations of these projects that they are motivational and engaging (Means and Olson, 1995).

Other research has investigated the effects of online communication on writing (Fabos and Young, 1999; Salomon et al., 2003), with the expectation that it will provide a supportive writing context where writing is transformed into a social act of communication, as students are writing to a real audience when participating in these exchange projects. It is also argued that online communication will enhance the writing process, with students writing more informally and proficiently. In addition, it has the potential to be used as tool for cultural understanding. Unfortunately, Fabos and Young (1999) after having conducted an extensive review on the effects of telecommunication exchange projects concluded that many of the expected benefits are "inconclusive, overly optimistic, and even contradictory" (p. 249). A more recent review by Salomon et al. (2003) on the effects of using technological tools to support writing arrived at similar conclusions.

Supporting the social process and community building: The recent development of the so called *social software* (e.g., blogs and wikis) and Web 2.0 is a recognition of the importance of the social process in supporting learning. Computer-supported collaborative learning (CSCL) is a field of study focusing on how people can learn together with the use of computers. For example, the recent work undertaken by Stahl (2006) demonstrates how students collaborating online on solving math problems can construct group knowledge exceeding the knowledge of individual group members (CSCL will be discussed in detail in Arvaja et al., in this Handbook). Extensive research has also been conducted on the effectiveness of the Knowledge Forum (http://www.knowledgeforum.com), an environment designed to support knowledge building communities, previously known as Computer-Supported Intentional Learning Environment (CSILE) (Scardamalia and Bereiter, 2003). The Knowledge Forum functions as a collaborative environment and a communal database, with text, graphics, and video capabilities. This knowledge-building environment provides a shared workspace to supports idea development and collaborative knowledge building. Students in this networked multimedia environment contribute ideas relevant to the topic under study in *notes* for other students to comment upon, leading to dialogues and shared understanding. These ideas are systemically interconnected, and deeper understanding is gained through exploring these interconnections. Tools are provided in the environment for the learners to revise, critique, build on, reference, organize and *rise above* their own ideas, as well as ideas of other members of the community. More detail about the Knowledge Forum is found in Chan and van Aalst (2008) in this Handbook.

Conclusion

This chapter aimed at providing a general overview of how ICT has been used to support learning, within the context of the changing conceptions of learning. Although a range of promising and effective applications and tools have been described to provide examples of the different ways technology can be embedded in learning environments underpinned by learning principles drawn from learning sciences research, it should be noted that overall the use of ICT in the classroom has been rather limited. The exemplar works described in this chapter have nearly all been conducted as small-scale projects. When conducted in classrooms, they were also directed and sometimes even taught by the researchers involved in the project. How these successful projects can be sustained and scaled up so that robust computer-supported learning environments can be used equitably by students on a wider scale is a key issue to consider in the future. This also brings up the important issue of how the classroom culture can be changed in response to the use of technology to support learning (Windschitl, 2000), as well as how ICT can *work out* in practice (Selwyn, 2000).

This overview chapter has also provided evidence that the research focus of ICT in education has been changing, and increasingly attention has been given to the learner, rather than to the technology. Also, there is a better understanding that technology should not be driving pedagogy. However, after more than 30 years of using computer technology in the school system, and a wealth of research has been gathered on its effects on learning outcomes, we have to admit that we do not know much about what actually occurs to the learner during the learning process, when technology is used to support such a process. As suggested by Windschitl (2000), it is perhaps more fruitful for researchers to dig deeper with regard to what happens to the learner during an ICT-supported learning activity, rather than just measuring its learning outcomes. This approach is more likely to reveal why a certain computer-supported learning environment is more effective than others. This is in line with Selwyn's (2000) call for the need for rigorous qualitative research focusing on *what does happen*, and a challenge from Maddux (2003) to educational technology researchers to be more robust in their research, as there is also a concern about the quality of educational technology research and what can be considered as evidence.

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3.2

INTERACTIVE LEARNING ENVIRONMENTS: REVIEW OF AN OLD CONSTRUCT WITH A NEW CRITICAL TWIST

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Introduction

There is no real consensus or agreed conception of what the domain of interactive learning environments encompasses. To clean up this messy construct, an overarching framework is proposed for understanding the competing dimensions and the interconnecting metaphors of human cognition. This new twist of an old construct argues that it is dangerous to adopt single metaphor solutions of learning and naive to assign interactive potential to the features of new digital technology without a deeper consideration of pedagogy. In this regard, the chapter is extended by a critical pedagogical approach that goes beyond narrow psychological conceptions of technology and the learning process. At a deeper level, the case is made for a more enduring interactive digital culture aimed at producing critical thinkers, critical consumers, and critical citizens.

Origin of Interactive Learning Environments

The precise origin of the domain of interactive learning environments is difficult to trace. Although the notion of interactivity tends to evoke images of new digital technology, the concept of interactive learning stretches back into the roots of human civilization. Thus, we need to think beyond the latest enthusiasm for interactive whiteboards, as there is more to this concept than the touch of an electronic screen.

Arata (1999) makes the point that Aristotle first introduced the concept of interactivity. More recently, John Dewey was a strong advocate of *learning by doing* where students develop understandings through active experience. In contrast to the

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dominant theory of behaviorism, the progressive movement believed that learning was about interactive participation rather than passive transmission of information to mere spectators (Dewey, 1938). This movement was the early seeds of the theory of constructivism, where learning is an active process of knowledge construction. There are many different faces of constructivism, but in a broad sense this theory claims that learning is an active and meaningful process, preceding by and through conversations (Jonassen, 2000; Jonassen et al., 1999). A socio-cultural blend of constructivism goes even further by claiming that learning is mediated by the use of language, tools, and the production of external artifacts leading to the construction of new understandings (Crook, 1994).

The computer is an important learning tool in the mediation process. In the context of computers, the concept of interactivity has been commonly associated with hypertext. That is, the term coined by Theodor Nelson in the 1960s refers to nonsequential writing, allowing choices to the reader (Grabe and Grabe, 1998). With the advent of multimedia in the 1990s, the idea of hypertext became known as hypermedia when dynamic hot links could be read and explored off an interactive screen. Multimedia first through the increased capacity of CD-Roms and later the rapid growth of the World Wide Web (WWW) created many new possibilities for human–computer interaction.

The concept of interactivity is also linked closely with the emergence of the field of artificial intelligence (AI). In 1970s, new ideas about human–machine interactions began to influence how software tools could be used to support the learning process. Through the incorporation of AI techniques, a number of tools were developed as partners to extend human intelligence (Salomon et al., 1991). For example, the development of Logo™ arose out of the work of Papert and colleagues associated with the Artificial Intelligence Lab at MIT. The basic premise of Logo™ was that young children could develop advanced cognitive and metacognitive skills by learning how to program a computer. This was a new kind of experience where in learning how to teach a turtle how to think, children embarked on an exploration of how they themselves think (Papert, 1980).

Logo™ did not transform the learning environment as Papert envisaged, while the theory of constructionism (Harel and Papert, 1990), a subtle and original variation of Piaget's version of constructivism, became a central metaphor. In short, constructionism is the idea of *learning by making*, but Harel and Papert (1991) stress the point that the theory is richer, deeper, and more multifaceted than conveyed by this popular catechism. They explain that constructionism – the N word rather than the V word – adds 'the idea the learner is consciously engaged in constructing a public entity' (Harel and Papert, 1991, p. 1).

In this sense, the difference between instructionism and constructionism was more than a binary split in the way of thinking about learning, but a fundamental difference in the *nature of knowledge* and the *nature of knowing*. It represented a major change in understanding the nature of interactivity and how people could learn with technology.

What is the Domain of Interactive Learning Environments?

A brief account of the origin of the concept does not answer the question: What is the domain of interactive learning environments? This is not an easy question to answer, as the domain is still an ill-defined field of study. The increased computational power of new digital technologies, coupled with contemporary developments in learning theory, has created even further branches to the original concept. Indeed, the domain has refaced and become increasing fragmented in the new digital landscape with many different guises. In short, interactions can be of many types. The forms of interactivity tend to be as diverse as working through an intelligent tutoring system (ITS) to new distributed forms of learning, using a learning management system (LMS). What the growth of new digital technology has done is expand the focus of the domain beyond some of the pioneering work.

The truth is that there is no singularly agreed definition of the domain of interactive learning environments. In the subcategory of *technology* under on the *eLearning Reviews* Web site, an interactive learning environment is defined as software for educational purposes, for supporting the learning process where the focus is on learning through the interaction with the computer (The Swiss Centre for Innovations in Learning, 2006). Notably, the terms *interactive learning environment* and *educational software* are used interchangeably.

In this definition, the importance of human–human interaction is understated, and the concept of interactivity does not extend to distributed and virtual worlds. Rather the so-called *object world* is described by traditional synonyms, such as computer-assisted instruction, computer-assisted learning, computer-based learning, computer-based training, computer-supported learning, and educational software.

Arguably, a fuller description of the domain, inclusive of both object and virtual worlds, is found in the academic journals within the field. For example, *The Journal of Interactive Learning Research* [ISSN 1093-023X] published by the Association for the Advancement of Computing in Education claims to accept papers related to the underlying theory, design, implementation, and so on, of the following interactive learning environments:

> [A]uthoring systems, cognitive tools for learning, computer-assisted language learning, computer-based assessment systems, computer-based training, computer-mediated communications, computer-supported collaborative learning, distributed learning environments, electronic performance support systems, interactive learning environments, interactive multimedia systems, interactive simulations and games, intelligent agents on the Internet, intelligent tutoring systems, micro worlds, virtual reality based learning systems (Association for the Advancement of Computing in Education, 2005, p. 2).

In describing the scope of the journal, each of the terms in the title are carefully explained with the term *interactive* referring to the key presence of a computer within the learning environment. More specifically, Reeves' (1999) explains that a learning environment is *interactive* in that a person can navigate through it, complete challenging tasks, and collaborate with others.

In terms of learning, Reeves (1999) states this concept has evolved over the last century, and the journal adopts an inclusive definition ranging from the development of mental states and abilities to problem-solving and higher-order outcomes such as intellectual curiosity and lifelong habits of learning.

However, even this all-encompassing definition is open to critique. In the above quote, strong emphasis is placed on individual cognition at the expensive of networked learning where attention is given to the connections between learners. The concept of *networked learning* is an example of a recent branch of the root domain of interactive learning environments, which recognizes the socio-cultural nature of the learning process (Steeples and Jones, 2001). Since the development of the Internet, this concept has established a strong foothold in the literature and networked learning focuses on connections with people and information and collaborations that support one another's learning (Wikipedia, 2007).

When taken as a whole, the domain of interactive learning environments is evolving and wide ranging, as it encompasses a number of subdomains of learning and technology. Some of these subdomains are still emerging, whereas others have become virtually obsolete. It is noteworthy, for example, no entry exists in Wikipedia for the term *interactive learning environments*. The key point is that many people are using different terms to describe the broader domain, and there is no real consensus in the literature. As the recent example of networked learning illustrates, new subdomains now rival and challenge traditional definitions of interactive learning environments. Indeed, the term *environment* has taken new meaning with the growth of virtual learning communities and some of these subdomains arguably compete as domains in their own right.

Although this linguistic analysis has its limits, and should not distract from the bigger picture of interactive learning, the final word is left to the journal of the same name. Founded in 1990, *Interactive Learning Environments* [ISSN1049-4820] is a peer review journal that publishes articles on all aspects of the design and use of interactive learning environments in the broadest sense. In describing the relevant domains of application from learning theory to all kinds of electronic teaching, four specific themes are identified: individual learning, group activity, social and organizational issues, and courseware. Although each of these themes is elaborated on under the aims and scope of the journal, the publisher acknowledges that "the field of interactive learning environments is developing and evolving rapidly" (Taylor and Francis Group, 2006, p. 1).

Thus, the question of "what is the domain of interactive learning environments?" is likely to be always difficult to answer as studying the field of technology and the learning process is like learning to fly a plane while still being built (Strudler, 2003). However, like aviation the domain of interactive learning environments has a long history and as knowledge of learning and the application of technology for educational purposes has expanded, so too has the conception of this domain. The common theme is that both the plane and new digital technology share an interest in flying toward the horizon.

What Assumptions Underpin Instructional Design?

Although the idea of interactive learning environments is useful, it is problematic to present a concise and widely accepted definition of the domain. Instead, it is more fruitful to understand some of the core assumptions that underpin the principles of instructional design. In this context, the term *instructional design* refers to the process used to intentionally plan learning experiences that are appropriate to learners (Norton and Wiburg, 1998). Although there is a danger of oversimplification, assumptions about the instructional design of interactive learning environments fall within two main theoretical schools of thought: a techno-centric and a human-centric perspective.

A techno-centric perspective focuses on structural elements of software and the design of computer systems that contribute to different kinds of human–computer interaction. These tend to be highly specialized applications giving students greater interactive support. Richards (2006) describes this techno-centric viewpoint as tending to focus on the design of technology-mediated repositories for content, for learning objects, or for basic drill and practice. Although this interpretation does not recognize the full breadth of interactive technology, such as micro worlds, intelligent agents, and virtual reality, the basic premise is that designers adopt abstract and theoretical principles of instructional design with little consideration of the context in which their solutions will be used. For instance, those developing new instant response systems popularly known as *clicker technology* may have little understanding of the needs and requirements of teachers in integrating these devices into the learning environment. In other words, the gap in the instructional design process is the failure to take into account how teachers intentionally plan and students respond to different learning experiences.

In contrast, a human-centric perspective takes more account of the social context of learning. It recognizes that the whole culture of the learning environment can affect learning in important ways (Salomon and Perkins, 1996). Thus, this perspective addresses some of the contextual factors rarely envisaged by the system developers. Though often sophisticated, the designers of such systems usually give insufficient consideration of the "wider modes of use and classroom support and the changing styles of teaching/learning that might ensue" (Akpinar and Hartley, 1998, p. 51). A human-centric view is grounded, therefore, within the realities of pedagogy rather than the theoretical design of technology per se. In the case of clicker technology, teachers have to plan how to manage a set of remote devices in a busy classroom and anticipate how students might choose to use them to subvert the learning intentions. For instance, a disruptive student can attain even greater attention by selecting inappropriate responses to an item bank of questions on a large screen. Such contextual factors can rightly lead to pedagogical decisions not to employ certain technology.

The key point is that a tension exists between those who adopt relatively narrow conceptions of design focused on technological systems, architecture, and human–computer interface and those who gravitate more toward the role and implementation of computer tools in educational contexts (Richards, 2006). Although these two perspectives are often treated polemically, appearing at different ends of a design continuum, they are not mutually exclusive. After all, new interactive technology, such as *clickers*, affects the design of the learning environment by creating opportunities for learning not possible by other means. However, equally the way people decide to employ clicker technology affects how it is used for educational purposes.

Such polarization is unhelpful. Instead a dialogical framework is required in answering the basic design questions of (a) deciding on the foundations of learning, (b) choosing appropriate contents, (c) choosing appropriate tools, and (d) choosing appropriate activities and related assessment tasks (Norton and Wiburg, 1998). A framework that promotes reciprocity and steers a delicate balance between these two perspectives is one of the major challenges still facing the domain of interactive learning environments.

Although reconciling the competing instructional design perspectives may be an ambitious goal, Merill (2002) asks the question: Do these design theories and models have fundamental underlying principles in common? In analyzing a number of approaches to design, he draws on Reigeluth's (1999; cited in Merill, 2002) distinction between two kinds of instructional methods: basic methods and variable methods. Merill prefers to call basic methods as *first principles* of instruction. His premise is that a set of first principles is evident in most instructional design theories and models, and even though the language used to describe them might differ between theorists, most would agree that these principles are necessary for effective learning (Merill, 2002). There are five first principles:

Principle 1 – Problem-centered: Learning is promoted when learners are engaged in solving real-world problems
Principle 2 – Activation: Learning is promoted when existing knowledge is activated as a foundation for new knowledge
Principle 3 – Demonstration: Learning is promoted when the instruction demonstrates what is to be learned and when new knowledge is demonstrated to the learner
Principle 4 – Application: Learning is promoted when learners are required to apply their new knowledge or skill to solve problems
Principle 5 –Integration: Learning is promoted when learners are encouraged to integrate (transfer) the new knowledge or skill into their everyday life

According to Merril (2002), problem-centered instruction is common to most of the theories and models. This reflects much of the current work in cognitive psychology, where it is claimed that students learn more effectively when engaged in solving problems (Mayer, 1992; cited in Merril, 2002). The idea of problem-centered instruction is well represented in the literature, as evidenced by Jonassen's (2004) influential work on the different kinds of problems for designing interactive learning environments. He argues that learning to solve problems is the most important life skill, and "problem-based learning may be the most significant innovation in the history of education" (Jonassen, 2004, p. xxii).

Cutting across these spheres are two broad perspectives of instructional design – the techno-centric and human-centric – that have yet to form a truly dialogical relationship. Although Figure 1 shows the gap that exists between the perspectives, they are anchored within a set of common principles, which revolve around problem-centered

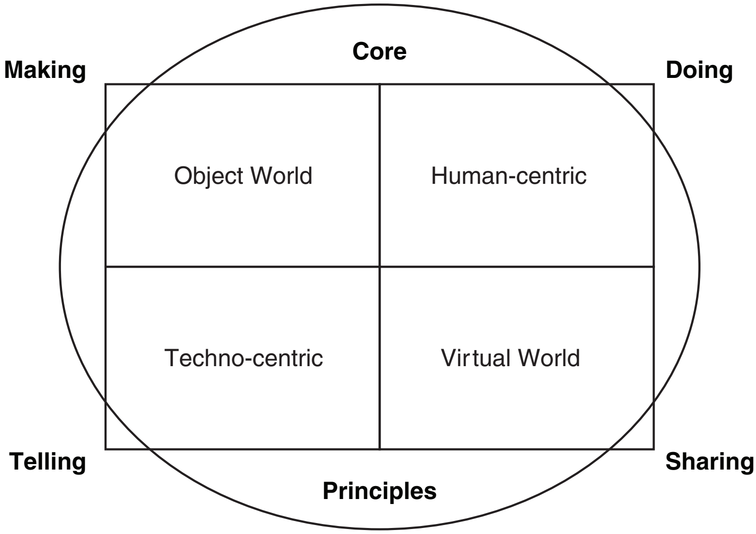

Fig. 1 Domain of interactive learning environments

learning and in particular the theoretical tradition known as constructivism (Jonassen et al., 2003). This tradition is built upon the central metaphors of the old idea of *learning by doing* and the new concept of *learning by making*, and even more recently *learning by sharing*, which is in stark contrast to *learning by telling* – that is, the instructionism of traditional behaviorism.

Digging a Little Deeper

On the surface, the above mentioned synthesis of the literature is useful. However, the conceptual elegance of Figure 1 does not tell the full story. There is a false dualism between behaviorism and constructivism, as no single comprehensive theory exists that covers the four key dimensions of human cognition: (a) the individual nature of cognition, (b) the social nature of cognition, (c) the situated nature of cognition, and (d) the distributed nature of cognition. Indeed, depending on epistemological point of view, it could be argued that there is unlikely to be one constructed or agreed upon learning theory. Even Jonassen (2003), possibly the staunchest proponent of constructivism, acknowledges this point.

The current ascendancy of constructivism, irrespective of the particular variation, in the design of interactive learning environments should not be accepted at face value. Although the 8 key principles of cognition and learning proposed by Salomon and Perkins (1996) and the 14 principles of a learner-centered framework for e-learning offered by McCombs and Vakili (2005) show that there is convergence of a large part on the basic tenets that form the constructivist tradition, we do not have absolute answers. Moreover, the consequences of constructivism for teaching and the use of technology are not clear-cut, and there is considerable debate as to how they should be implemented in both object and virtual educational settings (Dalgarno, 2001).

In a broad sense, the divergence of opinion falls into two schools of thought: social constructivism and psychological constructivism (Richardson, 2003). The first is concerned with epistemology, and the second focuses on development and learning theory. However, it is difficult to separate the two types, and Dalgarno (2001) describes three pedagogical and epistemological interpretations of constructivism that overlap these categories. Radical or naïve constructivists emphasize the individual nature of each learner's knowledge construction processes and suggest that knowledge can only be known by the individual. Moderate constructivists more willingly accept that knowledge exists independent of the individual and situated context but instruction should engage learners in problem solving activities that allow them to construct knowledge they can apply to personally meaningful tasks. A third view argues that learning occurs through meaningful problem solving, but that learners require *scaffolding* provided by teachers, experts in the field, and by collaboration with peers. This latter view of constructivism is often closely associated with a socio-cultural learning perspective, although this perspective and the idea of learning by sharing have their own well-developed body of literature.

In a similar taxonomy, Moshman (1982; cited in Dalgarno, 2001) describes the different interpretations of constructivism as *endogenous*, *exogenous*, and *dialectical*, and all three of these categories exist within the techno-centric and human-centric conceptions of interactive learning environments.

Despite this finer level of analysis, there is more to this story. On last count, Phillips (1995) identified over 30 blends or variations of constructivism. Put bluntly, constructivist theory is a messy construct. It attracts a collection of different viewpoints under the one umbrella that has rightly been subject to serious criticism (Bowers, 2005). There is a fundamental problem of what people really mean when they talk about constructivism.

Despite this, the academic debate over constructivism has struggled to dislodge many of the popular catechisms within the discourse of the teaching profession. Indeed, psycho-pedagogy – pedagogical approaches based on popular ideas – has increasingly become part of the rhetoric as evidenced by the current personalized learning movement (Burton, 2007). According to Burton (2007), insufficient skepticism and a superficial reading of psychological ideas has led to psycho-pedagogic approaches becoming dangerously self-referential.

In reality, constructivist methods are very time consuming, there is no guarantee that students will discover what you want them to find out, and rather than help learners construct new knowledge, the teacher often needs to deconstruct existing knowledge (Richardson, 2003; Wen and Tsai, 2003; Winn, 2003). Moreover, constructivism is not the only cognitive perspective demanding a place in the sun. Add the growth of interest around metacognition, brain functioning, learning styles and multiple forms of intelligence, along with the literature on communities of practice (CoP), and the ground becomes very shaky indeed. For people trying to understand the domain of interactive learning environments, it seems like an incomprehensible jigsaw of competing metaphors, contradictions, and paradigm shifts.

Connecting the Metaphors

This section attempts to connect and fit together the different learning metaphors. Sfard (1998) argues that a clearer view of learning is possible by *digging* out the root metaphors that underlie both popular conceptions and scientific theorizing of human cognition. By concentrating on the root metaphors, rather than on specific theories, Sfard contends that light can be shed on the fundamental assumptions underlying our theorizing of learning. Such an approach has merit in helping to clean up the ill-defined and messy nature of the literature surrounding the domain of interactive learning environments.

A quick analysis of the current discourse on learning, Sfard (1998) continues, is enough to realize that contemporary thinking is caught between the *acquisition metaphor* and the *participation metaphor*. Although the metaphors are not equivalent to any single theoretical conception of learning, Sfard argues that any theory may be classified as *acquisition-orientated* or *participation-orientated* if it discloses a clear preference for one of the metaphorical ingredients over the other. For example, any learning theory – behavioral, cognitive, or constructivist – that focuses on the acquisition of knowledge and development of concepts, by either passive reception or an active and constructive process, can be conceptualized in terms of the acquisition metaphor (Sfard 1998). This view of learning embodies the idea that knowledge is a property of the mind, and the individual is the basic unit of knowing (Paavola et al., 2004). Paavola and Hakkarainen (2005) explain that this approach views the mind as a container of knowledge but learning can still be seen as an active process that fills the container.

In contrast, the participation metaphor views learning as a process of participation in shared learning and cultural practices rather than something that merely happens inside the head. The learner becomes a member of a community by gradually moving from peripheral to full participation, and in so doing acquires the skills to communicate and act according to its socially negotiated norms (Sfard, 1998). This view of learning focuses on *knowing* and not so much on knowledge in the traditional sense (Paavola et al., 2004). Paavola and Hakkarainen (2005) explain that knowledge is an aspect of participation in cultural practices, and thinking and knowing are distributed over both individuals and their environments. Within the participation metaphor, learning is located in networks of distributed activities and is a social process of knowledge construction and enculturation.

To summarize, the acquisition metaphor represents a *monological* view of learning, where important things happen within the human mind, whereas the participation metaphor represents a *dialogical* view, where the emphasis is on interaction with culture, other people, and the surrounding environment (Paavola et al., 2004). The latter view embodies a number of different perspectives on the nature of the dialogical relationship between culture, people, and environment.

The key point that Sfard (1998) emphasizes is to make progress in understanding learning, with or without technology, familiarity, and appreciation is required of both metaphors. Each has something to offer that the other cannot provide and relinquishing either may have grave consequences. Sfard (1998) argues that educational practices have a propensity for extreme recipes, and the trendy mix of constructivist approaches has often translated into a total banishment of teaching by telling. The truth is that no two students have the same needs and because teachers arrive at their best performance in different ways, "theoretical exclusivity and didactic single-mindedness can be trusted to make even the best educational ideas fail" (Sfard, 1998, p. 11).

The lesson is that one metaphor is not enough. The idea of a plurality of metaphors is reflected in the work of a number of writers (Dede, 2008; Mayer, 2004; Roblyer et al., 2003). Sfard makes a case for viewing the acquisition metaphor and the participation metaphor as mutually complementing discourses. According to Sfard (1998), we need to accept the fact that even though the metaphors we use are good enough to describe subfields and small projects, none of them suffice to cover the entire field. By analogy, Roblyer et al. (2003) note, "like the blind man [person] trying to describe the elephant each focuses on a different part of the problem and each is correct in limited observations" (p. 54). A strong case exists for connecting the metaphors to better understand the full range of possibilities that technology affords.

However, another metaphor can be added to the mix. Paavola et al. (2004) argue that there is a need to include a *knowledge creation* metaphor. This metaphor proposes a *trialogical* approach where learning is a process of knowledge creation by which common objects of activity are developed collaboratively through mediated processes (Paavola and Hakkarainen, 2005). In this sense, learning focuses on interactions through these objects of activity – not just between people or within the mind. According to Paavola et al. (2004), a good example of the knowledge creation metaphor is the *Knowledge Forum*, where there is a deliberate effort to advance communal knowledge and restructure schools as knowledge-building communities (Scardamalia and Bereiter, 1994). Bigum (2003) promotes a similar view in claiming that new digital technology needs to be located in knowledge producing schools. In sum, a *trialogical* approach goes beyond the emphasis on individuals and the need to *acquire* knowledge, or on community and the need to *do* or *know* something, by concentrating on solving problems, producing new thoughts and objects, and advancing communal knowledge through collaborative inquiry.

Cleaning Up a Messy Construct

To summarize the discussion thus far, the domain of interactive learning environments is broadly defined and open to many interpretations. Some common principles emerging from the literature on the design of interactive learning do not tell the full story; the study of human cognition remains open to conjecture and learning is a messy construct. Moreover, constructivist theory suggests that there is a single metaphor solution to the problem of learning when one metaphor is not enough to explain the complexity of human cognition. Although research has given rise to some consensus of what we know about learning and the learning process, the synthesis of evidence provides no recipe (Bransford et al., 1999). A more complete understanding of the learning process requires a dialogical (and trialogical) approach in which the acquisition, participation, and knowledge creation metaphors are viewed as both competing and mutually complementing discourses.

This form of border crossing fits neatly Bransford et al. (1999) major synthesis of the literature in which they argue that much of what has been learned about human cognition can be accommodated and melded together by designing learning environments, which feature four perspectives – that is, environments that are *student-centered*, *knowledge-centered*, *assessment-centered*, and *community-centered*.

They argue environments that are learner-centered are consistent with the evidence suggesting that students use their current knowledge to construct new knowledge and that what they know and believe affects how they interpret new information. They add, however, that effective learning environments must also be knowledge-centered (Bransford et al., 1999). Attempts to teach thinking skills without a strong base of factual knowledge do not promote problem-solving ability or support transfer to new situations. Rather the ability to think and solve problems requires well-organized knowledge that is accessible in appropriate contexts. They also argue that learning environments must be assessment-centered (Bransford et al., 1999). Feedback is fundamental to learning. Along with summative assessment, formative feedback is needed to provide students opportunities to revise and improve the quality of their thinking and learning. Finally, Bransford et al. (1999) argue that learning environments must promote a sense of community in which people learn from one another and continually attempt to improve. They extend the notion of community to the broader community outside of the school and include connections to families, content area experts, and so on. Ultimately, they argue these perspectives must be conceptualized as a system of interconnected components that mutually support each other.

The point to be made is that rather than arguing one learning perspective, one teaching approach, one instructional design model, or one metaphor is better than another, there is growing recognition that a variety of methods and perspectives are appropriate (Sfard, 1998). Indeed, the implication is that each has an important place, which contributes to the interconnectedness of the whole. In this sense, rather than the perspectives being in competition their differences become complimentary. Thus, the relationship between the different learning theories and perspectives cannot be encapsulated on a simple linear dichotomy from behaviorism (teacher-centered instruction) to constructivism to socio-cultural theory (learner-centered instruction).

With this in mind, an overarching framework is proposed to synthesize the literature on instructional design and clean up the messy construct of learning in the context of new digital technologies. This new twist of an old construct aims to weave together the commonalities and make explicit the tensions between the different learning perspectives. It does not see them on a linear axis but rather seeks to understand the nuances of each perspective and locate these within a larger dialogical framework. In this sense, a dialogical approach recognizes that theories are not stable or fixed, impervious to change, and that true insight occurs in the tension and interface between voices in a dialogue (Wegerif, 2006).

The framework is anchored within the acquisition, participation, and knowledge creation metaphors that underpin a more eclectic understanding of learning. Figure 2 illustrates how the three root metaphors interact and connect with a number of other theories and perspectives. At the core of learning is Bransford et al. (1999) four interlocking student-centered, knowledge-centered, assessment-centered, and

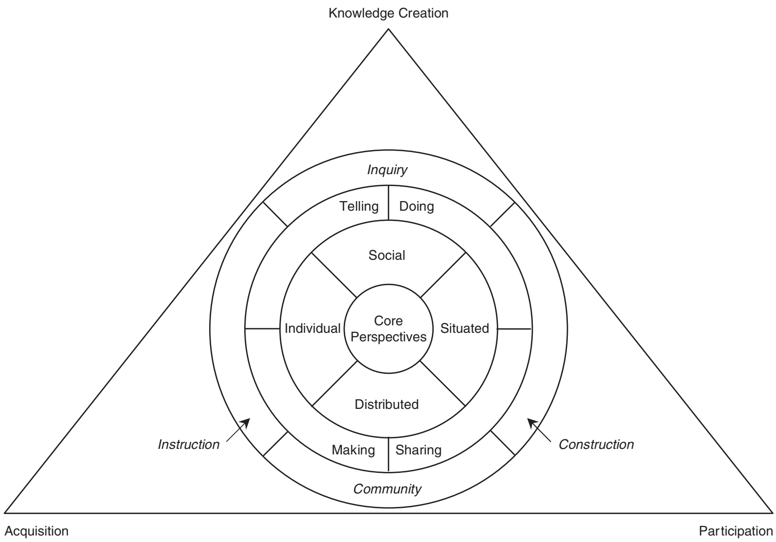

Fig. 2 Spinning the metaphors of learning

community-centered perspectives. The four key dimensions of human cognition – individual, social, situated, and distributed – surround these perspectives and operate on a rotating pinwheel that can revolve according to the tools, teaching techniques, and specific learning experiences.

On the outer layers of the inner circle, a dialogical relationship is recognized between techno-centric and human-centric models of instructional design as illustrated by the dynamic between learning by telling, doing, making, and sharing. Finally, using Jonassen's (2000) concept of *mind tool*, these four approaches to learning are overlaid within a new framework incorporating four categories of technology use across both object and virtual worlds: (a) mind tools for instruction, (b) mind tools for construction, (c) mind tools for inquiry, and (d) mind tools for community. Like the approaches to learning, these categories sit on an independent pinwheel that can spin freely depending on the nature of the task and pedagogical assumptions. A real strength of the instruction, construction, inquiry and community (ICIC) taxonomy is that each mindset can be spun and repositioned to align with the appropriate metaphor. Together these dynamic and interdependent pinwheels, set within a larger framework of the root metaphors, offer a combination of possibilities when researching, thinking about, and designing instruction within the domain of interactive learning environments.

Mind Tools for Instruction

The use of mind tools for instruction embodies a number of possibilities. On the one hand, the focus may be on the acquisition of knowledge by the individual through passive forms of electronic instruction. This might involve students working on their own through an integrated learning system or using a new learning object to understand an important concept. Thus, when used in this manner the mind tool helps to promote individual cognition within a knowledge-centered and/or assessment-centered perspective that best fits the acquisition metaphor. On the other hand, teachers may use the same software for very different purposes, a point not acknowledged in many existing taxonomies of technology. For example, a group of students may be exploring a digital learning object in preparation for hands on activity in which they need to build an electrical circuit. In learning by *doing*, the students are participating around the mind tool with an emphasis on social cognition from a student-centered perspective. The key point is that mind tools for instruction can support an *information banking* conception of learning but can also lay the foundation for problem-centered learning consistent with Merril's principles of instructional design.

Mind Tools for Construction

The use of mind tools for construction is where students build their own knowledge by engaging in meaningful problem-solving activities. This might involve a project approach following the principles of a "hyper composition design model" (Grabe and Grabe, 1998), where small teams produce a digital video on a local issue. This kind of learning by *making* probably fits the participation metaphor and promotes both social and situated cognition within a student-centered perspective. Yet, the same type of mind tool construction activity can be used in accordance with the acquisition metaphor. Students may be required to do a multimedia project on a class theme and share their results using PowerPoint™. Even though students personally construct the information from a number of sources, this kind of task may be very knowledge-centered with an emphasis on individual cognition. The lesson is that the pedagogical context defines whether the mind tool activity aligns with the acquisition, participation, or knowledge creation metaphor.

Mind Tools for Inquiry

The use of mind tools for inquiry might involve students conducting critical internet-based investigations. They could use the Web to research a genuine problem or controversial issue and then publish their findings for a wider audience. In the process, they might debate the issue, reflect upon the evidence, and consider which strategies are best for getting specific information. Conflicting information from a variety of sources will require students to determine which ones are not only factual, but also trustworthy. Thus, the emphasis is on *knowing* as opposed to the acquisition of factual knowledge. It follows that this kind of activity falls under the participation metaphor but potentially from a knowledge-centered perspective, as there are elements of individual and situated cognition. In contrast, as a mind tool for inquiry, the Web can be used for very different types of investigations. Teachers can use Webquests for narrow investigations of topics in which the focus is on students acquiring a set of facts. Although these basic facts may be crucial for a more demanding activity still to come, this example fits the acquisition metaphor from an individual cognition and assessment-centered perspective. Once again, the pedagogical context of the activity shapes that metaphor which best describes the nature of the learning.

Mind Tools for Community

The use of mind tools for community affords opportunities for distributed relationships where students can learn from other people without geographical constraints. For example, a class might join an online environmental education network as they study their local river system in the wider context of pollution and global warming. In so doing, the students may form intellectual partnerships with experts in the field where in discussing their results in a wider community, they engage in thinking processes not possible through conventional methods. This type of networked learning recognizes that human intelligence is distributed across culture, and expertise is rarely the preserve of single individuals. It follows that the activity fits under the knowledge creation metaphor and community-centered perspective in which the emphasis is on social and distributed forms of cognition. At the same time, using mind tools for community can take on a very different meaning if students merely participate in *keypal* activities. Although the Internet opens up a new world of connectivity for the exchange of ideas between people, such activities may do little to foster genuine communities of practice. In other words, online learning activities beyond the classroom may still come under the acquisition metaphor if the main emphasis is on enhancing individual cognition, even though there is a strong community perspective.

In summary, this overarching dialogical framework helps to provide a more complete map of the unstable terrain of human cognition. It illustrates the messy nature of learning and highlights the inadequacies of single metaphor solutions in the context of new digital technologies. This is the major contribution of the framework for teachers, teacher educators, and researchers currently locked in a narrow constructivist view of learning where direct instruction has become unfashionable. The proposed ICIC taxonomy, pinned and revolving around a much larger conceptual framework, serves to explain the raft of learning opportunities afforded by technology. Although the framework does not offer an easy roadmap for learning, this new twist of an old construct provides a useful dialogical way of thinking about the domain of interactive learning environments, steeped in deep thinking and rich understandings of the learning process.

Interaction for What Kind of Future

Putting a different spin on learning has its limits, as a critical twist still needs to be added to the mix. At a far deeper level, different interest groups and stakeholders to legitimize the use of technology for very different ends have borrowed the language of the so-called new ways of learning. The popular catechisms of learning have arguably become code words and a discourse of persuasion for competing economic and vocation rationales, linked to the rhetoric of the new knowledge economy. As President Bill Clinton once stated:

> Frankly, all the computers and software and Internet connections in the world won't do much good if young people don't understand that access to new technology means… access to the new economy (cited in Cuban, 2001, p. 18).

Codd (2005, p. xv) writes, economic objectives appear to have replaced citizenship as the primary political purpose of public education. The lesson is that the domain of interactive learning environments is now infected by the ideological language of a kind of "enterprise pedagogy" – that is, the celebration of innovation, entrepreneurship, and learning for the real (unjust) world (Brown, 2005a). More sophisticated psychological frameworks that go beyond single metaphor solutions do not take into account the moral, ethical, and political dimensions of pedagogy that underpins teachers' work. As Bruner (1973) minds us, a theory of instruction is a political theory and those who formulate pedagogy without regard to the wider educational context merit being ignored.

The key point is that considerations of learning need to go beyond self-referential psychology by taking into account the political economy of knowledge (Burton, 2007). In other words, teaching is inherently political work involving individual and collective judgments about what is worth teaching, why and how (Brown 2005b). Thus, the missing question in the literature is: What type of interactive learning environment for what kind of future?

This question recognizes that participation in knowledge creation communities may do little to produce critical thinkers, critical consumers, and critical citizens. After all, communities of practice can be very conforming and may simply encourage groupthink. A more critical interactive digital culture is required that moves thinking away from future technological innovations to future generations. An emphasis on the type of digital culture that we might want to create for our children, their children, and so on is the missing link if education *for* critical citizenship is to be brought to the forefront of discussion.

Conclusion

This chapter attempts to persuade readers that the domain of interactive learning environments is far more complex than typically understood. It has a long history and the concept of interactivity can incorporate a raft of perspectives with different assumptions that lead to different ends. Although the theory of constructivism has been particularly influential, it has not been entirely helpful and remains a messy construct. To clean up the domain of interactive learning environments an overarching dialogical framework was proposed for understanding the competing metaphors of human cognition, along with the learning possibilities afforded by new digital technologies. In moving beyond single metaphor solutions of learning, the framework provides a way forward with a much richer and deeper appreciation of the interconnected nature of pedagogy. For this reason, a further critical twist was added by locating the domain of interactive learning environments in the bigger picture of educational reform. The objective was to expose a further gap in the literature by showing that designs for learning are designs for the future. The real question is whose future. On this note, the final word is given to Alvin Toffler:

> All education springs from images of the future and all education creates images of the future. Thus all education, whether so intended or not, is a preparation for the future. Unless we understand the future for which we are preparing we may do tragic damage to those we teach (Toffler, 1974, cover).

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3.3

ONLINE LEARNING COMMUNITIES IN K-12 SETTINGS

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Introduction

The twenty-first century has been characterized as the Knowledge Age and the Digital Age. As we crossed into the new century, a number of reports on K-12 education, such as "enGauge®21st Century Skills: Literacy in the Digital Age" (North Central Regional Educational Laboratory, 2003) and "Results that matter: 21st Century skills and high school reform" (Partnership for 21st Century Skills, 2006), questioned the adequacy of school education in preparing students for new challenges. In the twenty-first century, students need to develop new skills and knowledge, inter alia, knowledge innovation capacity, and digital literacy, for the survival and growth of individuals and for contribution to the new economies (Anderson, 2008). Learning communities (Bielaczyc and Collins, 1999) and knowledge building communities (Scardamalia and Bereiter, 2003) have been proposed as educational models that schools should adopt to address such critical needs.

A parallel development in the Digital Age is the advancement of computer network technologies, particularly the Internet, which have dramatically changed the ways people are connected, blurring the line between face-to-face and online communication. Beyond communication, computer networking technologies have profound impact on the notion of community, which was once confined by physical and geographical locations. With increasing access to the Internet, new forms of

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community, known as online communities, began to emerge. The term, social software, was coined to refer to a wide range of online software including Internet discussion boards, messaging, Web blogs (e.g., www.blogger.com), social book marking tools (e.g., www. blinklist.com), wikis (e.g., en.wikipedia.org), and others. These developments capitalize on the collective intelligences and dynamics of the worldwide community. The pervasive use of such platforms among individuals is typically around the sharing of music, pictures, opinions, and the like, rather than in domains of school work or what is typically referred to as formal learning.

The confluence of these developments gives rise to the genesis of online learning communities. As an emerging field of study, there are many questions on online learning communities yet to be answered. This review attempts to examine the literature with the goal to clarify the concept and boundary of research on online learning communities, identify the major trends of research, and to suggest pertinent issues for future research.

This review is guided and organized around the following questions:

1. What are online learning communities?
2. What are the theoretical foundations underpinning learning in online learning communities?
3. What are the major studies on online learning communities? Are there common themes among these studies?
4. What are some guidelines and principles of fostering, facilitating, and supporting online learning communities?
5. What are some pertinent research issues to be explored?

Defining Online Learning Communities

Online learning communities, otherwise known as virtual learning communities (Henri and Pudelko, 2003), or cyberspace classrooms (Palloff and Pratt, 2001), is an emerging field of study that is still being defined by researchers. In this review, we attempt to define online learning communities by explicating each key dimension of online learning communities progressively: psychological and social dimension (community), technological dimension (online community), and educational dimension (communities of learners).

Community

Derived from the Latin word *communis*, the word community suggests commonness and joint ownership. What are common and shared can be locations, interests, identities, or a combination of the above. From a sociological perspective, a community is a cohesive social entity that is commonly defined within a geographical location (Tönnies, 1955). From a psychological perspective, members of a community can be connected in mind (McMillan and Chavis, 1986). This *sense of community* (McMillan and Chavis, 1986) has four key dimensions: (a) membership, (b) influence, (c) integration and fulfillment of needs, and (d) shared emotional connection. Within the community, the members develop a sense of identity and belonging which in turn helps to define the boundaries and criteria for membership to the community. As the members interact with each other, mutual influence develops among members. There is also a dialectical relationship between individuals and the group: individuals contribute to the community and the community has influence on individuals. The cultures and norms within the community provide the fulfillment of needs of individuals, and at the same time reward and reinforce their practices. Through the shared experience and history, members develop a strong sense of emotional connection to the community. A community is thus both systems and processes where diverse human needs can be fulfilled, including survival, socialization and support, and sense of identity.

The earlier forms of communities are bounded by geographical locations. However, the psychological sense of community could exist beyond the geographical boundary and ride on the advancement of network technology, giving rise to the flourish of online communities.

Online Communities

The advent of network technology results in the development of numerous technologies for computer-mediated communication (CMC). Email, newsgroup, list server, Web-based bulletin-board, Internet relay chat (IRC), and multiuser dungeon (MUD) are examples of CMC that could potentially be used to support online communities (Lazar et al., 1999). Of particular interest are technologies developed purposefully in the service of learning, known as computer-supported collaborative learning (CSCL) technologies. One distinct characteristic of CSCL technologies is the pedagogical support embedded in the software, for example, Knowledge Forum (Scardamalia and Bereiter, 2003), Collaborative and Multimedia Interactive Learning Environment (CaMILE), and Scaffolded Multi-User Integrated Learning Environment (SMILE) (Guzdial et al., 1997).

There is a consensus among many researchers that defining online communities with technologies as the key attribute is insufficient and unproductive (Stahl et al., 2006). According to Kirschner Materns, and Strijbos (2004), design of CSCL environments should take into consideration social, technological, and educational dimensions of the environment in the service of learning. The educational dimensions of the environment determine the learning activities and tasks for intentional learning; the social dimensions facilitate relevant social interactions among learners toward learning goals; and the technological dimensions provide a *physical* environment that facilitates and supports learning.

Following the classification schema by Lazar and Preece (1998), online communities can be classified as (a) the technology dimension, (b) attributes of the communities, (c) relation to physical communities, and (d) boundedness. The relation to physical communities provides the contextual information about the historical development of the communities, the attributes of the communities help define the goals and purposes of the online communities, and the boundedness defines the sociological elements that are critical to the development of a sense of community. More specifically, Preece (2000) proposed that an online community consists of people, a shared purpose, policies, and computer systems that mediate social interaction.

Communities of Learners

Community of learners (CoLs) stresses the intentional goals of learning. A learning community is cohesive and has a "culture of learning such that everyone is involved in a collective effort of understanding" (Bielaczyc and Collins, 1999, p. 271). In a learning community, both the individuals and the community as a whole are learning how to learn and knowledge is constructed through involvement in the community's shared values, beliefs, languages, and ways of doing things. Bielaczyc and Collins (1999) identified four characteristics of a learning community: (a) diversity of expertise amongst members, (b) shared objective of advancing collective knowledge, (c) emphasis on learning how to learn, and (d) mechanism for sharing what is learnt. One of the tenets for a successful CoL is that members in the community need to be organized around a structural-dependence principle. "The community should be organized such that students are dependent on other students' contributions in some way. It is important to have a valid reason for students to work together that makes sense to the students, such as a common task that requires their joint effort" (Bielaczyc and Collins, p. 288).

Online Learning Communities

Inheriting the characteristics of online communities and CoL, an online learning community was defined as "ensembles of agents, who share a common language, world, values in terms of pedagogical approach and knowledge to be acquired. They pursue a common learning goal by communicating and cooperating through electronic media in the learning process. The common interest of this type of community is the common interest in learning." (Seufert et al., 2002, p. 47). The key attribute of online learning communities that differentiates it from other communities is the sharing of a *common goal of learning*. They are different from other types of online community that exist for noneducational purposes such as informal information exchange or the building of social relations guided by personal interests. The common goal of learning entails sharing "a set of knowing, a set of practices, and the shared value of the knowledge that these procedures generate" (Riel and Fulton, 2001, p. 519). The participating individuals are valued for the knowledge they possessed and their desire to learn.

For K-12 education, there is an increasing number of studies on the design, development, and outcomes of online learning communities in blended learning environments, in particular, those that originate from communities within classrooms or schools (Manlove, Lazonder, and de Jong, 2006; Salovaara, 2005). Tapping the availability of diverse views and expertise across time and space that are afforded by the network technology such as teleconferencing, an online learning community might also include students from disperse geographical locations. An online collaboration project could include students from another school or country (Linn, Clark, and Slotta, 2003) or even individuals or groups from outside the school community such as trainee teachers, educational researchers, scientists, or experts who are keen in supporting the learning of the students (Maples, Groenke, and Dunlap, 2005).

Theoretical Foundations of Learning in Online Communities

As the goal of learning is what differentiates online learning communities from other online communities, it is pertinent to review theories underpinning learning in online communities.

From a social-cultural perspective, Vygotsky viewed learning as a cognitive developmental process that occurs through social interaction. Vygotsky (1962/1986) held that learning is embedded within social events, and learning occurs as a learner interacts with people, objects, and events in the environment. In addition, Vygotsky argued that the development of higher mental functions is mediated by signs and sign system, particularly speech and language. Through interaction with surroundings and communication with others via language, a person engages in metacognitive self-regulation of behavior and reflection in action. Through such a process, internalization and learning occur. In online learning communities, learning occurs through interaction among individuals who are connected through computer network as they interact via various modes, primarily language.

Also pertinent to socio-cultural learning is the notion of distributed cognition within a collaborative setting (Pea, 1993). In an online learning community, intelligence and expertise are distributed among various members. Each member, entering the community with different background, experience, and expertise, contributes different ideas and perspectives through computer-mediated interactions. This diversity of ideas, expertise, and perspectives becomes the collective resources for the community. In addition to distributed intelligence, there is also a distribution of responsibilities for difficult and complex learning tasks, which reduces cognitive overload of individuals and allows members to develop differential expertise (Roth, 1999).

Brown and Duguid (2000) characterized learning in communities as demand driven, a social act, and as identity formation. Building on the notion of situated cognition, Brown et al. (1989) also argued that learning is interwoven with context and activity. Learning is driven by demand, a real need, and as we engage in activity, social acts or practices, learning takes place. Contextual information is encoded in the process that indexes the personal knowledge that is constructed during the process. The implication is that the design of learning activities should be contextualized and premised on authentic problems. Learning should occur in rich situational and activity-practice context that allows for cognition by individuals in an interactional and dialectical relationship with other individuals, artifacts, ideas, tools, and problems.

Lave and Wenger's (1991) notion of community of practice (CoP) provides further insights into learning as social acts and as identity formation. In a CoP, people socially construct meanings, create and appropriate social cultural norms. At the periphery of a community, the participants start as legitimate peripheral participants, appropriating implicit and explicit knowledge through participating and observing. This process is epitomized by the process of apprenticeship, where apprentices gradually acquire skills of the trait, norms, and rules held by the core members within the CoP. Lave and Wenger (1991) characterized the learning journey as one that moves from legitimate peripheral participation to central participation of the practice. Beyond learning, by participating in the community, one also appropriates from the practice *ways of seeing* (Hung, 1999), meaning that the participants acquire a *lens* for seeing meanings that are identified with the CoP. Identity formation takes place through the appropriation of the beliefs, values, and skills required in a practice. Lipponen, Hakkarainen, and Paavola (2004) further differentiated between the participatory approach and the knowledge creation approach of learning in a community. On the one hand, the participatory approach happens when a novice is enculturated while moving from the periphery to the centre of a community. On the other hand, the knowledge creation approach advocates collaborative knowledge building with the constant goal of improving cultural artifacts and knowledge, as epitomized in knowledge building communities (Scardamalia and Bereiter, 2003).

Review of Studies on Online Learning Communities in K-12 Settings

In this section, we summarize research studies on online learning communities in K-12 settings. Although there are myriad of studies on learning mediated through electronic means, we will only focus on research studies that gear toward the formation of a community for learning. Online learning communities are chosen on the basis of the following criteria: (1) learning in K-12 settings, (2) use of computer network(s) as a mediation tool, and (3) evidence of a design effort toward fostering a sense of community. We will include both learning in formal and informal settings, as well as online and blended environments. Excluded are studies based on ad hoc groups collaborating or learning through computer network with no evidence of effort toward fostering a sense of community. On the basis of our criteria, we have chosen four online learning communities: Knowledge Building Communities (KBC), Quest Atlantis (QA), Virtual Math Team (VMT), and Web-based Inquiry Science Environment (WISE). Knowledge building community, strictly speaking, is a blended environment that involves both face-to-face and online interactions. We include KBC in this review as it marks an important milestone in the field of online learning communities as one of the pioneers in using Computer-Supported Collaborative Learning (CSCL) technology for learning in a community in K-12 settings. In addition, many design principles that can be used for online learning communities were developed through studies in KBC. Because of space constraint, we regret that we are not able to review other communities, like CoVIS (Chan and van Aalst, 2008; Edelson, Pea, and Gomez, 1995) or River City (Clarke, Dede, and Dieterle, 2008).

Knowledge Building Community

Knowledge Building Community (KBC) is pioneered by Scardamalia and Bereiter (2003), who define knowledge building as “the production and continual improvement of ideas of value to a community, through means that increase the likelihood that what the community accomplishes will be greater than the sum of individual contributions and part of broader cultural efforts"(p. 1370). Scardamalia and Bereiter (2003) argued that knowledge building leads to personal learning but the converse may not be true. In this sense, KBC is a super-ordinate concept that subsumes a learning community. Currently, KBC has been implemented in around 19 countries (http://www.ikit.org).

1. *Cognitive dimension:* Underpinning KBC is an expansive view of learning that emphasizes critical and creative work on ideas. The central idea of knowledge building is to get students to put their ideas in a public space (e.g., online forum); the ideas become objects of inquiry as they are made available to the whole community such that the ideas can be discussed, interconnected, revised, and superseded. Cognitively, the students learn to engage in knowledge building discourse, as they take collective responsibility to improve the ideas in the public space. It aims to empower students with the abilities to engage in metacognition and reflection and to construct knowledge substantiated with warrants and evidence. Researchers in several countries have reported positive effects of KBC (for example, see Scardamalia, and Bereiter, 1996; Hakkarainen, 1998; Tan, Hung, and So, 2005; Tan, Yeo, and Lim, 2005).
2. *Social dimension:* KBC uses Knowledge Forum (http://www.knowledgeforum.com/) that allows ideas to be displayed in a public forum so that intersubjectivity of ideas can be achieved when differences in opinions and perspectives are visible. The success of knowledge building communities depends largely on establishing socio-cognitive norms and values that all participants are aware of and work toward. For example, collective cognitive responsibilities for knowledge advances, constructive critique through knowledge building discourse, and continual seeking of idea improvement. In an online forum, the pace and turn-taking order is not controlled by teachers, thus facilitating renegotiation of institutional power (Tan and Tan, 2006). Students can assume greater power for social order. They also have more time for reflection, consulting authoritative resources, and formulating their responses.
3. *Technological support and infrastructure:* Specifically designed for KBC is the online collaborative tool called Knowledge Forum. The graphical interface is organized as views, which can be linked to other views on topics, questions, and problems. Participants put forth their ideas as contributions that serve the inquiry purpose and objects upon which the community can reflect, link, relate, and question ideas posted. The notes are linked graphically, allowing one to trace the development of and organize ideas. To facilitate knowledge building discourse, customizable scaffolds can be embedded in a note window. These are cognitive supports that scaffold and encourage learners to engage in more in-depth inquiry rather than superficial chatting. Knowledge Forum encourages idea improvement by allowing review and revision of notes, publications of views, and a *rise above* function, which encourages users to synthesize or summarize ideas at a higher level.

Quest Atlantis

Quest Atlantis (QA) (http://www.atlantis.crlt.indiana.edu/), undertaken by Indiana University, is a 3D multiuser virtual environment, which incorporates the strategies of online gaming and narration. Target at learners of ages 9–12, the design of QA is based on a triadic foundation of education, entertainment, and a set of social commitments. Currently, it has served 4,500 users distributed across seven countries through membership by association with elementary schools, children's museums, and after-school clubs.

1. *Cognitive dimension:* QA is designed based on three key features of *engagement, change, and understanding* (Barab, Thomas, Dodge, Carteuax, and Tuzun, 2005). On the basis of a participatory framework, children investigate relevant personal issues related to community, power, global and water in a fictional game context. They direct their own activities and share their personal experiences as they travel through worlds and villages in Atlantis to solve real world, inquiry-based challenges, called Quests. Through this experiential learning, children's understanding is derived from and modified through experiences, action, and reflection in this physical setting.
2. *Social dimension:* QA adopts a social agenda of empowering individuals and communities in its design. The design of QA takes into consideration seven principles to foster social commitment: personal agency, diversity affirmation, healthy communities, social responsibility, environmental awareness, creative expression, and compassionate wisdom in a child so that the lives of a child will be enhanced and hence developing children into knowledgeable, responsible, and empathetic adults (Barab, Thomas, Dodge, Squire, and Newell, 2004).
3. *Technological support and infrastructure:* To support participation in this community, the virtual world is housed on a central Internet server. Building on strategies from online gaming such as free play, role play, and adventure, it consists of both structural and motivational functions to encourage learning and social development. Structurally, it consists of a shared mythological context that establishes and supports program activities like the Quests. Its online spaces and its text-chat function provide the affordance for children, mentors, and Atlantian Council to interact with each other. With a well-defined advancement system, which rewards advancement in knowledge and wisdom, it encourages academic and social learning. With individualized homepage, children can build a portfolio to show their advancement in their works and develop the identity of the persona adopted in the virtual space.

Virtual Math Team (VMT) Project

VMT project (http://www.vmt.mathforum.org/VMTLobby/) focuses on the use of an online synchronous environment for students to talk about mathematics and solve mathematics problems (Wessner et al., 2006). VMT is an extension to the regular suite of interactive math education services offered in The Math Forum, an online resource for improving mathematics learning, teaching, and communication (Virtual Math Team, n.d.).

1. *Cognitive dimension:* The goal of the VMT project is to create a self-sustaining system and a noncompetitive environment that allows individuals become part of a well-working group and make progress together toward increasing their mathematics knowledge and problem solving skills (Wessner et. al., 2006). The environment is made up of a number of math discussion chat rooms that cater to different types of situation and math topics including challenging problems taken from The Math Forum.
2. *Social dimension:* VMT aims to foster collaborative knowledge building through math discourse among teachers, mathematicians, researchers, students, and parents (Virtual Math Team, n.d.). The environment, made up of a virtual lobby and chat rooms, provide the affordances for social interaction among the members. In these spaces, members could socialize in the virtual lobby, propose new topics, create a new room or join an existing room for joint work on a given or self-defined problem. In problem solving, new ideas are proposed and questions are posed. However, mentoring the process remains a challenge with students having to post summaries of their work and to request asynchronous feedback from their mentors.
3. *Technological support and infrastructure:* VMT provides a number of tools that support learning and communication such as textbox, whiteboard function, chat-log, and referencing tool. The textbox is a synchronous chat tool. The whiteboard function provides the shared space for drawing mathematical objects and graphical representation of the problem. A referencing tool allows users to refer to an area of whiteboard so that a specific area of a math object drawn on the whiteboard can be defined in the text box; it also allows one text posting to be connected to a previous one. The conversation in the VMT-chat can be saved and reviewed at a later time. It thus allows any newcomers to follow the historical happenings of the problem solving process.

The Web-Based Inquiry Science Environment (WISE)

WISE (http://www.wise.berkeley.edu/) offers a free online environment, where grade 5–12 students can log on to participate in inquiry projects jointly developed by classroom teachers, technologists, natural scientists, and pedagogical researchers (Linn and Slotta, 2000). A library of at least 25 inquiry projects has been set up and used by as many as 1,000 teachers and 100, 000 students (Linn, Clark, and Slotta, 2003).

1. *Cognitive dimension:* WISE uses the scaffolded knowledge integration approach which builds on the premise that eliciting ideas from students and combining, sorting, organizing, contrasting, integrating, creating, and reflecting on the repertoires of ideas help to build understanding (Linn et al., 2003). It aims to make thinking visible, make science accessible, help students learn from each other, and promote lifelong learning. Each WISE project also includes pretest, posttest, scoring rubrics, lesson plans, and commentary from teachers who have used the project. WISE could also incorporate hands-on activities and field

trips. The expected outcome is that students possess the disposition and skills capable of doing scientific inquiry, which will enable them to become consumers and contributors to the scientific enterprise.

2. *Social dimension:* Discussion tools such as *online asynchronous discussions* allow students to interact and learn from each other. There are two types of discussions: student-initiated discussions and large group question-and-answer sessions (Cuthbert, Clark, and Linn, 2002). Students are allowed to make contributions anonymously, which help to reduce stereotypical responses from others and encourage sharing of ideas. *Probing software* is used to group students who have different explanatory theories and perspectives together in electronic discussion groups, thus encouraging them to argue and work toward achieving a consensus. *Show and tell* allows students to showcase their work and seek feedback from others. Strategies are also incorporated to balance sustaining interactions and achieving the learning goals, such as requiring students to place their comments into categories before posting, grouping students' comments on the same topic together, and listing the number of comments with unanswered questions (Cuthbert et al.).
3. *Technological support and infrastructure:* In addition to the tools to support social interaction, other tools include *Inquiry Map*, a step wise procedural guide that serves to scaffold independent students' inquiry and learning; *Hints*, questions that allow students to make connections; *Evidence Pages*, consisting of authoritative scientific information and hyperlinks to provide students with the relevant background knowledge; *Principle Builder*, which provides a set of predefined phrases to help students construct scientific theories; and *Advance organizers*, which help students to focus on relevant materials on the different Web pages (Linn et al., 2003). Students' thinking is made visible through the use of *note* on which students record their ideas as guided by epistemological, metacognitive, or knowledge integration *prompts*. *Visualizations, graphing,* and *exploratory data analysis tool* are also available to support student thinking and make their ideas explicit.

Comparison of the Four Online Learning Communities

The unifying features across these online learning communities are the recognition that learning within a community is a social process, and advanced technologies are leveraged as mediation tools to support cognitive and social processes in the communities. We summarized three key characteristics that might contribute to the success and sustainability of these communities:

1. In the cognitive dimension, goals and types of pedagogical tasks and activities are grounded on theories or principles of learning. For example, KBC focuses on expansive approach of learning by emphasizing idea improvement; QA adopts a participatory framework that emphasizes inquiry-based learning and experiential learning; VMT focuses on mathematics problem solving through

math discourse; In WISE, students are guided to engage in scientific investigative practices.

2. In the social dimension, these communities strive on the strength of collective responsibilities and contributions as a community. For example, KBC explicitly stresses collective knowledge and community responsibility, students as epistemic agency, democratization of knowledge, and symmetric knowledge advancement. QA emphasizes social commitments to foster sense of purpose as individuals, as members of their communities, and as knowledge citizens of the world. In WISE, conscious attempts are made to collect students' experiences and represent them in an accessible and equitable manner, which represent the identities of the community members. In the least scaffolded way, students share ideas and negotiate solutions in VMT.
3. In the technological dimension, the four communities leverage technological advances to achieve goals beyond face-to-face settings. This is in contrast to the common criticism of putting old wine into new bottles, where technologies are used as bells and whistles to glamorize traditional modes of instruction. For example, in KBC, the graphical view allows idea development to be visualized; In QA, 3D technologies are used to create an immersive experience and to support real-time collaboration; In VMT, a variety of rooms allows participants to self-organize into groups characterized by shared interests and goals or be assigned a particular problem; WISE scaffolds the students for practices and daily tasks of scientists through the use of technology.

Notwithstanding these commonalities, the four online learning communities vary in terms of settings and origins, duration of existence, technological environment, norms and practices, forms of communication, cultural and political values, and the design of learning environments. These differences give rise to online learning communities with different character and ambience. In contrasting these online learning communities, we characterize them along several continuums (Table 1), for example, generic versus discipline-specific learning. This analytical approach aims to provide insights into the variations and different shades of online learning communities, and thus demonstrates the richness and potential directions that this field of study might progress.

Cognitive Dimension

The four online learning communities show some variations in the nature of cognitive tasks and activities. KBC and QA can be used for different subject domains, while WISE is designed for learning of science and VMT is designed specifically for mathematics problem solving. Within the situatedness and abstract continuum, WISE features strongly in approaching authentic practices of scientific investigations. KBC emphasizes student-initiated problems and authentic problems of understanding, making the concrete-abstract and everyday-scientific connections. QA adopts a simulation approach, using scenario and narrative to engage students in problem solving. VMT uses brain teasers and problems similar to classroom mathematical

Table 1 Comparisons of the online learning communities

Cognitive Dimension		
Generic	↔	Discipline specific
Abstract	↔	Situated, authentic
Participatory	↔	Expansive
Cognition	↔	Metacognition
Social Dimension		
Self-organized	↔	Intentional community
Expert-novice power	↔	Personal agency
Individual gain	↔	Collective gain
Technological Dimension		
No scaffolding	↔	Embedded scaffolding
Turn taking	↔	Multiple threads
Synchronous	↔	Asynchronous
Text	↔	Multimodal

problems, and thus is closer to the Abstract end of the continuum. KBC adopts an expansive view of learning by stressing innovativeness and idea improvement. The other communities adopt a participatory view of learning with tasks or activities predominantly designed by a team of experts. Metacognition is emphasized to varying extent, with KBC showing deliberate attempt to engage participants in *Rise Above*, that is, metacognition and reflection to advance collaborative knowledge. Metacognitive scaffolding is less apparent in other communities.

Social/Emotional Dimension

All four online learning communities included varying degree of technological support and scaffolding for social interactions among members. On the one hand, we see KBC declaring knowledge building as the pervasive goal in school curriculum with strong modeling and mentoring from the teachers, and on the other hand, VMT fostering a self-organizing community among members from diverse background. QA declares strongest mandate in fostering social emotional development among the members, for example, social responsibility, empathy, and environmental awareness. VMT represents the other end of the continuum where there are emergent interactions among members and social emotional development is incidental. One contrasting difference among the four communities is the power relationship. In WISE, for example, expert and mentor are explicitly recognized. QA and KBC emphasize the importance of empowering students as epistemic agency. Even though there is a strong presence of adults and experts in KBC, the importance of empowerment and appropriate use of authoritative sources is emphasized. All four communities use online communication tools to support interactions and collaboration among members. KBC advocates collective cognitive responsibility and symmetric knowledge advancement among all participants. This balance between individual and collective gains seems to be present in all communities.

Technological Dimension

Among the four online learning communities, we see greatest variation in terms of technologies. However, one commonality is the use of technology as mediation tool to support social and cognitive development. The technologies vary in terms of degree of embedded scaffolding. For example, Knowledge Forum has embedded cognitive scaffolds, whereas VMT uses online chat that imposes least amount of structural constraints or scaffolding for the participants. Asynchronous discussion forums in KBC and WISE allow participants to join in multiple thread discussions. Synchronous chat of VMT and online games of QA, however, requires participation at the same time and depends largely on turn-taking interactions. Another variation is the modalities of communication. Although text remains the main mode of communication in the four online learning communities, graphing and graphical representations are available in Knowledge Forum and WISE. A related difference is the use of discipline specific tools. For example, visualization and modeling tools are used in WISE to support scientific inquiry specifically.

Pertinent Research and Implementation Issues

In the above sections, we have covered much ground on cognitive, social/emotional, and technological dimensions of established and emerging online learning communities. There remain, however, several pertinent research and implementation issues in this field of work.

Contradictions with Traditional School Cultures and Practices

In many schools where preparation for high-stake national examinations is emphasized, the goals and motivations for schooling run in contradiction to the social constructivist and collective advancement ideals of online learning communities. One possibility is to view them as separate initiatives and maximize on their respective potentials in complementary ways. To do this, schools could find ways in which their students can participate in online communities, which could occur in informal settings, by preparing students with the media literacy skills for participating in these communities. Regardless of the tensions that arise, we see a transition where an increased emphasis in social constructivist forms of pedagogy, such as in CSCL, is gradually helping to weaken the strongholds of traditional pedagogies. When teachers and school practices are more learner-centric, learning communities might become more prevalent. Concomitantly, with the prevalent involvement of school students in online communities, schools will be compelled to change their traditional didactic practices because students will soon find schools boring and irrelevant. These push and pull factors will gradually change schooling and the practices of teaching and learning. Some pertinent research issues include (1) how to facilitate implementation of online learning communities within existing school cultures? (2) To what extent could online learning communities be implemented in formal school settings? (3) What are some concomitant systemic factors, such as high-stake assessment, which could be changed to facilitate implementation of online learning communities?

Issues of Authenticity of Learning

A fundamental challenge in the field of learning communities is that schools are perceived and criticized as insufficiently authentic, that is, with respect to communities of practice. Schools are trying to make learning more authentic by engaging students in practices that are nearer to what actual practitioners do but they are not sufficiently fostering in students the disposition toward disciplinary practices such as in the scientific practices. To *simulate* the authentic construction of meanings in any practice is to be as close to the professional practice as far as possible such as simulating the discipline-specific genre and talk for example in science (O'Neill, 2001). Petraglia (1997) pointed out that these simulations are a priori (preauthentication) designs. They have missed the in situ epistemological considerations that underpin constructivism and situated cognition. He argues that educational technologists have been *preauthenticating* learning materials and environments to correspond to the real world rather than fostering learners with the ability to interact with it. Thus, several issues remain, which include (1) should authentic disciplinary practices be the ultimate goal for schools? (2) If not, what could be the realistic goal in the authentic-simulation continuum?

Knowledge Acquisition Through Online Learning Communities

In general, research in the dimension of knowledge acquisition through online learning communities is scarce. This could be due to the current emphasis toward investigating and understanding the constructive processes involved in learning rather than the learning outcomes (Suthers, 2005). In this field of CSCL, some researchers hold that it is still in need of substantiating its claim for better learning outcomes (Hendriks and Maor, 2004). Even though knowledge acquisition is only one of the many learning outcomes that online learning communities are gearing toward, in a pragmatic sense, it could help to convince policy makers and practitioners about its effectiveness (Strijbos et al., 2004). A critical mass of participants in sustainable online learning communities could provide the fertile ground for fruitful research in this field. Some questions to explore include (1) what learning benefits could online learning communities demonstrate? (2) In what ways does students' cognitive development occur through participating in online learning communities? (3) In what ways could students' cognitive development be fostered in online learning communities?

Social-Emotional Outcomes

It is a challenge to foster for identity and dispositional enculturation of practices in online learning communities, while in informal online communities, people are expressing their identities and personal views (as in blogging and messaging) in the form of reflections and social interactions. There is a heightened and almost definitive sense of ownership. As discussed earlier, the factors that make or break a community, whether face-to-face or online are issues of trust and identity, clarity of purpose, and boundaries. QA emphasizes the socio-emotional outcomes but research in this dimension is rather scarce. Emerging technologies like MUVEs also bring new issues like the nature of (virtual) identity in a virtual environment. Some research issues include (1) in what ways could students' socio-emotional development be fostered in online learning communities? (2) What are the socio-emotional benefits online learning communities could offer to K-12 students? (3) In what ways is (virtual) identity developed in the online learning communities? (4) How does (virtual) identity affect students' behavior and learning outcomes?

Technological Advances

Advances in technologies continue to provide new frontiers and possibilities for online learning communities. Recent projects like Second Life and River City have demonstrated advance features of 3D virtual environment and shown promises of new affordances yet unseen in other online communities. River City is a MUVE that allows multiple participants to access virtual contexts simultaneously, representing themselves through avatars, communicate with other participants, interact with the digital artifacts, and take part in experiences that simulate real world problems (Clarke et al., 2008). Second Life, created by Linden Lab in 2003, is a 3D virtual world where members of the public can create their own avatars, build houses, start up businesses and schools, sell real estate, stage or enjoy entertainments, and just about anything they could do in the real world. Linden dollar is the currency used within this virtual world but it can be converted to US dollars at several online currency exchanges (http://www.secondlife.com/), thus behaving like a foreign currency in many aspects (Prisco, 2006). Pertinent research issues include (1) what are the affordances of advanced technologies that could facilitate learning in online learning communities? (2) What are the learning outcomes that could be achieved through these new environments? (3) In what ways do identities and community development occur in these new environments?

Conclusion

Online learning community, as an emerging field of research, builds on the foundation of online communities and communities of learners. As a nascent field of study, research findings have demonstrated the complexity and challenges of establishing and sustaining online learning communities. However, we can derive a few key dimensions from these research findings: cognitive, social, and technological dimensions. As learning is the distinctive goal that distinguishes online learning communities from other online communities, the cognitive dimension of learning within the community remains an important consideration in designing and implementing an online learning community. In addition, as a community, one cannot ignore the issues of trust and identity, clarity of purpose, and boundaries. Thus, the social dimension of the learning environment, in service of cognitive, emotional, and community development, becomes critical. Likewise, as an online community, the technological dimension cannot be neglected. Online learning communities are situated within a larger social, cultural, and political framework. Its existence and sustainability is dependent on systemic environment factors, such as existing school organizations and cultures, or even the larger societal views about schooling and education through alternative means and experience. We need to be cognizant of the dialectical relationship between the online learning communities and the systems and environment in which they are situated.

On the one hand, through the review of four online learning communities, namely, Knowledge Building communities, Quest Atlantis, Virtual Math Team, and Web-based Inquiry Science Environment, we highlighted some common principles and characteristics of these learning environments. On the other hand, their differences illustrate the richness and possibilities that this field of study could advance. We have also discussed several challenges and potential research issues for researchers, including the contradictions with traditional school cultures and practices, the issues of authenticity versus simulation approach in schools, the cognitive and socio-emotional outcomes of online learning communities, and the possibilities and impact of advances in technologies.

As the intended audience for this work is primarily researchers, implications for practitioners and learners are not elaborated. For example, teachers would need to be sensitive to socio-technological design and not just in content delivery. Designing for sociality and learning interactions will become key skills and dispositions for teachers, and these will be considered part of pedagogy. Students will have to learn to be a lot more innovative, open minded, and information and media savvy compared with previous generations of students.

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3.4

COLLABORATIVE LEARNING AND COMPUTER-SUPPORTED COLLABORATIVE LEARNING ENVIRONMENTS

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Introduction: Collaboration Defined

What is collaboration and collaborative learning, after all? Both in everyday discussions among practitioners in the schools and among researchers in the field of learning and instruction, the term collaboration is sometimes used very loosely and the definition of collaboration is blurred. In many notions, it has been regarded similar to cooperation, which is a typical activity in school projects, where the students work toward a shared goal, usually a shared product, but the actual work is divided. Students may divide the task into subtasks, which individuals complete alone. This kind of division of labor is called vertical (Dillenbourg, 1999), and in the literature, it is typically referred to as cooperation instead of collaboration (Cohen, 1994). In addition, collaboration is sometimes referred to very generally as a shared activity of the students, interaction between students, or participating in learning communities. However, in those notions, the nature of activity, interaction, or participation is not specified.

The most widely used definition of collaboration describes it as a construction of shared understanding through interaction with others (Dillenbourg, 1999; Roschelle and Teasley, 1995). It is assumed that in collaborative activity, the participants are committed to or engaged in shared goals and problem solving. Furthermore, collaboration is often defined in a way that necessitates participants to be engaged in a coordinated effort to solve a problem or perform a task together. Collaboration is also commonly referred to as coconstruction of knowledge (Baker, 2002), building

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collaborative knowing (Stahl, 2004), coargumentation (Baker, 2002), negotiating of shared meaning (Pea, 1993), construction of common knowledge (Crook, 2002), exploratory talk (Mercer, 1996), or coordination (Barron, 2000). Furthermore, the definitions of successful collaborative activity demonstrate the nature of collaboration, where cognitive, social, and emotional aspects are tightly intertwined.

Baker (2002) defines collaboration as "a symmetrical and aligned form of cooperation in problem-solving, independently of whether the participants agree or not" (p. 602). According to Baker, interaction is *symmetrical* if the participants adopt certain roles equally throughout the interaction, i.e., participate equally in problem solving. Even though Baker (2002) does not refer to symmetry of knowledge, a certain degree of knowledge symmetry is essential to enable equal roles (Dillenbourg, 1999). According to Van Boxtel (2000), all participants have to contribute equally to the elaboration and solution of the problem at hand.

In Baker's (2002) definition, the degree of *alignment* refers to the extent to which participants are *in phase* with respect to different aspects of the problem-solving activity, that is, to what extent they are genuinely working together. For example, interaction is nonaligned in a situation where students have no mutual (conceptual) understanding of the problem or the concepts at hand, and thus, are not genuinely able to work together (until they negotiate a shared understanding). Maintaining and constructing shared understanding requires continuous attention and reflection on one's own and other's understanding (Baker, 2002).

Mercer (1996) sees collaboration as shared knowledge construction. According to him, shared knowledge construction is manifested in talk. He distinguishes three forms of talk, namely exploratory, cumulative, and disputational talk. *Exploratory talk* occurs when participants engage critically but constructively in each other's ideas. In exploratory talk, statements and suggestions are offered for joint consideration. These are challenged and counter-challenged with justifications and alternative hypotheses. In exploratory talk, knowledge is made publicly accountable and reasoning is visible. *Cumulative* and *disputational talks* do not promote joint critical problem solving. In cumulative talk, the participants build positively, but uncritically on what the other has said. The participants use this type of talk to construct common knowledge by accumulation. Typical elements of cumulative talk are repetitions, confirmations, and elaborations. Disputational talk is characterized by disagreement, competitiveness, and individual decision making. There are only few attempts to solve problems together or to offer constructive criticism or suggestions. Only exploratory talk contributes to shared knowledge construction.

According to Barron (2003), collaborative activities have a dual nature, which means that the participants have to develop and monitor both the content space and the relational space. The content space refers to the cognitive aspect of collaboration: how the subject at hand is reasoned, how the ideas are developed in discussion, and how the shared understanding is constructed. Relational space refers more to the way in which participants orientate toward each other in dialogue (or monologue) and how willing they are to engage in interaction (Barron, 2003). The content and relational spaces are negotiated simultaneously, and thus compete for attention.

For example, if the relational space is more focused on competitive interaction or self-focused (individualistic) problem-solving, it prevents the participants from gaining joint attention and mutual engagement, and from reaching common understanding on the same topic. At the same time, success in the content space requires success in the relational space. The content and relational spaces thus have a reciprocal relationship, both being part of the same collaborative process, and are therefore hard to separate.

Research Traditions on Collaborative Learning

The definitions of collaboration as such do not explain how collaborative learning takes place. A more detailed analysis of specific forms of collaboration can contribute to our understanding of how to engage participants to solve cognitive conflict and identify what constitutes productive collaborative learning. In the history of research on collaborative learning, several researchers have anchored their research on two main traditions, namely neo-Piagetian ideas of socio-cognitive conflict (Doise, 1985) and Vygotsky's (1978) socio-cultural approach. Later notions of social aspects of learning vary from perspectives focusing on individuals that participate in group activities (Anderson et al., 1997) to perspectives focusing on groups that are made up of individuals (Greeno, 1998).

The research tradition building on the socio-cognitive perspective is interested in cognitive processes relevant to collaborative knowledge construction (Fischer et al., 2002). The underlying assumption of this approach is that the cognitive processes and outcomes of collaborative work are related. This type of research has focused on studying the relationship between the cognitive aspects of student interaction and individual learning. According to many studies, productive interaction manifested in cognitively high-level discussion is related to high-level understanding and learning (Howe and Tolmie, 1999; King, 1999). Positive results of collaborative interactions have been explained by the notion that peer interaction stimulates the elaboration of knowledge, and hence, promotes individual cognitive gains (Van Boxtel, 2001). Thus, the main interest is in studying how collaboration contributes to individual knowledge construction, the mental content of individual minds.

The socio-cultural approach to learning, building on the Vygotskian framework (1978), emphasizes the meaning of social interaction and activity in the process of knowledge construction, as well as the mediative role of tools and the historical and cultural settings in which the knowledge construction occurs. According to Wertsch (1991), it is not possible to study thinking and cognition independently of the social, interpersonal, cultural, and historical settings in which they occur. Cognition is a public, social process embedded within a historically shaped material world (Goodwin, 2000) in the sense that it relies on conceptual and material resources and tools that originate in our culture (Bliss and Säljö, 1999). According to the socio-cultural approach, understanding collaborative learning requires making sense of the conversation that students engage in and the tools that mediate their learning, rather than studying the mental content of individual minds (Hmelo-Silver, 2003). According to this view, learning is always situational and it must be considered in the context where it takes place. Thus, collaborative knowledge construction has to be analyzed within the context of the group situated in a larger community, where the knowledge is distributed in the material and discursive environment in the form of tools, symbol systems, social practices, and physical spaces (Goodwin, 2000; Stahl, 2004).

What is Computer-Supported Collaborative Learning?

Research on collaborative learning and the use of information and communication technologies (ICT) has been integrated in the research area called computer-supported collaborative learning (CSCL; Koschmann, 1996). Although there is no unified theory of CSCL, the common feature of the various diverse viewpoints is to focus on how collaboration supported by technology can facilitate sharing and distributing of knowledge and expertise among group or community members. Furthermore, the crucial question in CSCL is how peer interaction and work in groups supported by technology can enhance learning. Two main perspectives that have strongly contributed to the development of CSCL tradition are research on collaborative learning (Dillenbourg, 1999) and computer-supported cooperative work (CSCW) (Dourish, 1998). The latter focuses on the collaborative nature of work supported by groupware. It excludes issues of learning, but provides a basis for developing groupware tools that can be used for learning purposes (Häkkinen et al., 2004).

Lipponen (2001) has made a distinction between the collaborative use of technology and collaborative technology. The *collaborative use of technology* refers to situations where the computer can serve in a face-to-face event as a referential anchor, coordinate joint attention and interaction, be an object for manipulation, and thus, support collaboration (Lipponen, 2001). In this approach, technological tools are not designed as such to support collaboration, but they can be utilized in various ways for the purpose of enhancing collaborative learning. Such tools and environments are widely used, and many of them are available in the Internet and can be easily modified for different purposes. For example, different kinds of simulations and graphical representations in the computer screen can operate as reference objects that help participants to construct shared understanding (Roschelle and Teasley, 1995). In the case of computer-mediated communication, the technology may be used collaboratively in at least two ways. First, participant's thoughts and ideas are stored on a common platform, which serves as a public memory, and thus, are made available and visible for reflection in the long term. Second, participants are engaged in asynchronous (e.g., discussion boards) or synchronous (e.g., chat) discussions.

According to Lipponen (2001), *collaborative technology* refers to specific technological support for collaboration built into computer networks. Such collaborative technology in connection with corresponding pedagogical practices is usually called a CSCL environment. Different studies have revealed that CSCL environments can facilitate higher-level cognitive achievements such as critical reasoning, explaining, generating own research questions, setting up and improving one's own intuitive theories, and searching for scientific information (Scardamalia and Bereiter, 1994; Hakkarainen et al., 2002).

A common feature of collaborative technology is that it supports participants' cognitive activities by providing advanced socio-cognitive scaffolding. Knowledge Forum (Scardamalia and Bereiter, 1994; http://www.knowledgeforum.com/and http://csile.oise.utoronto.ca/) is a well-known example of a CSCL environment. It is basically an environment where students build and refine a database of notes. A note is a passage or picture representing student's idea or research question. When students create *notes* they are asked to label the type of their *note* (for example *Problem*, *My theory*). These types are called *Thinking types*, and they are intended to scaffold students' inquiry process. This environment is collaborative in the sense that notes are public in a Knowledge Forum's database, and students can build onto other students' notes, and they may refer to other's work and create new syntheses (Lipponen, 2001). In other words, this kind of environment can function as a collective memory for a learning community, helping to store the history of knowledge construction process for future revisions and use. The environment provides scaffolds in different areas, such as, text analysis, theory building (thinking types), and debating (Lipponen, 2001).

The following list presents some examples of well-known CSCL environments:

- Knowledge Forum and CSILE (Scardamalia and Bereiter, 1994): Knowledge Forum is a collaborative technology that enables students and teachers to work collaboratively in the support of knowledge building. Knowledge Forum is an electronic group workspace designed to support students and teachers in the process of knowledge building. It provides tools for sharing information, launching collaborative investigations, and building networks of new ideas. http://www.knowledgeforum.com/and http://csile.oise.utoronto.ca/ (see also in this handbook: Chan and van Aalst, 2008; Tan et al., 2008).
- Web-Based Integrated Science Environment (WISE; Slotta, 2002): WISE is a Web-based inquiry science environment through which students can examine real world evidence and analyze scientific controversies. http://www.wise.berkeley.edu/. Earlier version was Knowledge Integration Environment (KIE): http://www.kie.berkeley.edu/KIE.html (see also in this handbook: Chan and van Aalst, 2008; Tan et al. 2008).
- Belvedere (Suthers et al., 1995): Belvedere is collaborative technology for constructing and reflecting on diagrams of one's ideas, such as evidence maps and concept maps. It is designed to support problem-based collaborative learning scenarios. http://www.lilt.ics.hawaii.edu/belvedere/index.html
- Learning Through Collaborative Visualization (CoVis) (Pea and Gomez, 1992): CoVis is a community of students, teachers, and researchers working together to find new ways to think about and practice science in the classroom. http://www.covis.northwestern.edu/ (see also in this handbook: Chan and van Aalst, 2008).

There are also intriguing efforts based on utilizing game-based learning environments for the enhancement of collaborative learning, e.g., in mathematics (Scott et al., 2003), learning music composition (McCarthy et al., 2005), and in teaching environmental planning for young students (Kusunoki et al., 2000).

Challenges of CSCL

Although research shows that there are several possibilities for using technology to facilitate collaborative learning, it should be noted that collaborative learning is a complex phenomenon and may be difficult to implement successfully in institutionalized schooling.

Many studies in the field of CSCL deal with, e.g., virtual university courses, where tens or hundreds of students participate in discussion groups, usually through different kinds of asynchronous discussion tools, both with special technological support designed for facilitating collaboration (e.g., Knowledge Forum, Belvedere) and without any technological support tool (e.g., discussion boards). These studies have also revealed more pessimistic findings about the quality of interaction and shared knowledge construction on the Web. For example, studies evaluating shared knowledge construction (Arvaja et al., 2003) or the processes of knowledge construction, such as reciprocity (Järvelä and Häkkinen, 2002) or creating common understanding (Mäkitalo et al., 2002), have indicated that high-level collaboration, where participants are engaged in cognitively high-level interaction such as asking and answering questions, reasoning and argumentation, is rare in authentic computer-supported settings. Other problems that have been identified are short discussion threads (Arvaja et al., 2003) and unequal participation (Lipponen et al., 2001).

The biggest challenge in Web-based discussion is how to maintain interaction and knowledge construction. Jeong and Chi (1997) point out that in order to facilitate coconstruction of knowledge over computer networks, there has to be a social obligation to engage in active interaction. This argument is built on Clark's and Schaefer's (1989) notion, which emphasizes that for coconstruction to occur, it is not enough to make a contribution and it must also be accepted by the partner. It can be concluded that to create a sense of community in a Web-based environment there has to be a real need to make contact and to collaborate with other participants.

In face-to-face interaction, the process of constructing and maintaining mutual understanding requires less effort compared with computer-mediated interaction (Brennan, 1998). Face-to-face interaction provides the participants with immediate cues about each other's understanding and perspectives (Krauss and Fussell, 1991). For example, facial expressions convey effectively feedback about the state of common ground in face-to-face interaction. Also the affective tone is more easily mediated in face-to-face interaction, even though there are established practices in expressing emotions through computer networks, such as emoticons. As the interaction is based on text in a Web-based environment, the process of constructing and maintaining mutual understanding demands more and perhaps different effort. Knowledge construction becomes even more complex if you have limited background knowledge about the other participants in the Web-based environment. To interpret other people's perspectives correctly and thus to be able to collaborate in knowledge construction, it is essential that one should have information about other participants' knowledge, expertise, or group membership (Schober, 1998). For example, students in the same classroom already possess a certain common ground due to previous work experience compared with virtual university courses where students from different universities meet.

Gudzial and Carroll (2002) have offered the term *vicarious learning* to describe what takes place in asynchronous discussion forums. By coining this term, they present a defense of the low rates of discussion. According to them, students are engaged in shared understanding mechanisms, but vicariously. For example, there are few utterances in the discussion forum because the students recognize their own understanding in others and so they do not need to post a note to elaborate. Vicarious learning is, however, in this case computer-supported (or mediated) learning (CSL) rather than CSCL, if one wants to keep to the definition of collaboration described earlier.

Structuring Collaboration to Overcome Challenges in CSCL

Scaffolds

Scaffolds as used in Knowledge Forum (see earlier) are an attempt to structure collaboration in a CSCL environment. Also other examples of scaffolds built into technological systems, such as graphical argumentation tools, can support high-level interaction. Graphical argumentation tools can support collaboration by providing a shared context for students to discuss. With the support of such tools, collaborators construct external representations by selecting them from a limited set of objects and relationships. These are used according to certain rules. These objects are intended to structure, externalize, and coordinate students' ideas in shared communication. They support collaborative problem solving through structuring students' discussions and arguments (Jermann et al., 2004). One example of this kind of environment is a graphical argumentation system called Belvedere, which structures and facilitates students' communication (Suthers et al., 1995). Basically, the system supports group discussion about competing scientific theories. In the environment, students can create boxes and circles that represent *principles*, *hypotheses*, and *claims*, and these can be connected via links such as *explains*, *justifies*, or *supports*.

Scripts

It is argued that the promotion of collaboration requires approaches that help to structure collaborative learning situations as free-form collaboration does not systematically produce learning (Dillenbourg, 2002). One way to structure interactions is to design predefined scripts into CSCL environments. These collaboration or integrative scripts are sets of instructions prescribing how students should form groups, how they should interact and collaborate, and how they should solve the problem (Dillenbourg and Jermann, 2006). For example, to engage students to participate equally in collaboration, one can utilize cognitive diversity by making use of contradictory perspectives and interdependency by giving students different learning materials (Dillenbourg, 2002) or by assigning students reciprocal roles (Arvaja et al., 2003; Weinberger et al., 2005). Scripts may also integrate individual, cooperative and collaborative activities, as well as copresent and computer-mediated activities. Furthermore, scripts can introduce a time frame in distance education where students often have problems with their time management.

The risk of well-defined scripts is over-scripting collaboration. Predefined scripts can interfere with the richness of natural interaction and problem-solving processes. In addition, this kind of *educational engineering* approach can lead to attempting to attain effectiveness at the cost of the genuine notion of collaborative learning (Dillenbourg, 2002). The balance between the benefits and risks of structuring collaboration depends on how the designer aims to foster productive interactions and learning. For example, playing on participants' cognitive diversity and knowledge interdependency fosters different mechanisms than the purely vertical task division in collaborative groups.

Methodological Issues with CSCL Research

Typical research methods used in CSCL include content analysis of networked discussions, different types of discourse analysis, or quantitative summaries of computer-generated databases. Some researchers have also used social network analysis methods to visualize students' participation and roles in CSCL. They report that a social network analysis is an appropriate method for studying structures of interaction and relationships in a technology-based learning environment (Nurmela et al., 2003). These methods offer insight into the content and quantity of students' networked discussions as well as interaction structures at a general level, but they are not capable of revealing the quality of collaborative processes of the network and the ways in which collaborators shape each other's reasoning processes, neither do they reveal individuals' personal experiences or interpretations.

According to Crook (1999), most of the studies that claim to investigate collaboration have actually concentrated on evaluating the quality of collaboration as isolated speech acts (individual notes or postings), even though it reveals little about the efforts for shared meaning. The quality of Web-based interaction has been evaluated through analyzing and calculating the cognitive quality of discourse on individual messages (Gudzial and Turns, 2000). According to Stahl (2002), however, this kind of analysis disregards the content and nature of knowledge construction that may take place in interactions between the participants. Thus, this kind of analysis reflects a research tradition where knowledge is thought to be situated mainly in the heads of individual students, instead of knowledge situated and distributed also in the discourse between collaborators (Hmelo-Silver, 2003; Stahl, 2002).

While seeking methodological accounts for capturing the processes of collaborative learning or community building, we should bear in mind that the analysis of collaborative interaction cannot be isolated from the context in which it is embedded (Crook, 1999). To find out more about the nature of collaborative learning processes and what promotes collaborative knowledge building, different features affecting learning must be studied in the context of the joint activity, i.e., with relation to and in the form they occur in different learning environments. To study collaborative knowledge construction is to make visible the groups' process of meaning-making mediated by the tools used as resources. Typical methods for analyzing these collaborative learning processes include discourse and conversation analysis as well as ethnographical and other qualitative methods.

Salomon (1997) has also stated that it is the whole culture of learning environment with several intertwined variables that influence learning in a fundamental way. Thus, the analysis of CSCL settings should go beyond networked interaction by including the activities in face-to-face settings as well as taking account the history of the students participating in the learning activity (Crook, 2002). Even though the interaction would take place only through the computer, the knowledge construction activity is still grounded into wider contexts and mediated to the discussion by the history of individual students in the form of experiences, background knowledge, and attitudes. Thus, the unit of analysis should be the whole activity system of tasks, artifacts, interactions, symbols, social practices, roles, and community of practice, which absorbs the shared knowledge of the group (Stahl, 2004). In this regard, there is a need for methods of interactive practice such as virtual ethnography (Pöysä et al., 2004).

Conclusions

Recently, Roschelle and Pea (1999) argued that the Web has been over-rated as a tool for collaboration, and the term itself is in danger of losing its meaning while almost any Web facilities for correspondence or coordination across distance are marketed as *collaboration tools*. One can argue that today the days of *hype* have been left behind, and the area of CSCL has established itself as a significant field of research on collaboration and its pedagogical innovations – also outside the field of instructional technology. There are, however, still many challenges to face.

Despite many new innovative ways to support human cognition and learning with technology, the problematic nature of investigating human learning still remains: it is always a matter of complex interaction of cognitive and social factors, motivational and emotional aspects and the features of the learning context. Methodological challenges, then, relate to studying the mutual relationship between the collective and individual notions and to examining the situated dynamics of learning together; how the knowledge construction is mutually enhanced by both individual and collaborative thoughts and conceptions interacting in specific contexts. Thus, there is a need to better understand how individuals' mental processes relate to social and situational factors that influence cognitive performance and learning. Consequently, new methods are needed to capture the process of collaborative interaction and its contribution to learning. Furthermore, such methods should contribute to understanding the process of computer-supported collaboration as part of the wider social context of the participants.

It has been stated that an approach to collaboration solely in terms of face-to-face encounters is a very limited approach to CSCL (Lipponen, 2001). If we want to study collaboration in the sense of shared knowledge construction, however, we should also approach computer-mediated interaction from a perspective that comes from the research of face-to-face collaboration (Baker, 2002; Barron, 2003; Dillenbourg, 1999). As in face-to-face interaction, the basic nature of collaborative knowledge construction in the computer-mediated interaction is *engaging* in the process of constructing and maintaining shared knowledge or understanding. Yet, this is what has been missing when it comes to studying collaboration mediated through computers. Only a few attempts have been made to reveal what goes on *between* participants in computer-mediated interaction (Arvaja et al., 2007; Häkkinen et al., 2001; Lally and de Laat, 2002). In addition, even though there is an agreement of the need to structure students' activities in computer networks through collaborative technology, there still seems to be disagreement about what these needs are and how they should be structured in students' activity. The fundamental question of what collaborative learning is remains dynamic and guides our choices as researchers, designers, and educators in the field of CSCL.

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3.5

COMPUTER CONTEXTS FOR SUPPORTING METACOGNITIVE LEARNING

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Common Metacognitive Learning Outcomes

Some 30 years ago, Brown and Flavell introduced the concept of *metacognition* to the educational research community (Brown, 1975; Flavell, 1976). Metacognition is defined as an awareness of one's own thinking processes and the ability to control, monitor, and self-regulate one's own learning behaviors so that effective problem solving and deep understanding can be reached. Brown et al. (1983) did a comprehensive summary and analysis of metacognitive research. They concluded the analysis by suggesting that a variety of learning outcomes can be produced when people are engaged in metacognitive experiences. For instance, people who are aware of the limitations of their own memory and deliberately use rehearsal strategies recall more than those who are not aware of their own limitations (Wellman, 1977). In terms of content learning and problem solving, the research shows that people are able to apply what they learn in new situations, if they are involved in intentional instruction where they understand how, why, when, and where the new information and strategies are useful (Brown et al., 1983).

A third learning outcome, which has not been given enough attention, is the relationship between social interactions and metacognition. This is particularly important in terms of classroom teaching. Researchers have found that teachers interact with students with good and poor reading skills quite differently. Good readers are questioned about the meaning behind what they are reading, asked to evaluate and criticize materials, and so on. By contrast, poor readers primarily receive drills (McDermott, 1978). What kinds of metacognitive understanding get developed from these different kinds of social interactions for both students and teachers? This is an interesting question to explore.

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In this chapter, we discuss how different types of metacognitive learning outcomes can be developed from different situations and how different situations require different metacognitive skills. We focus on the following learning outcomes: (1) simple recall and memorization of facts; (2) more complex learning outcomes, such as problem solving; (3) domain subject learning; and (4) social knowledge. We then examine how today's computer tools have or have not reached their fullest potential to support these learning outcomes, and we suggest ways that computers tools can be designed to achieve these outcomes.

Recall and Memory

What Research Says

Among the learning outcomes, *recall* seems to get the most attention for a variety of reasons. First, the ability to recall or memorize is sensitive to developmental and learning material changes. Older children remember better than younger ones, and typical children recall better than children with developmental delays. The research also shows that when the materials are familiar and the items are distinct, age differences are minimal (Myers et al., 1987). Second, recall receives a great deal of attention as it is one of the most frequently used assessment measures by teachers, school systems, and national testing agencies.

Metamemory refers to learner awareness about his or her own memory systems and memory strategies. Research indicates that young students and novice learners have difficulty accurately estimating their comprehension and that metamemory strategy instruction should focus on specific strategic knowledge. Metamemory can be divided into two types: explicit and conscious knowledge and implicit and unconscious knowledge (Brown et al., 1983). An example of explicit metacognitive knowledge, which even preschoolers are consciously aware of, is that it is easier to remember a simple and short word than a long and complex word. Such self-monitoring enables people to generate a feeling of knowing that can help them predict how well they will remember later on. However, often, metacognitive knowledge is unconscious. For instance, good readers slow down their reading when the texts become difficult without realizing they are doing so (Siegler and Alibali, 2005).

Research on the relationship between memory and metacognition has been motivated by the assumption that children's increasing knowledge about their own memory and about the strategies they use to facilitate memorization can help them choose more effective strategies for memory. Whether or not metacognition facilitates memory is a somewhat tricky question. On the one hand, research shows that young or learning-disabled children tend not to use rehearsal or other strategies to facilitate their memory because they may not know that their memory capacity is limited (Brown et al., 1983). But once they are trained to use effective strategies, they greatly improve their memory performance. On the other hand, if older students are prevented from using effective memory strategies, they produce levels and patterns of performance that are very similar to younger children or children with learning disabilities. In addition, knowing the relative usefulness of strategies could improve children's strategy choices in a wide range of situations (Brown, et al., 1983; Siegler and Alibali, 2005). This is one of the most robust findings in the developmental literature (Belmont and Butterfield, 1971; Brown, 1975; Kail and Hagen, 1977).

However, metacognition alone may not improve memory – other ingredients need to be in place. These ingredients include developmental capabilities (the ability to associate and recognize things), use of broadly applicable memory strategies (such as rehearsal, organization, and selective attention), and knowledge about the specific content (Siegler and Alibali, 2005). Metacognition can considerably assist memory performance only when each of the ingredients is present (Siegler and Alibali, 2005).

Ways to Improve Memory Performance

There are several ways to help learners become effective in memory and recall tasks. One way is simply to rehearse the facts until they are remembered. This approach usually does not lead to understanding, especially when a task requires application of the facts learned (Brown et al., 1983). More effective ways are to employ different kinds of metacognitive and planful memory strategies, such as elaboration, identifying main ideas, and categorization of strategies (Brown et al., 1983).

Many researchers argue that the application of elaboration, categorization, and generation of strategies are important for comprehension and thus memory performance (Anderson and Reder, 1979; Bransford et al., 1982; Brown et al., 1983). However, the degree to which any of these strategies are successful in improving memory is influenced by the availability of relevant content knowledge (Chi, 1978). Nitsch (1977) showed that when students study the same concept in varying contexts, they are better able to understand the concept in new situations. Research by Hatano and Inagaki (1986) also shows that experiencing varied contexts is important to the development of adaptive expertise. Adaptive expertise is characterized as procedural fluency complemented by explicit conceptual and principle understanding that allows people to adapt what they learn to widely varied situations.

Computers as Metacognitive Tools to Enhance Memory

A program developed by Bransford and his colleagues (Cognition and Technology Group at Vanderbilt, 2000), the *Knock Knock*™ game, offers a promising example of using computers as metacognitive tools to enhance literacy and memory. *Knock Knock*™ helps children become aware of constraints on their own learning that they need to address to be successful with the game. For example, to achieve the best results children have to use broadly applicable memory strategies, such as rehearsal, organization, generation, categorization, and selective attention strategies. They also need to generate simple stories, based on the letters they hear or read. The children will also develop knowledge about the specific content that they are learning – letters, sounds, and story writing. To facilitate metacognitive development, children are asked to estimate how well they will apply the letters to a variety of different situations and discuss their applications with peers. The discussions among peers and with teachers also offer the students social support and help students recognize the usefulness of the strategies in helping them to perform the memorization and the application tasks. *Knock Knock*™ illustrates an approach of using computers to support recall and learning that should help students develop skills that are important for future success.

Content and Domain Subject Learning

What Research Says

In this section, we examine issues concerning the importance of acquiring content knowledge of any given discipline from the perspective of adaptive expertise development. Hatano and his colleagues introduced the concept of *adaptive expertise* in relation to masters in using the abacus. They proposed that abacus masters should be termed as routine experts if they have only developed procedural knowledge and skills about the abacus they learned, whereas adaptive experts understand the principles and concepts underlying the content and skills learned. He and his colleagues contrasted routine experts with adaptive experts, and asked the educationally relevant question of how "novices become adaptive experts – performing procedural skills efficiently, but also understanding the meaning and nature of their object" (Hatano and Inagaki, 1986, pp. 262–263). Procedural knowledge is often only useful for limited types of problems and situations. Comprehending principles underlying problems and content learned enables people to flexibly apply this knowledge to various new situations (Hatano and Inagaki, 1986).

As such, adaptive experts usually verbalize the principles underlying one's skills, judge conventional and nonconventional versions of skills as appropriate, and modify or invent skills, according to local constraints. Wineburg (1998) and others (Bransford and Schwartz, 1999) have added to this list by pointing out that adaptive experts are also more prepared to learn from new situations and avoid the over-application of previously efficient schema (Hatano and Oura, 2003).

A second perspective that Hatano and Inagaki suggested is that in stable environments, participation in one's own culture typically provides sufficient resources for learning and executing routine expertise. People have many pockets of routine expertise where they are highly efficient without a deep understanding of why. To develop adaptive expertise, people need to experience a sufficient degree of *situational variability* to support the possibility of adaptation. This variation can occur naturally, or people can actively experiment with their environments to produce the necessary variability. Hatano and Inagaki (1986) proposed three factors that influence whether people will engage in active experimentation.

One factor is whether a situation has *built-in* randomness or whether technology has reduced the variability to the point where there is little possibility for exploration.

Much software we reviewed often eliminates situational variability to help students focus on the procedural skill. This is particularly true of software aimed at helping students develop literacy and numeracy. For example, many math programs, such as *Math Blaster*™ (http://www.knowledgeadventure.com/mathblaster/), present students with a storyline or game-like interface, but these conceits are meant as a means of motivating students only, and in fact, math learning is presented in a drill and skill format, wholly divorced from any meaningful context in which math may be learned. Likewise, math-tutoring programs, such as Wayang Outpost (http://www.k12.usc.edu/WO/) (Beal and Lee, 2005), while providing a motivating storyline and individualized and helpful feedback to students on the procedure of solving a problem, do not provide varied situations in which the math skills may be needed. This may have the unintended consequence of preventing students from developing variations in that procedure in response to new situations.

The second factor involves the degree to which people are enabled to take *risks* in approaching a task. When the risk attached to the performance of a procedure is minimal, people are more inclined to experiment. "In contrast, when a procedural skill is performed primarily to obtain rewards, people are reluctant to risk varying the skills, since they believe safety lies in relying on the 'conventional' version" (Hatano and Inagaki, 1986, p. 269). Game-like software that provides rewards for successful performance of the procedure or skill will limit risk-taking, thereby limiting students' ability to adapt their understanding to new situations.

The third factor involves the degree to which the classroom culture emphasizes either *understanding* or prompt performance. Hatano and Inagaki (1986) state, "A culture, where understanding the system is the goal, encourages individuals in it to engage in active experimentation. That is, they are invited to try new versions of the procedural skill, even at the cost of efficiency" (p. 270). They proposed that an understanding-oriented classroom culture naturally fosters explanation and elaboration, compared with a performance-oriented classroom culture. Their views also echo the research findings by Bereiter and Scardamalia on the importance of engaging students in a knowledge and understanding-oriented society and their impact on adaptation and human development (Bereiter and Scardamalia, 2000; Scardamalia and Bereiter, 1996). Central to these concerns is people's ability to self-monitor their own understanding at a deep principle level.

Ways Metacognition Can Improve Content Learning and Adaptive Expertise

Neither metacognitive monitoring skills nor content learning alone will do the job of improving people's deep understanding of the subject matter leading to adaptive expertise in a specific domain. Rather, the two work in concert with one another in the following ways. First, utilizing familiar content knowledge improves the effectiveness of using different metacognitive strategies. Second, familiar content facilitates learning of new strategies such as elaboration (Bransford et al., 1982). Familiar content may also serve as "a kind of practice field upon which children exercise emerging memory strategies" (Siegler and Alibali, 2005, p. 262). Third, content knowledge facilitates people's metacognitive development by offering specific data and a context in which to monitor and revise their strategies and procedures. Research shows that metacognition works best when an individual has specific issues to work through (Chi et al., 1994; Lin and Schwartz, 2003). This is because people think best when they have a known specific context to work with (Gay and Cole, 1967). Indeed metacognitive monitoring is often retrospective, capitalizing on a specific past as opposed to a vague future.

Ample research shows that effective metacognitive interventions can improve people's understanding of deep principles that underlie content and problems in a given domain. The majority of metacognitive interventions involve either a strategy-training approach or a contextualizing knowledge and tools approach aimed at supporting students metacognitive monitoring and revision of understanding. In recent years, researchers have also started to recognize the importance of creating social interactions to support metacognition. Each of these approaches will be discussed below.

Metacognitive strategy training: The main purpose of strategy training research is to explore: (a) how specific sets of metacognitive strategies help people monitor conflicting thoughts and build a coherent understanding of a subject domain; (b) how specific metacognitive strategies will help people develop deep principles about the concepts learned; and (c) how different types of instructional supports for metacognitive strategies influence students' engagement in metacognitive activities. Metacognitive strategy training is usually used during the acquisition of either domain-specific or self-as-learner knowledge. Students usually stop at fixed intervals while learning specific subject domains to reflect on and revise their work. The interventions usually do not involve changing the existing school curriculum and classroom culture. The most effective approach to strategy training seems to be prompting students to self-explain or self-question as a way to engage in metacognitive thinking and modeling through social interactions.

The act of explanation helps students become aware of the strategies they are using and the content they are learning. For instance, Siegler and Jenkins' (1989) found children who were aware of using a new strategy subsequently generalized it more to other problems. However, research also indicates that students often fail to check and monitor whether or not they understand the content knowledge they are learning if they are not explicitly trained to do so (Brown et al., 1983). Chi et al. (1994) found that prompting self-monitoring in students leads to such awareness and stronger learning outcomes. Moreover, the prompted students who generated a large number of self-explanations (the high explainers) learned with greater understanding than the low explainers. Chi et al. (1994) reported that such monitoring through self-explanation helped students recognize principles underlying the content and procedures learned, and not just the procedures. This provides an important basis for the development of adaptive expertise (Hatano and Inagaki, 1986).

Researchers have also used video technologies to model effective strategy applications. For instance, Bielaczyc and her colleagues used video to model effective learning strategies employed by good problem solvers in the domain of LISP programming (Bielaczyc et al., 1995). Students were exposed to specific metacognitive strategies and received explicit training in their use. They found that mere exposure to good learning models was not sufficient. The key to the success in their design was to have students experience these strategies in their own learning, explicitly compare their own performance with that of the model, and take actions to revise ineffective learning approaches.

Contextualizing knowledge and tools: Contextualizing content learning and metacognitive acquisition is important in helping people recall and make sense of what they learn. Research shows that people's ability to understand the meaning of the concept learned seemed to depend on cues provided by context-specific situations under which the concept is originally learned (Bransford and Franks, 1976; Nitsch, 1977). This is because contexts provide constraints to the concept learned and enhance the specificity of the encoding (Tulving, 1982). In addition, contexts provide a framework that is needed for people to understand the purpose and significance of learning specific concepts and strategies. This view is consistent with what Brown and her colleagues (1983) call "informed training plus self-control" in which students are informed of the contexts within which the new strategies are most useful. These strategies also enhance self-control skills such as planning, checking, self-monitoring, and evaluation. Without such "conditionalized" knowledge, students face difficulties in using learned strategies in new settings (Brown et al., 1983). The interventions that have resulted in failures of understanding and transfer involve situations where students are taught strategies without understanding *why*, *when,* and *how* they are useful (Duffy and Roehler, 1989).

Computers as Metacognitive Tools to Scaffold Content Learning and Metacognitive Thinking

New computer technologies can provide powerful scaffolds and tools for principle-based content learning and metacognitive thinking by (1) displaying problem-solving and thinking processes (process display); (2) prompting students attention to specific aspects of strategies while learning is in action (process prompts); (3) modeling metacognitive thinking processes that are usually tacit and unconscious (process models); (4) creating social interactions through community-based activities; and (5) bringing exciting curricula on the basis of real-world problems into the classrooms to provide meaningful contexts and purposes for the content learning (Bransford et al., 1999; Lin et al., 1999). Several software programs utilize one or more of these elements in their design.

Process displays: Content-based software programs and online learning environments have been created that feature process display in the design. For example, the Web-Based Inquiry Science Environment (WISE) (http://wise.berkeley.edu/) (Linn et al., 2003) provides students with an inquiry map that displays the sequence of events the student will execute as he/she works in WISE. Therefore, each student can clearly see and reflect upon the activities he/she will perform, including engaging in discussion, gathering evidence, reflecting when prompted to do so, and engaging in hands-on experiments. This type of process display is also utilized in the Digital IdeaKeeper (Quintana et al., 2005).

Process prompts: Betty's Brain (http://www.teachableagents.org/betty) (Biswas, Schwartz, Leelawong, Vye, and TAG-V, in press) is a software program that utilizes teachable agents to help students learn topics in science, such as river ecosystems. The multiple agent approach allows for students to engage with the software environment as both a learner and a teacher. For example, one agent in this program is Mr. Davis, this agent is provided as a mentor to the student using the system. Mr. Davis provides feedback to students in the form of metacognitive prompts including the importance of goal setting, understanding chains of reasoning, and understanding how to self assess one's own learning and knowledge. Meanwhile, the teachable agent in the system, Betty, also incorporates metacognitive prompts by making seemingly spontaneous comments about her own learning, which prompts the student who is working with the software to reflect on how well he/she is teaching Betty.

Process models: iSTART (http://www.csep.psyc.memphis.edu/istart/front.htm) (Graesser et al., 2005) is an agent-based reading comprehension software program that integrates both process prompts and process models in its design. Two of the agents in the system are the Microsoft agents, Merlin and Genie. Merlin acts as a teaching agent and Genie acts as a student agent. In iSTART, Merlin asks Genie a question and Genie provides an answer, the student using the software is then shown a list of five metacognitive strategies and asked to pick which ones Genie used to solve the problem. By picking the strategies Genie used, the students are actively engaged in thinking about the metacognitive process. The software also features a trio of agents (an instructor and two student agents) who interact with one another to simulate and model the utilization of the targeted reading comprehension strategies.

Inquiry Island (http://www.thinkertools.org/Pages/sciwise.html) (White and Frederiksen, 2005) is a science-learning environment that also utilizes a number of design elements to enhance metacognitive understanding including process prompts, model prompts, and collaboration. Inquiry Island is a multiagent environment featuring software advisors related to tasks involved with inquiry, general cognitive, metacognitive, and social aspects of science learning and systems development issues (see Figure 1). The software provides a process display through the organization of the agents. For example, there is a task advisor for each step in the cycle of inquiry (e.g., Hugo Hypothesizer). These agents prompt students about processes through giving solicited advice. The process is modeled through the use of a notebook interface that has tabs for each of the steps in the cycle. Finally, Inquiry Island provides students an opportunity to assess both their own learning and the learning of their peers. Software-enabled peer assessment may assist in the development of a robust learning community.

Social interactions: Knowledge Forum (http://www.knowledgeforum.com/) (Scardamalia and Bereiter, 2006) is an excellent example of a software environment that makes thinking visible through process prompts and develops a community of learners through the interactive nature of the notes system. Students working in Knowledge Forum are prompted to express their theories and to provide evidence in support of these theories. These prompts help students to organize their ideas and to learn scientific argumentation skills. Students may respond to one another's notes

Fig. 1 Inquiry Island Interface

with confirming or disconfirming evidence. In this way, the group works collaboratively to understand ideas and concepts and to build their knowledge.

Real world problems: The fifth design element that supports content learning and metacognitive development is bringing real-world problems into the classroom as objects of inquiry. The Technology Enhanced Learning in Science (TELS) project (http://www.telscenter.org/) (Linn et al., 2006) is a Web-based, online learning environment that focuses on real-world problems (see Figure 2). The TELS project is

Fig. 2 TELS Real World Project Interface

devoted to making unseen science processes visible through animation and other graphical representations, and it emphasizes current dilemmas in science, heightening the real-life appeal of the curriculum to students.

Many of the software learning environments discussed in this section can be utilized to present varied content and learning situations to students. An important research question to pursue in relation to these environments is how they contribute to the development of adaptive expertise in students.

Other software environments for developing students' metacognitive abilities together with content learning are Digital IdeaKeeper (http://www.hi-ce.org/digitalideakeeper/index.html)(Quintana et al., 2005), Autotutor (http://www.autotutor.org/) (Graesser et al., 2005).

Social Interactions as Learning Mechanisms

What Research Says

In recent years, we have witnessed an increasing interest in research on what and how people learn through social interactions. This section reviews several avenues of recent research in social knowledge and ways such knowledge can profit from metacognitive thinking. There are several reasons why knowledge creation is viewed as a social act. First, interaction with other people is a significant catalyst to knowledge and skill building. For instance, there are many active lines of research in developmental psychology showing that adults and older siblings provide pivotal social scaffolding to support children's task performance and knowledge development (Rogoff, 2003; Siegler and Alibali, 2005). Such social interactions allow children to extend the range of their activities and to perform tasks that would be impossible for them to perform alone. However, not all social interactions will lead to improved knowledge and performance. In scaffolding children, adults have to tailor their support to children's level of skill development (Greenfield, 1984; Kermani and Brenner, 2001). Research also shows that social interactions play an important role in children's language development (Siegler and Alibali, 2005).

Second, our own perspectives and knowledge are often broadened and deepened as a result of social interaction. For example, children with siblings perform better on a false belief task than children with no siblings because they have more chances to learn about other people's thinking (Jenkins and Astington, 1996). Studies on social recognition memory show that people's memories benefit more from social interactions and conversations than individual learning, especially for difficult subjects (Wright et al., 2005). This is because social interactions provide more access and perspective cues that can be used to facilitate memory and recognition. People tend to neglect relevant and useful information that they do have in hand when they are left alone to learn and assess themselves (Dunning et al., 2004). Therefore, other people's views can expand metacognitive knowledge about one's own learning and understanding.

Third, social knowledge is important in helping people understand the social world and social interactions. There is evidence that one's behavior with respect to others is influenced in various ways by what one knows (e.g., believes, assumes) about what specific others know. For example, when college students are preparing for a test, knowledge about the instructor can help them anticipate what questions the instructor might ask them and how detailed their knowledge needs to be to pass the test. Knowledge about other people is particularly important in developing harmonious social interactions with others. Such knowledge helps people form mental models about what others know and feel, which can reduce the chance of offending other people and lead to better predictions and understanding about how others will behave and what others are thinking about and talking about in specific situations (Nickerson, 1999). This is particularly important for collaborative learning where communication among group members is critical to the success of group performance. In a series of four experiments, Karabenick (1996) found that participants' awareness of their colearners question asking activity affected judgments of their own and others' levels of comprehension. To coordinate and communicate effectively with other group members, people must have a reasonably accurate idea about what specific other people know and say. This is especially true for teaching. Teaching knowledge about students and parents is critical for teachers to effectively communicate and interact with students of other cultures (Lin et al., 2005).

Ways Metacognition can Improve Social Interactions and Vice Versa

Research literature portrays a symbiotic relationship between metacognition and social knowledge. On the one hand, metacognition has shown to have positive effects on social interactions. On the other hand, certain kinds of social interactions have shown to help people develop productive metacognitive skills.

Meta-social interaction: Meta-social interactions means "…keep[ing] track of how it is going and taking appropriate measures whenever it needs to go differently. Because this last suggests a regulatory as well as a feedback function for the monitoring process…" (Flavell, 1981; pp. 272–273). For instance, social metacognitive comments might include, "I sense that what I said has hurt your feelings" or "why did you say that" or "how did you come up with such a conclusion…" An awareness of what one knows and others know or do not know, and clarifications of group goals and responsibilities, which are metacognitive in nature, have been shown to facilitate social learning (Barron et al., 1998; Lin, 2001; Lin et al., 2007).

According to Flavell (1981), there are four kinds of metacognition that affect social interactions. They are (1) metacognitive knowledge (all the things you could come to know or believe about self and other people or group), (2) metacognitive experiences (any conscious cognitive or affective experiences or states of awareness related to social interactions; e.g., sudden awareness that you do not know what your collaborators are up to), (3) goals and subgoals (the various objectives that may be pursued during a social interaction), and (4) strategies (behaviors one carries out to attain these social goals and subgoals).

What sort of impact can metacognitive knowledge have on social interactions? It can lead one to select, establish, evaluate, revise, and terminate social cognitive tasks, goals, and strategies; it can lead one to take into consideration one's relationships with others and with one's own interests in the social interaction (Flavell, 1981). Metacognitive experiences can be brief or lengthy in duration, simple or complex in content. For instance, you may feel confused about what others are saying or you may feel that others are confused about what you are saying. Such awareness is helpful in strengthening social communication and relationship development because these confusions can be addressed and clarified while the conversations are ongoing (Flavell, 1981). Several studies find that monitoring and regulation of social interactions in group work can help students overcome obstacles in their progress toward successful solution of mathematical problems (Goos, 2002; Goos and Geiger, 1995; Shoenfeld, 1999). Goos (2002) reported that in the classroom, collaborative metacognitive activities were characterized by students offering their thoughts to peers for inspection, while acting as a critic of their partners' thinking. Such reciprocal interaction improved student learning significantly in comparison with groups that did not engage in such social monitoring and regulation.

Social interactions as a means to develop metacognitive knowledge and skills: Research indicates that certain kinds of social interactions can lead to metacognitive development. One way to encourage this is to develop communities where metacognitive discourse and deep understanding are the shared goals. For example, cooperative group work, whether in jigsaw or other approaches, requires that an individual reflect not only on his or her own efforts, but also on how those efforts relate to the group's goals. Alternatively, metacognitive thinking can benefit from social interactions when an individual seeks constructive criticism from a community and modifies his or her practices on the basis of group feedback.

The Fostering Communities of Learners (FCL) program provides an excellent example of developing learning communities to support metacognitive practice (Brown and Campione, 1996). Brown and Campione's interventions brought changes to the social structure in first through eighth grade classrooms in the subject areas of ecology and biology. There are three key components in FCL. Metacognitive activities are embedded in each of the components and are arranged into a learning cycle. The cycle begins by researching a set of topics in a specific domain, moves into sharing the research, and ends by performing consequential tasks to demonstrate learning.

At the beginning of the learning cycle in the FCL model, teachers and students make decisions jointly about which metacognitive activities to engage in, on the basis of the learning tasks at hand. For instance, reciprocal teaching activities (Palincsar and Brown, 1984) are called for when a research group senses trouble in understanding and explaining reading materials. Group collaboration is encouraged when students and adults take turns being the leaders, so that students are exposed to mature modeling of self-control, comprehension, and monitoring strategies and are then given the opportunity to practice these strategies (Brown and Campione, 1996). At this stage of the FCL model students may engage in guided writing and composing activities or in face-to-face or online consultation and reflection with peers or domain experts.

In the sharing section of the cycle, students communicate their research findings with members from other groups, by engaging in jigsaw and cross-talk activities. During cross-talk, the whole class engages in discussion led by both the students and the teacher. They take on metacognitive roles and ask each other to self-assess and report their research findings to date. The learning cycle ends by performing a consequential task, where a variety of forms of assessment are offered. These assessment activities include clinical interviews, transfer tests, and thought experiments. The consequential tasks are intended to help students revise their own learning, understand why they do what they do (rather than following a set of procedures) and provide teachers opportunities for feedback before the next instructional unit.

Computers as Metacognitive Tools to Enhance Social Interaction

Social interaction as a learning mechanism has many potential implications for the design and development of computer technologies as metacognitive tools. One is that people's knowledge can be conceptualized in terms of their ability to perform tasks with supportive social interactions. A second implication is that knowledge acquired through social interactions can be used to expand and deepen one's own knowledge and perspectives, which in turn can enhance social interactions and communications. A third implication is that certain types of social interactions, such as guided participation or scaffolding based on sensitive understanding of the learners, should be emphasized in the computer tool development process. Therefore, it may be valuable to design computer tools accompanied by classroom lessons and other types of educational activities to facilitate these types of social interactions.

Both Knowledge Forum and Inquiry Island are software environments that address these implications. For example, in Knowledge Forum, the emphasis is on community knowledge building (Scardamalia and Bereiter, 2006). Social interaction is an integral part of learning in this environment. Student knowledge building is scaffolded not only through the note prompts discussed in the previous section, but by learning from interaction with peers. In this environment, students learn to consider other's opinions or evidence and to resolve inconsistencies through discussion and argumentation. Likewise, Inquiry Island is an environment that not only emphasizes peer assessment, but also features agents that model social aspects of learning. These agents are the collaboration manager, the equity manager, the communication manager, and the mediation manager (White and Frederiksen, 2005). Students working in the Inquiry Island environment interact with these managers to learn more about how to work together in small groups to solve a problem.

Lin has also been developing a social metacognition software environment called the Ideal Student (see http://www.idealoquy.com/). In this environment, students advise an agent who is portrayed as a new student in their school. The students are asked to give the agent advice on the ideal qualities of a student in their school to help the agent adjust to this school. The ultimate goal of this environment is to make explicit students' social mental models of their school to help both teachers and students become aware of their own social mental models and possible sources contributing to such social mental models (Lin, 2001; Lin et al., 1999; Lin et al., 2005). Such awareness is the prerequisite for changing ineffective attitudes and social mental models. Teachers can also use the software to make explicit their social mental model of the ideal student. The environment gathers and aggregates data from many schools. These data are then available to users of the system. In this way, teachers may compare their own social mental models with their students and with students from other schools, as a result teachers can begin to use such *contrasting cases* to see their own classrooms more explicitly and clearly. This gives them a vantage point from which they can begin to use their knowledge about students to inform classroom instruction.

Another approach Lin and her colleagues are currently experimenting with is an environment that will help students develop knowledge of the self-as-learner (Lin et al., 2005). Their approach is to have students develop a sense of self-as-learner by teaching others in a virtual learning environment (e.g., technology-based social simulations). These *virtual kids* are equipped with many different kinds of personalities. The students' job in the classroom is to teach these virtual kids how to develop appropriate personalities and goals for learning, including self-beliefs, attitudes, and knowledge, for a wide range of learning situations. In addition, students are also asked to create different social environments that support these personalities. It is hoped that by teaching others and creating a supportive virtual environment, students will, in turn, develop a stronger metacognitive knowledge of self-as-learner. This kind of learning may also help students identify factors they need to consider in designing a supportive social environment. There are some exciting research opportunities in this area.

An intriguing question for future research and for software development is: how much metacognitive knowledge can people develop about themselves and the culture of their communities through the use of computer tools? Our view is that ones' culture can make a difference in the development of metacognitive knowledge, and software designed specifically for cultural awareness can highlight important aspects of learning and community practices that affect both teachers and students. Such software can help people see different perspectives and it can aid in an overall process of coming to know one another in a classroom environment.

Conclusion

In conclusion, there are various types of metacognition for different kinds of learning situations. Recall and metamemory, content knowledge and problem solving, and social interactions are all areas of learning that can be improved through metacognition. Recall and metamemory is enhanced through the metacognitive strategies of generation, elaboration, and categorization. The *Knock Knock*™ game is a good example of literacy software that utilizes these strategies.

We addressed content knowledge and solving problems in a domain through the lens of the development of adaptive expertise (Hatano and Inagaki, 1986). In general, content software will be improved by providing the situational variability needed to begin developing the skills related to adaptive expertise. Having noted this, we did find a number of outstanding pieces of software and online learning environments that have been designed to develop student's metacognitive abilities in concert with the development of content knowledge. These excellent environments include WISE (Linn et al., 2003), Betty's Brain (Biswas et al., in press), Digital IdeaKeeper (Quintana et al., 2005), Autotutor (Graesser et al., 2005), iSTART (Graesser et al., 2005), Inquiry Island (White and Frederiksen, 2005), Knowledge Forum (Scardamalia and Bereiter, 2006), and the TELS project (Linn et al., 2006).

Finally, we addressed the social aspects of learning and the role of metacognition in developing certain types of social knowledge. Social knowledge is a key aspect to successful group work and to classroom interactions as a whole. Both the Knowledge Forum and Inquiry Island are excellent examples of software that aims at fostering learning communities. Lin and her colleagues have also been engaged in the development of this type of software. These technology-based social simulations focus on developing both a sense of self-as-learner in the student, as well as an understanding of the social aspects of the learning environment they inhabit. We argue that reflection on this type of social knowledge will aid in the creation of productive classroom learning environments. In summation, an excellent first generation of software environments for recall/memory, content learning, and learning through social interaction has been created, and the second generation may well concern itself with the question of how these environments can be improved to assist in the development of metacognitive adaptive expertise.

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3.6

COLLABORATIVE INQUIRY AND KNOWLEDGE BUILDING IN NETWORKED MULTIMEDIA ENVIRONMENTS

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Introduction

Ever since their introduction, personal computers have been used as educational tools using multimedia to support knowledge construction. Current advances of Internet technology have spawned rapid growth in computing power, bandwidth, and networked learning. The emergence of networked multimedia environments can now support sustained inquiry, collaboration, and knowledge construction involving participants from distant communities. However, despite much enthusiasm and progress, the educational benefits of technology on student learning are assumed but remain unconvincing. Major questions remain to be addressed regarding the integration of learning, pedagogy, and technology for twenty-first century learning.

From an educational perspective, the technological developments are paralleled by the development of new learning theories in the last two decades that posit learning as a social and context-dependent process mediated by material and human resources (Bransford et al., 1999; Brown et al., 1989; Sawyer, 2006). Many researchers argue that more emphasis needs to be placed on having students learn in communities, on collaborative inquiry into real-world problems, and on enabling students to play a greater role in managing and evaluating their own learning (Brown and Campione, 1994; Cognition and Technology Group at Vanderbilt [CTGV], 1994; Linn and Hsi, 2000). Computer-based learning environments, including networked multimedia environments, are usually designed with a view to support such epistemological and metacognitive goals. However, it is proposed here that the integration of networked multimedia environments with classroom processes remains a problem that requires substantial pedagogical

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changes at classroom as well as systemic levels (Salomon, 1996). Such changes are essential for addressing educational challenges for the twenty-first century, an era characterized by a need to prepare students for participation in societies in which citizens' ability to contribute to sustained innovation processes is key (Bereiter and Scardamalia, 2006). To study how to integrate technology with classroom processes, design-based research (DBR) has emerged as a research methodology that examines the interaction among technology, context of implementation, and learning theory (Brown, 1992; Collins et al., 2004), and is becoming an important methodology for research on networked multimedia environments.

The goal of this chapter is to examine progress made in the last two decades toward integrating the use of networked multimedia environments into classroom learning. Our focus is not on the technologies per se, but on how these can support new educational models that emphasize *inquiry, collaboration*, and *knowledge building*; thus, we examine the integral relations of learning, technology, and context. We first review changes in *learning theories* (Section 2) and how these influence *design* of networked multimedia environments (Section 3). Following that, three traditions of work are reviewed, focusing on learning, technology, and educational context (Section 4). All three examples use DBR with iterations of design, implementation, and formative evaluation as the main methodology. Finally, Section 5 discusses the theoretical, pedagogical, and methodological implications for future research.

Changing Theories and Metaphors of Learning

From Knowledge Transmission to Knowledge Construction

Learning in traditional school settings is commonly viewed as the acquisition of bits of knowledge. Early computer-assisted learning based on drill and practice also implied learning as the accretion of information. In the 1980s, research in cognitive psychology focused on expertise and problem solving. Central to this research was the notion of *knowledge structures* – networks of concepts – and substantial research has shown that the knowledge structures students use in thinking about science are inconsistent with those of scientists (McCloskey, 1983). The dissatisfaction with knowledge transmission has led to the understanding of learning as a constructive process involving prior knowledge, metacognition, and collaboration.

In this climate, researchers examined the potential of computers for creating learning environments emphasizing more expert-like learning processes. In *Mindstorms*, Papert (1980) envisaged a new classroom culture characterized by problem solving, creativity, and focus on understanding. Many endeavors are now given to simulation and modeling with computer-based environments (White and Frederiksen, 1998; Jacobson and Kozma, 2000). Other major efforts include the *Schools for Thought* project, which tested three learning models: (a) Fostering Communities of Learners (Brown and Campione, 1994), (b) mathematical discourse and multimedia environment using the *Jasper Woodbury* series (CTGV, 1994), and (c) knowledge building using *Knowledge Forum* and progressive discourse (Scardamalia and Bereiter, 1994). The power of networked multimedia learning does not merely focus on technologies but on the understanding of how people learn that underpins their design.

From Information Exchange to Transformative Communication

Early computer-supported learning environments were based on a transmission model of communication, and this model continues to dominate the provision of online education, in which ICT is used to share information and ideas. However, it is now clear that a conception of communication as the *transmission* of information is no longer adequate. Pea (1994) argued that "because learning is not only a conserving enterprise, which seeks ritual belonging in order to perpetuate sameness and tradition, it is also *a quest to expand the ways of knowing*. It seeks to expand the problem niches to which past concepts and strategies and beliefs are applied. It must establish in its communicative activities the grounds for its own evolution." (p. 288, emphasis added). Pea, therefore, proposed a *transformative* view of communication in which the sender and receiver interact and create something that was not part of the information exchanged. In other words, communication is generative and changes both the sender and the receiver. In the context of ICT, we need to be wary of communication as the movement of packets of information down the *Information Highway*, and to additionally examine the extent to which such movements stimulate knowledge construction.

The design of many computer environments has focused on the transmission of information. More recently, online discussion has come to be viewed as students participating in a community; however, in a deeper sense, one may need to consider further how environments can be designed to support learning for transformation purposes. The idea of movement of information is still useful, as one cannot have communication without the movement of information, but it is not sufficient for explaining learning. We need to examine how students are engaged in meaning-making and how technology can be designed to support it.

From Individual Learning to Knowledge Communities

Earlier cognitive theories of learning were primarily theories of *individual* learning; over time these models have gradually incorporated *social* aspects of cognition, especially the role of *discourse*. Since the 1990s, cognitive and individual perspectives on learning have been expanded and integrated with perspectives that make social aspects of learning more prominent. There are now various models and perspectives emphasizing the social, distributed, and collective nature of learning including situated cognition (Brown et al., 1989), distributed cognition (Salomon, 1993), learning communities (Brown and Campione, 1994), activity theory (Cole and Engeström, 1993), and knowledge building (Bereiter, 2002; Scardamalia and Bereiter, 2006). In addition, studies of learning in nonschool settings led to perspectives that emphasize participation in social practices, for example studies of scientific laboratories (Latour and Woolgar, 1986) and communities of practice (Lave and Wenger, 1991).

The paradigm shift toward social aspects of learning is fundamental and underpins current developments in computer-supported learning. Rather than primarily studying individual problem solving, researchers now examine collaborative learning by groups of students, supported by computer technology. The multidisciplinary field of computer-supported collaborative learning now examines how computer-mediated collaboration scaffolds learning and understanding (Koschmann et al., 2002). These developments, as well as the growing influence of sociocultural perspectives, led to educational perspectives and metaphors positing learning as *participation* vs. views of learning as *knowledge acquisition*. Some progress has been made to integrate them. As Sfard (1998) argued, we need both of the metaphors. Paavola et al. (2004) further proposed a *knowledge-creation metaphor*, in which "the emphasis is not just on the situatedness of cognition or on social practices alone, but rather on development of knowledge-building practices and artifacts through mediated activities" (p. 570). Brown (2008) discusses these metaphors extensively in this handbook.

Twenty years ago, Cuban (1986) argued that educational technology had at that time failed to deliver on its repeated promise to transform education, beginning with film strips, radio, television, educational videos, and computers. The criticism is still levied against computer-supported learning. However, we propose that we are currently in a better position to advance from this state of affairs. First, it is now recognized that attention to the learning process must come first and the integration of technology into this process second. The crucial question is not what technology is needed to support existing educational practices but to develop *a deeper theoretical view of learning and teaching* and to examine how ICT can be used to support the new envisaged learning process as a mediational tool. Second, the research summarized above has shown that learning is very complex. To understand the impact of ICT on learning, we need to measure not only cognitive outcomes but also a wide range of moderating factors such as motivation, metacognition, epistemological understanding, and classroom processes (Bransford et al., 1999). We also need to examine learning on multiple time scales – from microanalyses of interactions occurring during learning activities to studies of long-term effects on students' thinking. Third, it is widely recognized that a new methodology is needed in which technology development and theory building stand in a dialectical relationship to each other, and educational innovations need to undergo iterative cycles of design, implementation, and formative assessment. This methodology, design-based research, though still in its formative stages, has become one of the main methodologies for research on computer-supported learning (Collins et al., 2004).

Views of Learning Underpinning Multimedia and Networked Learning Environments

In this section, we propose a scheme illustrating how changing views of learning influence the design of multimedia and networked environments that vary from (a) information delivery, (b) task-based learning, (c) inquiry-based knowledge construction, and (d) community-based knowledge building (Table 1). We discuss multimedia and networked learning separately to show the parallels of how designs of technology are influenced by changing views of learning while noting that multimedia and networked learning usually coexist in learning environments.

Views of Learning and Multimedia Learning Environments

Multimedia learning encompasses complex dimensions but basically refers to the combined use of words and pictures for enhancing learning (Mayer, 2005). There is much interest in the capabilities of multimedia environments whether using stand-alone or networked computers that can provide access to wide-ranging knowledge represented as text, graphics, video, and visual information. Early use of multimedia often involved drill-and-practice and *information delivery*, in which information was merely transmitted in a more engaging way; more recently such practices have been extended to the Internet (e.g., by posting powerpoint slides on websites). Though technology is used, we propose that such uses of multimedia tend to reinforce a transmission view of learning and take little advantage of their potential to support deep learning.

Table 1 Changing views of learning and design of networked multimedia environments

	Information delivery	Task-based learning	Inquiry-based knowledge construction	Scientific and knowledge communities
Multimedia learning	Drill and practice; reinforcement and response strengthening; multimedia used for presenting information in a more engaging way	Task and multimedia design; principles of coherence, continguity, and modality; matching design with task demands	Simulation, visualization and modeling for knowledge construction; support for conceptual understanding, inquiry process, and metacognition	Community and networked-based environments; distributed multimedia, and telecommunication for scientific practice; multimedia as collective conceptual artifacts; knowledge management for collective knowledge advances; networks of networks
Networked learning	Web sites and portals for access to information; delivery and exchange of information via Internet	Communication and interaction; online learning forums; structure and sequencing tasks	Scaffolds for collaborative inquiry and scientific argumentation among groups, classes, and networks	

Some researchers examine multimedia learning focusing on task-based learning and instructional design of multimedia. On the basis of two decades of research, Mayer and colleagues (2005) developed a theory with principles of how to arrange multimedia elements such as maximum coherence and contiguity (e.g., coordinating computers-generated animation and narration). Different media have various affordances, which need to be matched to the task demands. These researchers acknowledge generative and constructivist learning and active roles of students but they focus on task design and knowledge acquisition, using multimedia rather than inquiry-based learning.

With current emphasis on knowledge construction and inquiry, multimedia environments designs address knowledge structure, conceptual models, and strategies. Kozma (2000) discussed how multimedia affordances are particularly useful to promote learning of complex science concepts. Novice learners tend to rely on surface features and therefore have difficulty understanding science. Using multiple representations with simulation, animation, and modeling, researchers can design tools and environments with features that correspond to the underlying scientific entities and processes. For example, in ThinkerTools (White and Frederiksen, 1998), researchers designed environments using simulation to help students represent abstract entities that do not otherwise have a concrete character (e.g., force). Many scientific concepts and processes that are difficult to learn can now be made explicit and visible using conceptual models with multimedia affordances.

From a constructivist perspective, multimedia learning is often connected with roles of student agency, reflection, and collaboration, and it is students themselves who need to create coherence among different representations. Kozma (2000) showed that student think-aloud, as well as the combined effects of visualization and discourse could improve student learning in multimedia learning environments. In classrooms, roles of multimedia and discourse have been demonstrated well. An early and impressive example was the Jasper Project (CTGV, 1994) in which a multimedia presentation of an authentic situation (e.g., riverboat adventure) set the stage for (*anchored*) mathematical discourse and problem solving. This project was an early example of the use of design-based research to articulate design principles. More advanced views of learning involve using advanced networked learning technologies to support collaboration, discourse, and knowledge building in *communities* (see next section).

Views of Learning and Networked Learning Environments

Networked learning is emerging rapidly and one possible definition is "learning in which ICT is used to promote connections between one learner and other learners; between learners and tutors; between learning community and its resources" (Goodyear et al., 2004, p. 1). Similar to the design of multimedia learning, networked environments are influenced by different views of learning. At a basic level, networked learning is considered as the dissemination and exchange of information reflected in the widespread use of websites and portals. There is also frequent use of bulletin boards and forums for sharing and exchanging opinions. Similar to traditional forms of multimedia learning, these practices are based on views of learning as transmission and information exchange.

Another perspective on networked learning focuses on instructional design for communication, interaction, and knowledge acquisition. Common examples are online discussion forums, which are designed to promote interaction among students and teachers. Collaborative learning via a network may change the way students and teachers interact, enhance learning opportunities, and facilitate classroom discussion. Yet there is considerable evidence that student discussions in such forums are shallow and fragmented (Lipponen et al., 2003); some researchers argue for instructional designs that include sequenced tasks and structured guidance such as scripting to address these problems.

With changing perspective on learning, other researchers and designers focus on collaboration, inquiry, and knowledge construction. Though the early computer-based instruction focused on problem solving by individuals, a central current theme is to examine collaboration in computer-supported environments (Stahl, 2006). Computer-supported collaborative learning has emerged as a major strand of research (Koschmann et al., 2002) with major efforts to theorize collaboration and designing support to encourage discourse, inquiry, and knowledge construction. Considerable work has been done to help students develop scientific inquiry and discourse, using graphical representation of argumentation structure (e.g., *Belvedere*, Suthers, 2003; http://www.lilt.ics.hawaii.edu/lilt/).

A more advanced perspective of networked learning focuses on collaborative knowledge building in *scientific and knowledge communities*. Networked and multimedia capacities are integrated; researchers now use multiple tools and organize discourse around conceptual and physical artifacts in networked multimedia environments. Asynchronous discussion and telecommunication foster collaborative inquiry among students and sometimes even experts from different schools and countries. Going beyond communication and inquiry, some researchers use networked multimedia technology to support students' knowledge building in communities (Scardamalia and Bereiter, 2006); this perspective goes beyond collaboration focusing on *collective* growth. A new metaphor of learning has been proposed that examine learning as knowledge creation (Paavola et al., 2004).

Classroom Innovations and Networked Multimedia Environments

In this section, we discuss three traditions of work in education research that make innovative use of networked multimedia environments: knowledge integration framework, collaborative visualization (CoVis), and collective knowledge building. Although these have different emphases reflecting various metaphors, all three examples focus on efforts to make collaborative inquiry and knowledge construction more prominent in education, as called for by the *National Science Education Standards* (National Research Council [NRC], 1996), and build on studies of cognition, metacognition, and epistemological understanding (Bransford et al., 1999). They all employ design-based research as a method for examining innovations in classrooms, and involve partnerships among researchers, scientists, teachers, and designers. We selected these environments to illustrate the range of approaches examining the integration of learning theories, technology and curriculum, and to examine how these environments enable collaborative inquiry and knowledge building (also see Tan et al., this volume).

Knowledge Integration Environment and Scientific Inquiry

Marcia Linn and colleagues aim to scaffold scientific inquiry and understanding supported by technology (Linn et al., 2004). These researchers argue that science as taught in school is inaccessible to the majority of students, and aim to bridge science taught in school to problems from everyday life (Linn et al., 2004, p. 3). The *knowledge integration* perspective builds on research on students' misconceptions and development of scientific inquiry and argumentation skills; the key notion is to develop a *web of knowledge* that integrates such elements as evidence from information sources, experiments, personally held beliefs, and personal experience through a constructivist process of sense-making (Linn and Hsi, 2000).

In the knowledge integration perspective, students engage in inquiry using information from the Internet, and they work through problems and controversies connected to the curriculum that enable them to construct conceptual knowledge about science. Linn and colleagues design scaffolds for inquiry (procedural, cognitive, social), arguing that inquiry is like a guided tour that helps students to examine science concepts in ways that are relevant to their lives. Focus is placed on well selected scientific inquiry tasks that are relevant to the prescribed curriculum. While emphasizing scientific knowledge, knowledge integration promotes scientific inquiry via modeling and scaffolding emphasizing use of evidence and scientific argumentation.

This tradition developed from several earlier projects by Linn and colleagues (Linn et al., 2004; Linn and Hsi, 2000): the Computer Learning Project (CLP), Knowledge Integration Environment (KIE), and Web-Based Inquiry Science Environment (WISE, see wise.berkeley.edu); it has made extensive use of integrated networked and multimedia learning, and pioneered the use of computers as tools for visualizing scientific phenomena. Various technologies were developed to scaffold scientific inquiry, including visualization, information ecologies, online guidance, argumentation, and discourse tools. For instance, in *probeware*, the use of real-time data collection and visualization reduces the drudgery of data collection, plotting graphs, and thereby provides more time for interpretation (Linn and Hsi, 2000, p. 49); students use *SenseMaker* argumentation software to ensure that their explanations are not merely based on selected evidence but on *all* the evidence available to them (Bell and Linn, 2000). Multimedia and collaboration tools are integrated as students engaged in argumentation examining the evidence. Earlier tools for asynchronous online discussions used to help students learn from each other were *Multimedia Kiosk* and its Web-based sequel, *Speakeasy* (Hoadley and Linn, 2000; Linn and Hsi, 2000).

This tradition of work provides one of the most prominent examples of design-based research for the long sequences of design, formative evaluations guiding revisions to the designs after each implementation, and a large set of design principles. For over two decades, Linn and colleagues have also employed a partnership model establishing activity structures and networks for teachers, researchers, scientists, and technologists to design and refine designs. As well, Linn and colleagues developed sets of design principles integrating the use of networked multimedia environments with curricula in classroom context. At the core of KIE are four general pedagogical principles: (a) make science accessible by connecting to what students know; (b) make science visible by explaining scientific processes and illustrating connections; (c) help students learn from each other by building respectful and effective collaborations in the classroom; (d) promote lifelong science learning by supporting project work, and reflecting on scientific ideas (Linn and Hsi, 2000).

In sum, this research program, through a large series of studies, has led to a perspective on science learning – the Integrated Knowledge Perspective – described through four metaprinciples and a number of subordinate principles. This perspective has been developed from work in complex classrooms, using carefully sequenced inquiry projects. The researchers work from the assumption that scientific inquiry is complex and is not natural for students, and that it requires scaffolding using a variety of computer-supported tools and pedagogical strategies. In this respect, it can be said this research program is not *about* technology but about cultivating scientific inquiry as a strategy for lifelong learning; it provides a strong example of how cognition, curriculum, pedagogy, and the use of computer technologies can be integrated.

CoVis, Telecommunication and Scientific Practice

A second major model illustrating advanced use of multimedia networked learning via telecommunication is the *Collaborative Visualization Project* CoVis (see http://www.covis.northwestern.edu). This project addressed scientific inquiry through collaborative project work with advanced networking technologies, collaborative software, and visualization tools. Whereas knowledge integration emphasized constructive understanding, CoVis focused on developing scientific *practices*, using project work best illustrated by the *participation* metaphor. Through the use of collaborative and communicative technologies and project work, these authors aimed to transform science learning to resemble authentic practices of science.

Collaboration and Visualization: The key idea of CoVis was the use of interactive multimedia technologies connected via a network (Pea and Gomez, 1992). Distributed multimedia environments and network capacities made it possible for participants to express what they are thinking, to capture traces of those thoughts in new forms of representation, and to work jointly to create new artifacts. As participants work on joint artifacts, they engage in *conceptual learning conversations* (Pea and Gomez, 1992), in which they use symbols and terms in authentic situations to develop shared understanding.

There were two main kinds of tools: *scientific visualization tools* that use graphics, images, and motion to present large quantities of data; and *collaborative software* designed to support students as they conduct scientific inquiries as members of a community. Researchers aimed to have geographically dispersed teams of students work together on project-based scientific investigations with teachers and scientists as guides. For example, the *Collaboratory Notebook* was a groupware application designed to support students' collaboration in science projects. By using the Notebook, teachers and students could plan and track the progress of a project together; they also could share and comment upon each other's work. The collaboration tool was *tightly integrated* with the visualization software: all the visualization tools automatically generated a log of the experimenting process; students could annotate the log and put it in Collaboratory Notebook with comments for reflection and collaboration.

Technology-Supported Inquiry Learning: In a follow-up project, Technology-Supported Inquiry Learning (TSIL), Edelson et al. (1999) examined how to design technologies and curriculum to take advantage of scientific visualizations. These researchers developed, tested, and refined versions of software and accompanying curricula. The most important lesson learned was that "the implementation of TSIL requires an *integrated process of technology and activity design*. Specifically, to meet the challenges of inquiry-based learning, the TSIL design process must coordinate components that are integral to the student's learning processes including (a) the identification of motivational context, (b) the selection and sequencing of activities, (c) the design of investigation tools, and (d) the creation of process supports" (p. 440).

Telementoring and telecommunication: Another project for developing authentic science practices premised on transformative communication is telementoring (O'Neill, 2004; http://www.learningrelationslab.org). Working within a community of practice model, the telementoring model envisages students as newcomers to scientific practice to be advised in their inquiries by experts and mentors. Besides *enabling* and scaffolding inquiry, such models have considerable potential for teaching students about *what scientists do* as students develop relationships with scientific experts. Although in the past tapping into scientific expertise was highly impractical, networked communication via the Internet has changed this. At its core, telementoring is about building *learning relationships* with experts. O'Neill (2004) explored the benefits of building *social capital* (i.e., multiple relationships with others that constitute distributed expertise) by opening up the student–mentor relationships so that students and telementors can learn from the interactions of other collaborations besides their own. Telementoring presents another model of inquiry that may overcome problems of authenticity positing students as *little scientists*. The various relationships students build with scientists through telementoring may help to create more positive models for students regarding what scientists do and why it is valuable to society.

In sum, CoVis and related projects involved hundreds of teachers and thousands of students as researchers in *education testbeds* (Gomez et al., 1998). Although design experiments are now common forms for refining the design in individual or several classrooms, these researchers also examined the issues of scalability. These projects emphasize science inquiry as participation and developing authentic science practice, and distributed multimedia environments are used to make possible a transformative form of communication.

Knowledge Forum and Knowledge Building

A third tradition of work focuses on *knowledge building*, now identified as one of the five major models in the learning sciences (Sawyer, 2006). The Knowledge building model aims to address new educational goals in the twenty-first century addressing the need of citizens to work with and to produce knowledge. Bereiter and Scardamalia (2006) argue that schools need to provide students opportunities to work with ideas, and to create and innovate as members of knowledge-building communities. As in scientific communities, ideas are viewed as *conceptual artifacts* that can be examined and improved by means of public discourse within a knowledge-building community.

Knowledge building, an educational model that embodies the *knowledge creation* metaphor (Paavola et al., 2004), has roots in cognitive studies of expertise and intentional learning (Bereiter and Scardamalia, 1993; Chan et al., 1997; Scardamalia and Bereiter, 1994). As collaborative inquiry, knowledge building encompasses the cognitive benefits of scientific inquiry (Edelson et al., 1999) and learning how to learn. However, collaboration in knowledge building goes beyond working with others; it encompasses notion of *collective cognitive responsibility* for advancing the frontiers of knowledge. Similar to scientific communities, when students engage in knowledge-building discourse, they pose cutting-edge questions that help the community to advance its collective understanding. They take on progressive problem solving, in which they progressively seek to understand problems at deeper levels. Students make progress not only by improving their personal ideas but through their contribution to *collective knowledge advances*.

Integral to the knowledge-building approach is the use of an online environment, Knowledge Forum™ (http://www.knowledgeforum.com, formerly CSILE, Computer-Supported Intentional Learning Environments). Designed in the 1980s, CSILE was one of the forerunners of networked multimedia environments. It consisted of a multimedia database created by the students who wrote about their ideas and used graphics supported with cognitive prompts (*scaffolds*) such as "I Need to Understand" or "My Theory." Students could read each other's notes (messages) and comment on them; they could extend the knowledge-transforming process by returning to their own ideas, and the process was supported by codevelopment of the ideas by their peers. Knowledge Forum is designed to help students to refine, reframe, and advance their ideas. When writing a note in Knowledge Forum, students can add other notes as references, thereby creating an integrated web of notes (ideas) as their work progresses. The visual linkages between ideas provide multimedia objects created and refined by students that reflect the interconnected, dialogical, and progressive nature of knowledge that underpins the knowledge-building perspective. Discourse aimed at improving ideas is an important component of knowledge-building discourse that is often absent when online work is conceptualized as an online version of conversations (van Aalst, 2006).

The notion of improving *a community's collective knowledge* was central to the design from the beginning. In knowledge-building classrooms, students pose questions for inquiry and work collectively to question, examine, and improve their collective understanding through discourse supported by Knowledge Forum. In the last two decades, knowledge building has been examined using a design-based approach in classrooms with close collaboration among teachers, researchers, scientists, and technologists for continued improvement of knowledge-building theory, design, and practice (Scardamalia and Bereiter, 2006). Scardamalia (2002) proposed a system of twelve knowledge-building principles to inform design, pedagogy, and research including epistemic agency, real idea/problem, idea diversity, improvable ideas, rise above, community knowledge, symmetrical knowledge advances. Different strands of research include knowledge-building inquiry and discourse (Zhang et al., 2007), design principles for knowledge building (Hewitt and Scardamalia, 1998), and assessment of knowledge building (Lee et al., 2006; van Aalst and Chan, 2007).

The knowledge-building model is now implemented in many schools, organizations, and workplaces in different countries; efforts to implement and develop it are supported by the Knowledge Society Network, a knowledge network of researchers, teachers, scientists, designers working together to examine knowledge creation and technological advances (http://www.ikit.org). The knowledge-building perspective addresses the twenty-first century challenge by focusing on knowledge creation and collective work; it is not just about technology but about designing a new model of thinking and education (Bereiter, 2002; Bereiter and Scardamalia, 2006).

Theoretical, Pedagogical, and Methodological Issues

This chapter has examined how networked multimedia networked environments can be used to support and advance new educational models, which emphasize inquiry, collaboration, and knowledge building. We reviewed these three traditions because they reflect different metaphors, and they all involve sustained efforts integrating technology in classroom and school systems. These developments may help address the challenge of realizing the benefits of technology in classrooms, and we discuss lessons learned pertaining to theoretical, pedagogical, and methodological issues for integrating technology in classroom context.

Theoretical Implications and Issues

Primarily, research on networked multimedia environments supports and illustrates contemporary theories of learning – knowledge is not merely received but socially constructed, distributed, and situated in communities. A review of various education approaches has pointed to different emphases of what inquiry and knowledge construction entail. While they all encompass different facets of learning, we suggest the knowledge integration focuses more on constructive processing reflecting *knowledge acquisition*; CoVis focuses on *participation* and authentic science practices supported by telecommunication; and knowledge building examines collaboration as adding value to the community focusing on *knowledge creation* through progressive discourse (Paavola et al., 2004; Sfard, 1998). By examining different models and networked environments, one can gain a deeper view of different perspectives of learning. It would be difficult to compare the environments in terms of their relative effectiveness because of the different contexts and goals; they provide a range of approaches for *theorizing* and *enriching* learning.

Review of these networked multimedia environments also helps to illuminate theories of collaboration. For example, investigation of collective knowledge-building supported by Knowledge Forum can help us to theorize the notion of *collective agency* and provides further insight into what *collaboration* means. Traditionally, metacognition is individual-based, focusing on how individual learners reflect on personal learning and knowledge; with collaborative learning in these environments, we now need to consider *social metacognition*, in which students reflect, monitor, and take control of group cognition and knowledge creation in the community. As well, in networked multimedia environments, new kinds of collaborative learning will arise from collective work with communal data and objects not present before. Specifically, teamwork often involves the use of a complex symbolic representational system in discourse, providing the participants the *objects* about which they can engage in conversations about complex conceptual entities. Collaboration in telecommunication contexts would provide new meanings to collaborative representations as students jointly make meaning. How collaboration takes on new dimensions expanding the nature of learning in the twenty-first century needs to be investigated.

The different models and approaches also highlight different forms of scaffolding. In the knowledge integration perspective, scaffolds are used to help students to understand the tasks (e.g., procedural, social); in CoVis scaffolds help students in their reflection (for example, scaffolds in Collaborative Notebook help students to reflect and keep track of the process in collaborative inquiry); and in Knowledge Forum scaffolds are epistemic (e.g., a better theory, putting our knowledge together) and help students with theory building. Although scaffolds are usually considered to make learning tasks more manageable, some scaffolds used in knowledge building could make thinking more complex. Reiser (2004) questioned the nature and meaning of scaffolds and considered their different purposes for structuring as opposed to *problematizing* learning. These different uses and designs prompt us to consider what scaffolding is really about. The design of the networked multimedia environments points to the need to develop theories of scaffolding that can further support students' collaborative inquiry and knowledge building.

Pedagogical Implications and Issues

We have used a scheme illustrating how technology is influenced by changing views of learning (Table 1) and argue that more awareness is needed of the epistemologies underpinning their development to guide classroom designs. Furthermore, classroom practice can be enriched with design principles derived from iterative classroom studies. Although there are different emphases, all traditions consider cognitive, social, and technological dynamics for promoting metacognition, collaborative inquiry, and scientific practice in research communities; they all highlight the importance of developing rich knowledge and inquiry, and tackling complex understanding in rich domains. There also are different emphases. For example, knowledge integration focuses more on cognitive and conceptual principles (e.g., making science accessible) whereas knowledge building emphasizes socio-cognitive dynamics and building of community knowledge (Hewitt and Scardamalia, 1998). For classroom practice, knowledge integration uses sequences of projects for scientific inquiry; CoVis emphasizes open-ended project work; and in knowledge building, learning designs are most emergent. There may be different learning goals and contexts and understanding of various design principles can enrich classroom practice.

For pedagogical and technological change to take place, we also emphasize the roles of student and teacher epistemology. Iterative design studies can show that emphasis is not on technology per se: emphasis is given to the understanding of *student models* of knowledge as well as the cognitive and collaborative strategies students use in multimedia-networked environments. Teachers need to be aware of how students jointly make meaning; it is not just the capabilities of these environments but how students make sense of the activities enabled by technology that matters. It is clear now that successful use of networked environments does not merely hinge on changing the technology or instruction; it requires that teachers reflect on their beliefs. Teachers need to change from seeing students as information receivers to valuable contributors of knowledge; they also need to change from providers of information to colearners with students in knowledge-building communities. How changes in epistemological and pedagogical shifts can take place are critical issues that need to be explored.

There also are issues of *sustainability and scalability* that need to be addressed for impacts of technology in education. All three of the traditions of work we discussed involve hundreds to thousands of teachers, researchers, and scientists working together in teacher and knowledge networks. Many challenges exist about how innovative practice can be scaled up and sustained in ways they are intended and how teachers can be prepared for new modes of networked multimedia learning. However, networked multimedia environments also provide opportunities. Not only do students learn from each other, teachers can learn from each other in building new knowledge. Taking the theoretical underpinning of knowledge building, teachers and students need to be transformed by means of their own goals and activities and collectively build new knowledge about innovative practices in communities.

Methodological Implications and Issues

Research on the use of networked multimedia learning in classrooms is complex. How can researchers conceptualize, design, and assess roles of learning and understanding? We consider methodological issues relating to *diversity, context,* and *scope*. First, the field is complex and diverse; not only are there different conceptual models and frameworks, researchers also use different methodologies such as experiment, cognitive analysis, case study, ethnography, and design-based methods. These different models, frameworks, and approaches make the comparisons of learning environments difficult.

Nevertheless, it may be useful to note that different methodologies can provide varied ways to examine the nature and roles of technology and cognition in context.

In this chapter, we have emphasized using design-based approach to study learning and cognition and technology development in *classroom context*. Design-based approaches address the dialectical relations between theory and design. They enable the researchers and teachers to work with multidisciplinary teams in designing the environment, while simultaneously studying the phenomena including student and teacher learning in the complex environments. All three educational models made use of design-based studies over several decades for designing and examining innovative practices in the classroom. This method also provides possibilities to address issues of relevance when teachers work with researchers jointly to examine problems of technology integration in classroom. Although highlighting the value of design-based approach for studying innovations, problems need to be acknowledged. For example, design-based studies are complex and often efforts to document changes and improvements over iterations of designs may not be systematic. Design-based studies are most suitable for tuning designs in classrooms but with increased need to examine scalability, and there is also a need to develop methodology to study change in systems and networks.

We also need to consider the *scope* of inquiry as methodology is related to theoretical and technological advances. We now understand that learning cannot just be measured with academic performance; a complex array of factors and indices need to be examined to trace progress of learning, cognition, and understanding. The three educational approaches reviewed examined different facets of learning, including cognition and social dynamics of learning and classroom activities and systems. It is also realized that we need to study collaboration on different time scales ranging from a few minutes to several weeks or much longer. Despite various complexities, technology also opens up much wider possibilities for research on learning. For example, we can now have detailed traces of students writing (and thinking) on the computer and video research has opened up new possibilities. The complexity of examining learning, technology, and context requires continued examination of new methodological possibilities for making progress.

In summary, this chapter addresses the question of how networked multimedia environments can meet new goals of education supporting inquiry, collaboration, and knowledge building, and how they can improve our understanding of the learning processes. We argue for the need to examine the complex interrelationships among cognition, technology, and context in addressing the challenge of making ICT relevant for education. This chapter reviewed changing perspectives of learning and considered how the design of technology reflects these changing views. We then examined how theory and design evolve in classroom context relating to three innovative examples for addressing new goals of education. These three approaches have different emphases but they all share the commitment of advancing student inquiry, collaboration, and knowledge construction for twenty-first century learning while illuminating the learning processes in complex classroom context.

There are many challenges and new possibilities with realizing the potentials of technology in education. We propose that technology needs to be informed by learning theories, and student learning process can be illuminated with investigating how technology is used in classroom context. The need for theory–design–context integration also calls for new methodological approaches. In this chapter, we have emphasized design-based approach – researchers are not just describing classroom change or testing the effectiveness of environments, they are designing for change while examining theory and design in classroom context. There needs to be the development of a classroom culture focusing on inquiry, collaboration, and knowledge building as well as fundamental changes in pedagogy and epistemology.

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Section 4

IT COMPETENCIES AND ATTITUDES

4

IT COMPETENCIES AND ATTITUDES

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Section Editors

Since the early days of Information Technology (IT) use in education, attitudes and competencies of students (and later teachers) have been in the domain of interest of researchers, because they appeared to be an important factor in the decision to use IT in educational practice. In 1995 the US Office of Technology Assessment (US Congress, 2002) reported that helping teachers "effectively incorporate technology into the teaching and learning process is one of the most important steps the nation can take to make the most of past and continuing investments in educational technology" (p. 8). Most researchers agree that the successful use of computers in the classroom is dependent on positive attitudes toward computers (Lawton and Gerschner, 1982; Woodrow, 1992). IT standards have now been established in the USA (Thomas and Knezek, 2002) and other nations, reflecting the importance of positive attitudes as well as adequate competencies in successful technology implementations in education.

In this section six chapters are presented spanning (1) IT in education issues, (2) standards, (3) self-report findings, (4) observation findings, (5) student attitudes and competencies, and (6) emerging characteristics of teacher leaders in IT.

In Chapter 4.1 attitudes and competencies are presented as key intervening variables influencing IT-grounded teaching and learning. Instruments and methods for gathering data as well as formal models for representing associations among many variables are presented.

In Chapter 4.2 authors point out that information and communication technology (ICT) has made its way into industry, communication, education, work, and even recreation. To address this educational need, ICT should become an integral component of students' educational experiences and, henceforth, every teacher's and education leader's professional skill set. The International Society for Technology in Education has developed sets of performance standards describing ICT knowledge and skills for student learning, teaching, and school administration. The standards development process included a wide range of educational stakeholders and resulted in the publication of the USA National Educational Technology Standards for students, teachers, and administrators.

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Chapter 4.3 focuses on self-report findings regarding IT attitudes and competencies related to education. For teachers, positive attitudes, competencies, and self-efficacy are important components of highly integrated use of technology in the classroom. Access is important —as well as attitudes and competencies. For students, attitudes and competencies are largely not a concern in the twenty-first century, except for students who have no access to IT at school, and also none at home. Evidence is emerging that this class of students is at a disadvantage in academic subjects as well as in technology skills.

Chapter 4.4 provides insight into how observational measures can contribute to the study of attitudes and competencies in ICT in education. The first part of the chapter outlines the meaning of observational techniques as a tool of research and explains what is important when planning an observational study. Several specific video- and audio-supported observation techniques, as well as advantages and challenges of observational techniques in general, are presented. In the second part of the chapter the focus is on findings from empirical studies that used observational techniques. The chapter ends with the conclusions that observational measures have the potential to deliver meaningful, unique data and that attitudes and competencies toward IT tend to be positive in most of the studies reviewed.

Chapter 4.5 focuses on student attitudes and competencies toward ICT, with a particular emphasis on equity issues such as gender, age, ethnicity, or social economic status. The most frequently reported sociodemographic parameter of the digital divide is gender. In most western countries the participation of females in the IT profession is not only low but is also still falling. Studies on computer attitudes, competencies, or use among students with different cultural or social economic backgrounds are still scarce, although the differences between these groups are substantial as well. In the United States in particular, differences between female and male students in attitudes toward computers have been the subject of many studies since the 1980s. In modern times the number of studies on the "gender gap" in computer attitudes exceeds that on computer competences and abilities by large. Because of their reciprocity, computer attitudes, computer anxiety, and computer competences should be studied in coherence and not as a causal relation.

Chapter 4.6 presents a typology of four dimensions of teacher leadership: (a) a disposition to continually learn from and improve practice, (b) collaboration with peers through critical examination and evolution of each other's teaching, (c) participation in geographically diverse communities of practice, and (d) making professional contributions through speaking, writing, and teaching. Teacher leadership, from this perspective, is inherently grounded in professional engagement, which in turn is linked with constructivist teaching philosophies and teaching practice and exemplary use of computers. The chapter concludes by pointing to several ways that technology leadership might be fostered.

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4.1

THE IMPORTANCE OF INFORMATION TECHNOLOGY ATTITUDES AND COMPETENCIES IN PRIMARY AND SECONDARY EDUCATION

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Introduction

Since the early days of Information Technology (IT) in education, attitudes and competencies of students (and later teachers) have been in the domain of interest of researchers, because they appeared to be an important factor in the decision to use IT in educational practice. In 1995 the US Office of Technology Assessment (US Congress, 1995) reported that helping teachers "effectively incorporate technology into the teaching and learning process is one of the most important steps the nation can take to make the most of past and continuing investments in educational technology" (p. 8). Although during the 1970s the study of effective incorporation into teaching and learning often focused on the specific impact an IT intervention might have on student learning (Marshall and Cox, 2008), by the mid-1980s the emphasis had shifted toward the study of intervening variables such as attitudes and competencies. This was in part due to the low recorded level of IT usage by teachers and students in spite of large increases in IT resources in schools and informal educational settings (Marshall and Cox, 2008). Some specific examples serve to add emphasis to this point:

– Although the Second Information Technology in Education Study confirmed a rapid improvement in the student–computer ratios at all levels of education during the late 1990s worldwide, the study also showed that the actual integration of computers in classrooms remained limited (Pelgrum and Anderson, 1999).

J. Voogt, G. Knezek (eds.) *International Handbook of Information Technology in Primary and Secondary Education, 321–331.*

– Only about one-third of US teachers used computers on a regular basis at the end of the twentieth century, although the majority had computers in their classrooms (Becker et al., 1999).
– Even as of 2006, in only 10 of 32 countries studied by the Program of International Student Assessment did students report using computers frequently (a few times per week or more) in spite of the fact that more than 90% had access to computers in school (Organisation for Economic Cooperation and Development, 2005, as reported by Voogt, 2008).

Simply placing technology in schools has not been sufficient to ensure educationally relevant use.

Role of Attitudes

Since the early 1980s most researchers have agreed that the successful use of computers in the classroom is dependent on positive attitudes toward computers (Lawton and Gerschner, 1982; Woodrow, 1992). As observed by Marshall and Cox (2008), over the past quarter century a large number of research studies have been conducted into attitudinal and motivation/personality factors toward IT in education. Many of these contained attitude surveys consisting of questions about fear of computers, extent of liking technology, attitudes toward using technology in school, and so forth – and have shown strong links between pupils' and teachers' attitudes and the effect on IT use and learning (Marshall and Cox, 2008). Christensen (1997, 2002) was able to demonstrate that positive IT attitudes in teachers, which were fostered through needs-based, technology integration training, were transferred to their students. This latter finding illustrates the complex interplay of training, attitudes, competencies, and transfer to students that appears to exist in the IT-in-education world.

Requirements of Competency

In the accountability-centered environment that surrounds late twentieth and early twenty-first century education, proficiency in technology itself has also assumed an important role for technology integration. Testing of proficiencies on an international scale has been underway since the International Association for the Evaluation of Educational Achievement (IEA) developed the Functional Information Technology Test in 1990 and administered it across 21 national educational systems (Pelgrum and Plomp, 1993). Conceptual models of the use of IT in education, which included competencies, attitudes, and other factors, have also been in place since the early days of IEA (e.g., Pelgrum and Plomp, 1993). These concepts have been refined over the years to emerge in modern day derivatives such as the will, skill, tool (WST) model of technology integration (Knezek, Christensen, Hancock and Soho, 2000) to be discussed in detail in a latter section of this chapter. Other schools of thought (e.g., Schulz-Zander, Pfiefer and Voss, 2008) have made a strong case that observations of teaching and learning activities are necessary to establish a true picture of what IT behaviors and skills actually are exhibited among students and teachers in formal and informal learning environments. Regardless of method of verification employed, there appears to be a universal agreement that competency in the use of IT is a prerequisite to successfully employing IT in teaching and learning. Still largely unknown is in what situations minimal proficiency is adequate to reach the threshold of effective teaching with technology, versus situations in which higher competencies result in additional student gains. A related area that is beginning to take a high profile is that of technology self-efficacy (confidence in one's competence) – which research is showing to be fostered by positive attitudes and which in turn fosters higher academic performance (Miura, 1987; Kinzie, Delcourt and Powers, 1994; Liaw, 2002). Self-efficacy, which is based on social cognitive theory (Bandura, 1977, 1986), is unique in that it spans competencies and attitudes. Self-efficacy and other issues will be further addressed in a later section of this chapter.

Verification Through Standards and Tests

Professional societies and policy-making bodies have begun to address the issue of which attitudes and competencies should be fostered in teachers and students. IT standards have been established in the USA and in other nations (Thomas and Knezek, 2002, 2008) that reflect the importance of positive attitudes as well as adequate competencies in successful technology implementation. Procedures and instruments for assessing standards naturally follow the creation of standards (e.g., Kelly and McAnear, 2003). In the USA discussion has proceeded to the development of an IT competency test for teachers based on the approved standards (see http://www.iste.org). Testing teachers in IT competencies is not a new idea in itself, however. Certifications such as the European Pedagogical ICT License (http://www.epict.org) have begun to appear in many areas of the world.

Concerns About Overstandardization

Nevertheless, even as technology attitudes and competencies are gaining prominence in the realm of IT in education, a parallel movement is evolving back toward the place where Marshall and Cox (2008) have noted it all began. Specifically, as the randomized, experimental trials approach to studying the impact of IT in education is implemented by the No Child Left Behind Act of 2001 in the USA (US Congress, 2002), and by similar policies in other nations, attitudes and competencies run the risk of becoming two of the many variables well controlled by a randomized design and therefore largely forgotten. The emphasis is currently returning to the study of the impact a specific IT intervention might have on student learning, as it was in the 1970s (Marshall and Cox, 2008). While strong research designs such as those long advocated by Campbell and Stanley (1963) are clearly needed, one should also not forget their basic definition of an experiment as a systematic manipulation of one variable, and observation of the effect on another variable. There are many ways to assess the impact of IT in education based on this definition, and several that have been successfully employed will be described within the context of the findings among the chapters in this section.

The Need for Asking Good Questions

Collis and Moonen (2001, 2005) have identified two basic ways that IT can be used in education: (1) as a core technology that is an expected part of the infrastructure (replacing blackboards, etc.), or (2) as a complementary technology (PDAs, Web 2.0, Google Earth, etc.) that adds a new dimension to a learning environment that was not previously possible (see Moonen, 2008). Roblyer (2004) has developed a different classification scheme based on four rationales for using IT in education: (a) to establish relative advantage, (b) to improve implementation strategies, (c) to monitor impact on societal goals, or (d) to report on common practices in order to measure sociological impact and shape directions accordingly. Moonen (2008) argues that complementary technologies have a greater potential to transform education because new technologies create opportunities for solutions to pedagogical problems. Moonen (2008) also observes that implementation of complementary technologies is more difficult and a major transformation has not yet occurred. Roblyer argues that relative advantage may often be the best IT implementation rationale:

> When there is a clear need for a better instructional method than those used in the past, researchers can propose that a given technology-based method is the best choice because it offers the combination of relevant symbol systems, processing capabilities, and logistical feasibility to address the need—and then do research to support that it has this relative advantage and clarify the conditions under which it works best (Roblyer, 2005).

It seems unnecessary to debate whether (or in which situations) transforming the education system versus establishing the relative advantage of a new technology over an old way of doing things is a better goal. The point of this paragraph is simply to say that there is, or should be, a reason, a goal for the chosen use of IT in education. This goal serves as a lens through which the researcher conducts a study and interprets the findings. Findings in turn should always be read with the goal of the study in mind.

Theoretical/Conceptual Foundations

Most studies regarding IT in education are conducted within a specific theoretical or conceptual framework. A few of the key concepts that underlie most work in attitudes and competencies are described in the paragraphs that follow.

What is an attitude? One long-standing definition is that “attitude is the affect for or against a psychological object” (Thurstone, 1931, p. 261). Some definitions describe attitudes as having affective (feeling), cognitive (thinking/knowing), and behavioral (action) components. However, the emphasis in most studies related to IT tends to be on the affective component. Many studies conducted in the late twentieth and early twenty-first century cite Fishbein and Ajzen (1975), who defined attitude as “a learned predisposition to respond in a consistently favorable or unfavorable manner with respect to a given object” (p. 6).

What do we mean by competencies? These come in two relevant forms: (a) competencies about IT in education, and (b) competencies about academic subjects such as math and science that are believed to be mediated by IT in education. Although educational initiatives frequently target both kinds of competencies, Watson (2001) has pointed out that dual-purpose initiatives may cause conflicting demands for teachers. Voogt (2008) provides a detailed discussion of this topic.

Which theoretical frameworks are common? Much of the research conducted on IT attitudes and competencies is based on the concept of diffusion of innovations (Rogers, 1983). Educators’ rates of adoption of IT often fall into categories similar to Roger’s (1) innovators, (2) early adopters, (3) early majority, (4) late majority, and (5) laggards – and this has research implications. For example, Christensen and Knezek (2008) have demonstrated strong connections between IT attitudes and competencies and stages of adoption of technology.

Much research is also based upon the concerns-based adoption model (CBAM) (Hall and Rutherford, 1974; Hall, 1979), which is grounded in Fuller’s (1969) work with concerns theory. This conceptual framework focuses on the types of issues (concerns) educators work through when adopting a new innovation. CBAM’s two components—Stages of Concern and Levels of Use—have been successfully applied to IT as an educational innovation. For example, Giordano (2007) showed that teachers’ concerns shifted from “learning to integrate the Internet” to “how to manage the task with students” over the course of a professional development training activity. She also found that the types of concerns exhibited by teachers were related to teachers’ years of teaching experience and level of Internet access in their classrooms.

The Apple Classrooms of Tomorrow (ACOT) framework for teacher stages has been used in a large number of studies since the mid-1980s. ACOT labeled the stages of evolution in its classrooms as entry, adoption, adaptation, appropriation, and invention (Dwyer, Ringstaff and Sandholtz, 1989). Hancock, Knezek and Christensen (2007) have demonstrated that ACOT stages of evolution, CBAM Levels of Use, and Stages of Adoption of Technology (Christensen, 1997) derived from Roger’s diffusion of innovation, together form a unified construct they have labeled technology integration.

Principles of educational psychology (teaching and learning, pedagogical practice) are also woven throughout the studies of IT attitude and competencies. Classical texts such as *Learning and Human Abilities: Educational Psychology* (Klausmeir and Ripple, 1971) provide a comprehensive research-based foundation to this field, while a discussion by Dede (2008) in this Handbook provides an overview of which types of IT-based interventions align with behaviorist (Pavlov, Skinner) versus constructivist (Piaget, Papert) perspectives. Social constructivism (Vygotsky, 1978) is also a prominent theoretical framework that is relevant to several chapters addressing IT attitudes and competencies. One example of a chapter couched in constructivism is Riel and Becker’s (2008) examination of responses from more than 4,000 educators who provided data for a comprehensive study in the late 1990s of the state of technology in education in the USA. Analysis of the data set based on constructivist principles resulted in identification of a new category of technology-infusing educators called teacher leaders. This category of teaching-with-technology professional seeks out new courses and higher education, attends conferences, and leads training sessions for their peers. The key attributes appear to be similar to the description of personal entrepreneurship teachers by Drent (2005). Indicators for these distinguishing characteristics have not yet been formalized to the point of developing a measurement scale. Yet the characteristics appear to be destined, through classification of status of importance, to become the foundations of other measurement scales in the future.

Formal Models of Attitudes and Achievement

Several models have been developed in recent decades that attempt to quantify portions of the relationship between attitudes/dispositions and achievement. One that is based upon diffusion of innovation (Rogers, 1983), educational psychology (Klausmeir and Ripple, 1971), and the measuring/modeling approach of structural equation modeling (Schumacker, 1996) is presented as an example for this chapter. The

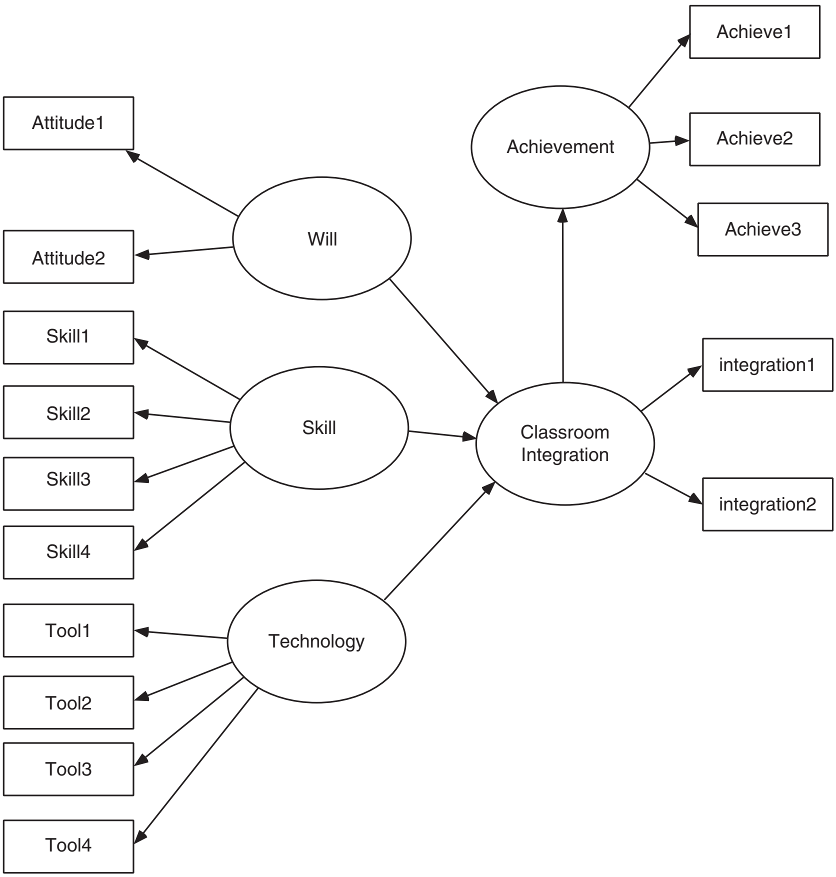

Fig. 1 Will, skill, tool model of the impact of technology integration on academic achievement

will, skill, tool (WST) model (Knezek, Christensen, Hancock and Shoho, 2000; Morales, Knezek, Christensen and Avila 2005) includes classroom technology integration as a key intervening variable. As shown in Figure 1, the model includes three key elements for successful integration of technology: will (attitude) of the teacher, skill (technology competency), and technology tools (access to technology tools). The left half of the WST model is generally aligned with a number of other models that emphasize removing internal and external barriers, increasing usage and skills, or building toward desirable goals, as the path to meaningful classroom technology integration (Rogers, 1999; Vannatta and Fordham, 2004; Zhao and Cziko, 2001). The right half of the model is consistent with research by McCombs and Marzano (1990) showing that achievement outcomes can be viewed as a function of two characteristics, "skill" and "will" – plus there is an addition by the WST authors of technology access (tools) as a predictor of academic achievement.

Studies using the WST model have shown that up to 90% of the level of technology integration in the classroom can be explained by will, skill, and tool measures (Morales, 2006). Level of integration, in turn, accounts for about 10% of student achievement in computer-based tutorial and practice in word/sentence construction and comprehension for early elementary reading (Knezek, Christensen and Fluke, 2003; Morales, Knezek, Christensen and Avila, 2005). If the effects of technology integration as an intervention are found to be cumulative over consecutive years, then one can envision a scenario in which students who begin first grade with a highly qualified, technology-integrating teacher and are placed in a comparable classroom with intellectually engaging computer applications each year show much higher academic achievement by the end of high school than do their peers who were without such an enriching education.

Self Report and Observation Measures for Determining Attitudes and Competencies Toward Technology

How does a researcher go about securing data to test hypotheses based on theories and models like those previously described? Time-honored traditions for developing surveys and tests (e.g. DeVellis, 1991) have been applied to the field of IT over the past 15 years. The result is a serious of instruments for students, teachers, and administrators developed by researchers such as Christensen (1997), Christensen and Knezek (1997; 1999), Griffin and Christensen (1999), Knezek and Christensen (1996; 1998). Ropp (1999), Soloway and Norris (Soloway, Norris, Knezek, Becker, Riel, and Means, 1999) – built upon the earlier work of international scholars such as Gressard and Loyd (1986), Hall and Rutherford (1974; Hall, Loucks, Rutherford and Newlove, 1975), Kay (1993), Pelgrum (Pelgrum, Janssen Reinen, and Plomp, 1993), Russell (1995), Sakamoto (Knezek, Miyashita, and Sakamoto, 1994), and Zaichkowsky (1985). These measure attitudes, skills, and levels of technology integration. Some also measure self-efficacy, which has been previously defined in this chapter as confidence in one's competence. Many of these and similar instruments will be referenced in the chapters of findings that follow.

External observers have widely been regarded as an accurate means of assessing actual teaching and learning with technology behaviors (Dirr, 2003). Outside observers offer unique insights into the dynamics of teaching and learning with technology (Wetzel, Buss, Padgett and Zambo, 2003). Mixed methodologies that involve self-reporting and interviews/observation often yield complementary findings. For example, self-report surveys often indicate what is occurring in the school environment while follow-up observations can reveal more specific reasons why the technology-related events take place. One case in point is an observation-based analysis by Schulz-Zander, Büchter and Dalmer (2002) that identified positive effects of ICT on students' cooperation and collaboration. Observation-based methods are featured by Schulz-Zander, Pfiefer and Voss (2008).

Summary and Conclusions

Over the past two decades governments and other funding entities have called for evidence regarding how IT makes a difference in education. Competencies in IT as well as traditional academic disciplines have taken a prominent role since the introduction of the No Child Left Behind Act in the USA, and of similar laws in other nations, in the early twenty-first century. However, researchers and policy makers have also known for decades that attitudes play an important role in obtaining positive outcomes. For example, Winston Churchill is credited with the observation that "Attitude is a little thing that makes a big difference." In this chapter the importance of attitudes and competencies is presented within an academic framework of rationales, methodologies, and theoretical benefits to be gained from carefully using indicators of attitudes and competencies to guide the path toward productive use of IT in education. The following chapters in this section focus on what we think we know, and what we think we need to know, regarding the role of attitudes and competencies for IT in education.

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4.2

INFORMATION, COMMUNICATIONS, AND EDUCATIONAL TECHNOLOGY STANDARDS FOR STUDENTS, TEACHERS, AND SCHOOL LEADERS

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Rationale for Information and Communication Technology Standards

The universal potential for each nation's development lies in its human capital. Regardless of status in the current world economy, regardless of natural resources or financial capital available, and regardless of world positioning in the domains of ideas and innovation, there is a global understanding that nations become and remain strong through effective education systems that develop human capital – and in this era of globalization, through education systems that benchmark well worldwide.

In pursuit of world-class education, many ministries of education at the national, state, or province level document expectations of achievement by students, teachers, or school leaders, and in some cases they document all three. While these expectations may take the form of recommendations, guidelines, benchmarks, or frameworks, standards are established frequently. Increasingly, jurisdictions adopt standards for information technology (IT) or information and communication technology (ICT) in schools, particularly standards for ICT skills to be mastered by students and educators.

ICT skills standards are important in defining achievement expectations for students and defining expected capabilities of educators. As the world becomes increasingly digital, and we experience the globalization of education, the importance of these standards increases. Standards help to ensure that students complete their education prepared for the world of work and prepared to be contributing

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citizens, and standards help to ensure that teachers and school leaders are capable of taking advantage of ICT to provide competitive education services.

In many cases these standards define IT skills and higher order skills necessary to use ICT and learning technologies to improve learning, teaching, and school leadership. In the United States, for example, student standards developed by the International Society for Technology in Education (ISTE) specify foundation IT skills as well as skills necessary to learn effectively and live productively in an increasingly digital world. Similarly, the National Educational Technology Standards (NETS) for teachers and school leaders in the USA include more than simple foundation IT skills expected of educators (ISTE, 2000, 2002a,b).

United Nations Educational, Scientific and Cultural Organization (UNESCO) has a project underway to develop ICT teacher competency standards that combines teacher ICT skills with other areas of teacher work. By combining ICT skills with emergent views in pedagogy, curriculum, and school organization the standards are intended to improve teacher practice in a way that contributes to a higher quality education system. In total, these teacher competency standards address six components of the educational system: policy and vision, curriculum and assessment, pedagogy, ICT, organization and administration, and teacher professional development (UNESCO, 2006).

IT-related competencies for teachers were developed in England in 1998 and revised in 2002. In the revision, required competencies were replaced by nonstatutory guidance for teacher training and more specific guidance for IT (Selinger and Austin, 2003). Teachers are required to pass tests of foundation ICT skills in order to gain qualified teacher status (UK Training and Development website http://www.tda.gov.uk).

In Australia, the National Goals for Schooling were adopted by all commonwealth and territorial ministries of education, and they call for students leaving school to be confident, creative, and productive users of new technologies, particularly IT, and understand the impact of those technologies on society (Pearson, 2003). Each of the states has developed IT competency requirements or guidelines for teachers (Downes et al., 2001).

A framework for policy for initial teacher education developed in Northern Ireland in 1997 identified teacher training in IT as a key issue. In Finland the project called OPE.fi set criteria for both preservice and inservice teachers. All teachers were to have achieved basic IT skills by 2004, and half of all personnel in educational institutions were to have achieved high-level skills. In both cases these initiatives involved the national ministries of education. Other countries such as Costa Rica, Indonesia, and Malaysia are working to develop student ICT skills standards.

The development and application of standards for ICT in schools support a shared vision for the role of digital tools and resources in education. Standards, therefore, focus effort and commitment, and they ensure alignment of materials and resources, curriculum, instruction, and assessment. They provide a basis upon which to assess student success in achieving expectations and serve to communicate to employers what capabilities they can expect from successful students. Standards are a critical tool in establishing, communicating, meeting, and assessing expectations related to ICT in schools.

The National Educational Standards (NETS) developed by the ISTE represent a mature and comprehensive set of standards for use of ICT in schools. Because they have been adopted across the USA and used heavily in other regions of the world, we will take an in-depth look at ISTE's NETS.

Establishing New Learning Environments Supported with Technology

The challenge facing America's schools is the empowerment of all children to function effectively in their future, a future marked increasingly with change, information growth, and evolving digital tools. Technology is a powerful tool with enormous potential for changing outdated educational systems to systems capable of providing learning opportunities for all, to better serve the needs of twenty-first century learning, communications, work, and life. The ISTE and the public at large recognize the potential of technology to change education and improve student learning. Technology has become a powerful catalyst in promoting learning, communications, and life skills for economic survival in today's world. Through its NETS Project, ISTE is encouraging educational leaders to provide learning opportunities that produce technology-capable students. The primary goal of the ISTE NETS Project is to enable stakeholders to develop national standards for educational uses of technology that facilitate school improvement in the United States and beyond.

ICT Standards for Students

The ISTE technology standards for students are divided into six broad categories. Standards within each category are to be introduced, reinforced, and mastered by students. These categories provide a framework to guide planning of technology-based activities in which students achieve success in learning, communication, and life skills. The NETS Project has developed the standards for students to guide educational leaders in recognizing and addressing effective use of technology to support PK-12 education. These are listed in Figure 1.

Barriers to Adoption of Standards for Students

Through the ongoing use of technology in the schooling process, students can be empowered to achieve important technological capabilities. Primary factors often cited as affecting achievement of ICT potentials are (1) access to hardware, software, and communications resources, and (2) a classroom teacher who understands how to facilitate student learning through application of these resources. Shortcomings in these factors can often serve as barriers to adoption of student standards.

Access is the initial and often most difficult barrier for some schools to overcome. To address access issues, decisions must be made regarding details such as electrical wiring and other infrastructure necessary to support the computers and servers; physical space for the routers, hubs, servers, CD towers, and key network equipment; levels

National Educational Technology Standards for Students: The Next Generation

"What students know and be able to do learn effectively and live productively in an increasingly digital world..."

1. **Creativity and Innovation**
   Students demonstrate creative thinking, construct knowledge, and develop innovative products and processes using technology. Students:
   a. apply existing knowledge to generate new ideas, products or processes.
   b. create original works as a means of personal or group expression.
   c. use models and simulations to explore complex systems and issues.
   d. identify trends and forecast possibilities.

2. **Communication and Collaboration**
   Students use digital media and environments to communicate and work collaboratively, including at a distance, to support individual learning and contribute to the learning of others. Students:
   a. interact, collaborate, and publish with peers, experts or others employing a variety of digital environments ad media.
   b. communicate information and ideas effectively to multiple audiences using a variety if media and formats.
   c. develop cultural understanding and global awareness by engaging with learners of other cultures.
   d. contribute to project teams to produce original works or solve problems.

3. **Research and Information Fluency**
   Students apply digital tools to gather, evaluate, and use information. Sudents:
   a. plan strategies to guide inquiry.
   b. locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media.
   c. evaluate and select information sources and digital tools based on the appropriateness to specific tasks.
   d. process data and report results.

4. **Critical Thinking, Problem-Solving & Decision-Making**
   Students use critical thinking skills to plan and conduct research, manage projects, solve problems and make informed decisions using appropriate digital tools and resources. Students:
   a. identify and define authentic problems and significant questions for investigation.
   b. plan and manage activities to develop a solutions or complete a project.
   c. collect and analyze data to identify solutions and/or make informed decisions.
   d. use multiple processes and diverse perspectives to explore alternative solutions.

5. **Digital Citizenships**
   Students understand human, cultural, and societal issues related to technology and practice legal and ethical behavior. Students:

Fig. 1 (continued)

a. advocate and practice safe, legal and responsible use of information and technology.
b. exhibit a positive attitude toward using technology that supports collaboration, learning and productivity.
c. demonstrate personal responsibility for lifelong learning.
d. exhibit leadership for digital citizenship.

6. Technology Operations and Concepts
Students demonstrate a sound understanding of technology concepts, systems and operations. Students:
a. understand and use technology systems.
b. select and use applications effectively and productively.
c. troubleshoot systems and applications.
d. transfer current knowledge to learning of new technologies.

Fig. 1 National educational technology standards for students: The next generation

of access (broad band, wireless, etc.) in each classroom, laboratory, or library; selection and installation of software necessary to support the educational curriculum of the school; security measures; and necessary technical support at sufficient levels to facilitate increased and effective use of ICT in instruction (UNESCO, 2002).

The second key factor includes the classroom teacher who is skilled in facilitation of technology-supported learning. This person assumes responsibility for establishing the classroom environment and preparing the learning opportunities that facilitate student use of technology to research, learn, communicate, make decisions, and develop knowledge products. Consequently, it is essential that all classroom teachers be prepared to provide their students with these learning opportunities. Both professional development programs for classroom teachers and preparation programs for future teachers must provide these standards-based, technology-rich experiences. Standards and resources from the ISTE sites (http://www.iste.org and http://cnets.iste.org) provide educational technology standards for classroom teachers that are widely applied in teacher education programs preparing teachers to play essential roles in producing technology-capable students.

New Skill Sets for Teachers

Professional development and teacher preparation programs must engage practicing teachers and future teachers in technology-rich curricula and pedagogical learning so that they, in turn, can empower their students with the learning advantages that technology can bring. Schools and classrooms, both real and virtual, must have teachers who are equipped with technology resources and skills and who can effectively provide learning experiences so that students learn the necessary subject matter content while incorporating technology concepts and skills. Real-world connections, primary source material, and sophisticated data-gathering and analysis tools are only a few of the resources that enable teachers to provide rich and powerful opportunities for conceptual understanding.

Figure 2 identifies traditional approaches to learning employed by teachers and movement to corresponding "new" strategies often associated with effective learning environments for today's P-12 and university students. These strategies combine to provide new learning environments that are based on classic learning research (Dale, 1969) and more recent research supporting student-centered learning, multisensory/multimedia approaches to learning, simulations, critical thinking, problem-solving, active/inquiry-based learning, planning, and authentic learning opportunities. Today's ICT resources can support these types of strategies, resulting in effective new learning environments.

The strategies juxtaposed in Figure 2 suggest that teachers should plan learning activities in which they allocate less time using traditional learning strategies listed in the left column and more time applying the more engaging strategies in the right column that more effectively address student learning needs. The following ICT standards for

Establishing New Learning Environments

Traditional	Incorporating New Strategies	New Environments
Teacher-centered instruction		Learner-centered environments
Single sense stimulation		Multisensory stimulation
Single path progression		Multipath progression
Single media		Multimedia; Hypermedia
Isolated work		Collaborative work
Information delivery		Information exchange, publication, creation
Passive learning		Active/exploratory/inquiry-based learning
Factual/literal thinking		Critical thinking, informed decision-making
Reactive response		Proactive/planned action
Isolated, artificial context		Authentic, real world contexts

Fig. 2 Establishing New Learning Environments

teachers clearly guide educators toward development of the new learning environments supported by technology as outlined earlier. The NETS for teachers (NETS-T) focus not only on technology skills and knowledge of concepts but also on knowledge, skills, and dispositions related to integration of ICT in the planning, teaching, and assessment processes as well. These are described more fully in the following section.

ISTE National Educational Technology Standards for Teachers

The NETS-T include six standards and performance indicators addressing each of the standards (ISTE, 2000). These ICT guidelines for teachers are designed to be general enough to be customized to fit state, university, or district guidelines and yet specific enough to define the scope for each standard. The standards identify the global expectations, and the performance indicators for each standard list measurable outcomes. The NETS-T standards and performance indicators shown in Figure 3 are valuable tools for developing assessment tools to measure a teacher candidate's grasp of applying technology to support student learning. Also, the standards and the performance indicators provide guidelines for evaluating use of technology by teachers currently in the classroom.

The ISTE National Educational Technology Standards for Teachers (NETS•T)

I. TECHNOLOGY OPERATIONS AND CONCEPTS. *Teachers demonstrate a sound understanding of technology operations and concepts. Teachers:*
   a. demonstrate introductory knowledge, skills, and understanding of concepts related to technology (as described in the ISTE National Education Technology Standards for Students)
   b. demonstrate continual growth in technology knowledge and skills to stay abreast of current and emerging technologies.

II. PLANNING AND DESIGNING LEARNING ENVIRONMENTS AND EXPERIENCES. *Teachers plan and design effective learning environments and experiences supported by technology. Teachers:*
   a. design developmentally appropriate learning opportunities that apply technology-enhanced instructional strategies to support the diverse needs of learners.
   b. apply current research on teaching and learning with technology when planning learning environments and experiences.
   c. identify and locate technology resources and evaluate them for accuracy and suitability.
   d. plan for the management of technology resources within the context of learning activities.
   e. plan strategies to manage student learning in a technology-enhanced environment.

Fig. 3 (continued)

III. TEACHING, LEARNING, AND THE CURRICULUM. *Teachers implement curriculum plans that include methods and strategies for applying technology to maximize student learning. Teachers:*
   a. facilitate technology-enhanced experiences that address content standards and student technology standards.
   b. use technology to support learner-centered strategies that address the diverse needs of students.
   c. apply technology to develop students' higher order skills and creativity.
   d. manage student learning activities in a technology-enhanced environment.

IV. ASSESSMENT AND EVALUATION. *Teachers apply technology to facilitate a variety of effective assessment and evaluation strategies. Teachers:*
   a. apply technology in assessing student learning of subject matter using a variety of assessment techniques.
   b. use technology resources to collect and analyze data, interpret results, and communicate findings to improve instructional practice and maximize student learning.
   c. apply multiple methods of evaluation to determine students' appropriate use of technology resources for learning, communication, and productivity.

V. PRODUCTIVITY AND PROFESSIONAL PRACTICE. *Teachers use technology to enhance their productivity and professional practice. Teachers:*
   a. use technology resources to engage in ongoing professional development and lifelong learning.
   b. continually evaluate and reflect on professional practice to make informed decisions regarding the use of technology in support of student learning.
   c. apply technology to increase productivity.
   d. use technology to communicate and collaborate with peers, parents, and the larger community in order to nurture student learning.

VI. SOCIAL, ETHICAL, LEGAL, AND HUMAN ISSUES. *Teachers understand the social, ethical, legal, and human issues surrounding the use of technology in PK-12 schools and apply those principles in practice. Teachers:*
   a. model and teach legal and ethical practice related to technology use.
   b. apply technology resources to enable and empower learners with diverse backgrounds, characteristics, and abilities.
   c. identify and use technology resources that affirm diversity.
   d. promote safe and healthy use of technology resources.
   e. facilitate equitable access to technology resources for all students.

Fig. 3 The ISTE national educational technology standards for teachers (NETS-T)

ICT Standards for School and School-System Leaders of K-12 Education

In the USA leaders of schools, school systems, and systemwide programs are often referred to as *administrators*. The documented importance of a shared vision among the multiple levels of an organization indicates the need for technology standards for administrators in K-12 education. ISTE facilitated and managed the development of the technology standards for school administrators (TSSA), which identify performance standards for the technology skills, knowledge, and dispositions of administrators of K-12 education. The TSSA Collaborative developed a core set of standards that include foundational standards for all administrators and sets of specific indicators for the superintendent (head of the local school board or system), school administrator (head of a school, principal, or assistant principal), and district level program administrator (director of one or more curriculum or special program areas for a local school system). School administrators must understand and support the use of technology at all levels so that they can work not only with their own faculties, but also work collaboratively with universities on appropriate field placements and guide new teachers as they incorporate technology into their classroom instruction.

The TSSA effort provided a framework for considering what school leaders must know and be able to do to ensure optimum benefit from technology use. The following list of *Seven Obvious Reasons Administrators Should Know Technology* has been developed by the authors to identify compelling arguments supporting specific preparation in the effective use of technology for education leaders.

1. Technology, used well across a school system, constitutes significant school reform. We have a wealth of evidence that indicates that the most important single factor in implementing school reform and, especially, in maintaining it, is effective leadership.
2. When technology is used well, the curriculum changes, the learning resources change, the classroom changes, and roles within that classroom change most of all. Options expand through technology for meeting diverse needs, and for meeting them with multiple strategies.
3. Technology redefines "qualified and competent teacher." This has implications equally for inservice professional development, preservice teacher education, and professional staffing of schools.
4. It is a clear expectation that administrators leading one of the most important and pervasive enterprises within any community must personally use technology to be credible as role models and as information-age professionals.
5. Technology opens schools and school systems to the outside community and to the world in unprecedented ways, and it is imperative that administrators know what is *really* going on within the hallowed walls and be able to communicate about that efficiently and effectively.
6. With accountability for both student learning and operational efficiency taking on everincreasing importance, technology-based strategies hold tremendous potential to assist with operations, management, monitoring, assessment, information handling, and reporting.

7. Technology presents new challenges related to ethical behavior, security, and safety. These challenges present sophisticated and essential opportunities for developing responsibility among young learners that will serve them as adults in society.

ISTE has adopted the administrator standards developed through the TSSAs Collaborative as the ISTE National Educational Technology Standards for Administrators (NETS-A). The NETS-A Standards shown in Figure 4 embraced the TSSA vision by extending it to include additional administrative job roles. These standards are a national consensus among educational stakeholders of what best indicates effective school leadership for comprehensive and appropriate use of technology in schools. The standards were created as a result of a national consensus-building process that the ISTE NETS Project has used in development and refinement of all of their sets of standards.

The TSSA Collaborative and the many professionals who contributed to this effort realize the wide range of roles administrators play in schools, even when titles are similar. School and system size, degree of site-based governance, community characteristics, and strengths of individual administrators are but a few of the parameters that may cause variations in actual job roles. For this reason, wise consumers of these standards will apply this resource in ways that acknowledge the local context of school leadership.

ISTE National Educational Technology Standards for Administrators (NETS•A)

I. LEADERSHIP AND VISION.

Educational leaders inspire a shared vision for comprehensive integration of technology and foster an environment and culture conducive to the realization of that vision. Educational leaders:

a. facilitate the shared development by all stakeholders of a vision for technology use and widely communicate that vision.
b. maintain an inclusive and cohesive process to develop, implement, and monitor a dynamic, long-range, and systemic technology plan to achieve the vision.
c. foster and nurture a culture of responsible risk-taking and advocate policies promoting continuous innovation with technology.
d. use data in making leadership decisions.
e. advocate for research-based effective practices in use of technology.
f. advocate on the state and national levels for policies, programs, and funding opportunities that support implementation of the district technology plan.

II. LEARNING AND TEACHING.

Educational leaders ensure that curricular design, instructional strategies, and learning environments integrate appropriate technologies to maximize learning and teaching. Educational leaders:

a. identify, use, evaluate, and promote appropriate technologies to enhance and support instruction and standards-based curriculum leading to high levels of student achievement.
b. facilitate and support collaborative technology-enriched learning environments conducive to innovation for improved learning.

Fig. 4 (continued)

c. provide for learner-centered environments that use technology to meet the individual and diverse needs of learners.
d. facilitate the use of technologies to support and enhance instructional methods that develop higher-level thinking, decision-making, and problem-solving skills.
e. provide for and ensure that faculty and staff take advantage of quality professional learning opportunities for improved learning and teaching with technology.

III. PRODUCTIVITY AND PROFESSIONAL PRACTICE.
Educational leaders apply technology to enhance their professional practice and to increase their own productivity and that of others. Educational leaders:
a. model the routine, intentional, and effective use of technology.
b. employ technology for communication and collaboration among colleagues, staff, parents, students, and the larger community.
c. create and participate in learning communities that stimulate, nurture, and support faculty and staff in using technology for improved productivity.
d. engage in sustained, job-related professional learning using technology resources.
e. maintain awareness of emerging technologies and their potential uses in education.
f. use technology to advance organizational improvement.

IV. SUPPORT, MANAGEMENT, AND OPERATIONS.
Educational leaders ensure the integration of technology to support productive systems for learning and administration. Educational leaders:
a. develop, implement, and monitor policies and guidelines to ensure compatibility of technologies.
b. implement and use integrated technology-based management and operations systems.
c. allocate financial and human resources to ensure complete and sustained implementation of the technology plan.
d. integrate strategic plans, technology plans, and other improvement plans and policies to align efforts and leverage resources.
e. implement procedures to drive continuous improvement of technology systems and to support technology replacement cycles.

V. ASSESSMENT AND EVALUATION.
Educational leaders use technology to plan and implement comprehensive systems of effective assessment and evaluation. Educational leaders:
a. use multiple methods to assess and evaluate appropriate uses of technology resources for learning, communication, and productivity.
b. use technology to collect and analyze data, interpret results, and communicate findings to improve instructional practice and student learning.
c. assess staff knowledge, skills, and performance in using technology and use results to facilitate quality professional development and to inform personnel decisions.
d. use technology to assess, evaluate, and manage administrative and operational systems.

Fig. 4 (continued)

VI. SOCIAL, LEGAL, AND ETHICAL ISSUES.
Educational leaders understand the social, legal, and ethical issues related to technology and model responsible decision-making related to these issues.
Educational leaders:

a. ensure equity of access to technology resources that enable and empower all learners and educators.
b. identify, communicate, model, and enforce social, legal, and ethical practices to promote responsible use of technology.
c. promote and enforce privacy, security, and online safety related to the use of technology.
d. promote and enforce environmentally safe and healthy practices in the use of technology.
e. participate in the development of policies that clearly enforce copyright law and assign ownership of intellectual property developed with district resources.

Fig. 4 ISTE national educational technology standards for administrators (NETS-A)

Preparation of Specialists for Leadership in ICT

The rapid infusion of technology into schools requires a new generation of leaders who are able to use the new tools to enhance their own productivity and decision-making activities and who understand the importance of using technology to support the learning process. Leadership is a critical factor in the successful integration of ICT, instructional practices, and curriculum. Research has shown that without effective and supportive leadership, changes in the teaching–learning process and widespread, effective uses of technology in learning are not likely to occur. The following research conclusion underscores the importance of effective and supportive leadership for technology implementation: “Because technology implementation requires policy, budget and finance, and various other organizational mechanisms, technology programs are doomed unless key administrators, as well as teachers, play active roles in these programs” (Anderson and Dexter, 2000, p. 19).

As a means of encouraging educators to prepare for positions of leadership in ICT, the ISTE Accreditation and Professional Standards Committee has developed accreditation standards for teacher preparation programs preparing specialists in ICT and standards for school and system leaders in K-12 schools (NETS-A). The ICT specialization guidelines have been adopted by the National Council for Accreditation of Teacher Education (NCATE; http://www.ncate.org) and are currently used for evaluation of teacher education program accreditation.

ISTE/NCATE accreditation standards for programs for educational computing and technology (ICT for education) specialists include the following:

- ISTE/NCATE Standards for Educational Computing and Technology Facilitation – programs preparing teachers of ICT or campus and school leaders who support teachers' integration of technology in their classrooms
- ISTE/NCATE Standards for Educational Computing and Technology Leadership – advanced programs preparing local, state, or regional educational technology coordinators and chief technology officers
- ISTE/NCATE Standards for Secondary Computer Science Education – initial programs preparing secondary teachers of computer science (ISTE, 2002a)

These standards can be found on the Internet at the ISTE NETS website (http://cnets.iste.org) or at the NCATE website (http://www.ncate.org).

Essential Conditions to Support ICT in Educational Environments

When a school, district, or a university teacher education unit adopts or adapts standards to identify how technology will be infused throughout its curricula, faculty in the teacher education programs, teachers from P-12 environments, and administrative leaders should be included in the planning effort. This team should develop plans, giving consideration to their own conditions, culture, and context. For long-term success it is critical for these plans to support self-sustaining implementation of technology infusion within the teacher education or P-12 school program. As educational entities have implemented ICT in educational settings, researchers and evaluators have noted specific barriers that prevent or restrict successful technology infusion. The ISTE NETS Project has studied these commonly cited limiting conditions. From these, a set of essential conditions necessary to create learning environments conducive to powerful uses of technology has been developed. The ISTE NETS essential conditions list these crucial elements for supporting efforts to integrate ICT in schools and in teacher education programs.

When planning for implementation of ICT in schools and teacher education, the planning team should consider each essential condition and note whether, and to what extent, it is present. The context, culture, and extent of collaboration among stakeholders will affect how adequately the conditions are met. These will also determine the types of strategies that might be used to solicit support if the essential conditions are not currently in place. The 13 essential conditions are listed in Figure 5.

Potential for Catalytic Change

When used across a school system, ICT can serve as a catalyst for change in resource strategies, learning tools, communication, planning, operations, management, decision-making, curriculum, teaching, and learning – in short, as a catalyst for transforming education. It also presents challenges in safety and security, and it

Essential Conditions for Implementing ISTE Standards

Necessary conditions to effectively leverage technology for learning:

1. **Shared Vision.** Proactive leadership in developing a shared vision for educational technology among school personnel, students, parents, and the community.

2. **Implementation Planning.** A systemic plan aligned with a shared vision for school effectiveness and student learning through the infusion of ICT and digital learning resources.

3. **Consistent and Adequate Funding.** Ongoing funding to support technology infrastructure, personnel, digital resources, and staff development.

4. **Equitable Access.** Robust and reliable access to current and emerging technologies and digital resources, with connectivity for all students, teachers, staff, and school leaders.

5. **Skilled Personnel.** Educators and support staff skilled in the use of ICT appropriate for their job responsibilities.

6. **Ongoing Professional Learning.** Technology-related professional learning plans and opportunities with dedicated time to practice and share ideas.

7. **Technical Support.** Consistent and reliable assistance for maintaining, renewing, and using ICT and digital resources.

8. **Curriculum Framework.** Content standards and related digital curriculum resources.

9. **Student-Centered Learning.** Use of ICT to facilitate engaging approaches to learning.

10. **Assessment and Evaluation.** Continuous assessment, both of learning and for learning, and evaluation of the use of ICT and digital resources.

11. **Engaged Communities.** Partnerships and collaboration within the community to support and fund the use of ICT and digital resources.

12. **Support Policies.** Policies, financial plans, accountability measures, and incentive structures to support the use of ICT in learning and in district and school operations.

13. **Supportive External Context.** Policies and initiatives at the national, regional, and local levels to support schools in the effective implementation of technology for achieving curriculum and technology (ICT) standards.

Fig. 5 Essential conditions for implementing ISTE standards reemphasizes ethical and legal behaviors. School leaders who fail to grasp the magnitude of the professional challenge in ICT leadership for schools and school systems may not have progressed to a twenty-first century understanding of the implications of technology for teaching, learning, communication, and education leadership – nor technology's roll in a successful global economy. Administrators, policymakers, and other education leaders who are progressive in their leadership for ICT in schools understand the roles technology can play in schools and in society. They establish a shared vision among all stakeholders that succinctly captures the expectations of the school community for a focus of technology use in the enterprise of schooling. Through an emphasis on standards and benchmarks for student learning, the school leader clearly and frequently reminds all involved of the educational standards, or expectations, related to ICT.

Now, more than ever before, it is essential that students, teachers, and school leaders are equipped with technology resources and opportunities to prepare them for the technological changes in our world. The ubiquitous presence of ICT has become a reality that profoundly affects the administrative and instructional decisions made regarding student learning within educational systems worldwide.

Summary and Conclusions

The ISTE has articulated sets of standards to provide guidance and consistency of achievement to teacher education programs and student performance. Administrator standards for incorporation of ICT in education have been developed as well. These standards are used widely in several countries and serve as the NETS for the United States of America. The ISTE NETS-T identifies standards and performance indicators describing what all teachers (preservice and practicing teachers) should know about and be able to do with technology. Whether an institution is establishing a new teacher education program, redesigning an existing teacher education program, or planning professional development for practicing teachers, the NETS-T standards can provide a substantial foundation for infusing technology in the planning process. These standards also constitute a valuable resource for ministries of education outside the USA. Countries as diverse as Canada, India, Malaysia, the Philippines, and Jamaica are making use of the NETS-T as they prepare their teachers to meet international standards.

When examining technological innovation across the globe and its effects on the world economy, it is clear that the world has changed, and that our educational curricula and the strategies for delivery of those curricula must change as well. If our schools are to adequately prepare the children of today to become productive workers and decision-makers in the information- and technology-rich workplaces of tomorrow, schools and universities must adjust their programs to provide new learning environments – environments where students, teachers, and education administrators have opportunities to make use of ICT resources for learning, teaching, and administration. The ICT standards and essential conditions included in this can serve as guidelines for updating our educational systems to meet the practical technological requirements of tomorrow.

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4.3

SELF-REPORT MEASURES AND FINDINGS FOR INFORMATION TECHNOLOGY ATTITUDES AND COMPETENCIES

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Introduction

A self-report survey is a psychological inventory that is reported by the subject. It often asks direct questions related to perceptions, attitudes, or intended actions (NEIRTEC, 2007). There are numerous rationales for using self-report surveys to assess information technology (IT) attitudes and competencies, and some special considerations as well. One rationale is that the technique typically has an anonymous quality not possible through outside observation. Also it is difficult to observe certain indicators such as attitudes and beliefs from outside the person, and therefore data provided by the subject may be more accurate than data gathered by an outside observer. In many situations, time constraints and funding restrictions make self-report the only practical solution for gathering data. The most important consideration in using self-report surveys is the quality of the tool. Well-validated and reliable instruments are required to be able to report valid and reliable results.

Self-Report and Survey Research

According to Albreck and Settle (1991) survey research is frequently used to gather information that is not available from another source or more difficult and expensive to obtain otherwise. For decades paper and pencil instruments have been used to gather survey research information, but recently online data acquisition systems have taken a dominant role.

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Online data acquisition systems have created a revolution in the amount of data that can be gathered from technology in education projects. Online survey administration systems have reduced person-months or person-years of data gathering and tabulating effort to a matter of a few weeks (Knezek and Christensen, 2000). This has made it practical to carry out studies on a two-person or three-person research team scale that were unheard of just a decade ago. Longitudinal studies (Christensen et al., 2005) and large-scale point-in-time research projects (Project Tomorrow, 2006; Christensen et al., 2005) have used online data acquisition successfully.

Critics of online data acquisition contend that the data may not be as reliable as those gathered from paper and pencil surveys, or that teachers and students without technology proficiency (or access) may be excluded in the process. However, the authors' own research (Knezek and Christensen, 2002) found no significant differences in the reliability of data gathered from students via paper versus online; and the authors have found that in many US school districts the percentage of teachers with computers and Internet access outside of regular instructional hours, at school or at home, is now approaching 100%. In many school systems, including one large public school district in Texas, all teachers have had their own laptop for more than a decade (Owen et al., 2005).

The IT attitude and competency findings reported in this chapter are typically based on self-report data gathered through questionnaires. These data, especially when gathered from students and teachers, most often are recorded through online data acquisition systems. Many studies gathered observation data as well and hence could be referred to as mixed-methods research (Johnson and Onwuebuzie, 2004). Some issues associated with self-report versus observation are addressed in the following section of this chapter.

Self-Report vs. Observation

The question of the value of self-report versus observation data is an area where tools now exist to accurately address the issues. Cattell (1973) pointed out that almost every information-gathering procedure in education employs an observer. When the observer is the person about whom the information is being gathered, we call this procedure self-report. The primary issues in this area are three:

– Is an outside observer a more accurate (consistent, reliable) reporter of activities such as the level of technology integration a teacher is able to accomplish in the classroom, than the teacher him/herself?
– Is an outside observer a more appropriate (unbiased, relevant, valid) judge of activities such as the level of technology integration a teacher is able to accomplish in the classroom?
– What are the practical limits, including instructional time ramifications and cost-benefit considerations, of the two techniques?

These questions do not typically have simple answers, and yet there are emerging areas of consensus where quantitative and qualitative researchers are beginning to agree. It appears that well-done self reporting (no high stakes, valid and reliable instruments) on a large scale, complemented by well-selected (nonintrusive, randomly assigned, systematically reported) observations of the same environment, may be the most cost-effective approach to gaining a true picture in most IT in education environments. Initial findings are emerging which indicate that a well-trained outside observer may provide a slightly more valid (relevant) appraisal of a classroom environment than does the teacher him/herself, but that the teacher may provide a more reliable (consistent) appraisal than an observer who is typically in the classroom 1 or 2 hours of a school year (Knezek et al., 2005). One finding that has emerged is that both the teachers themselves and outside observers with rich knowledge of daily classroom activities are reasonably accurate judges of teachers' classroom integration abilities. However, in one study, the observers tended to rate the teachers 27% lower than they rate themselves (Knezek et al., 2005). Further research is needed to confirm this number, which is noteworthy because it is the same decrement that occurs in industry for employees versus ratings by their managers (Noonan, 1996).

With regard to the primary focus of this chapter – IT attitudes and competencies – the authors contend that attitudes might logically be more trustworthy from self-report data, because by definition (see Knezek and Christensen, 2008) they involve the appraisal of an affective component that we assume is inside the individual. Competencies, on the other hand, are normally defined in terms of behaviors and could be reasonably assessed by observation as well as by self-report. One common definition of competency is "having suitable or sufficient skill, knowledge, experience, etc., for some purpose" (Webster's, 2001).

Assessing the Magnitude of Self-Report Findings

Regardless of how data are gathered, at some point statistical analyses are typically carried out, and findings are reported from the survey-based research often employed for assessing attitudes and competencies. How does a reader of findings regarding IT attitudes and competencies know if a particular finding is important for education? Effect size (ES) is a standardized measure of the magnitude of an intervention that has been commonly employed in meta-analyses related to CAI (Kulik and Kulik, 1991; Liao, 2007) and other technology applications. Reporting of effect size is now strongly encouraged for all quantitative research studies (APA, 2001) and is required for publication in many journals. Information technology and teacher education researchers who follow the USA Institute for Education Sciences guidelines for "strong" or "possible" evidence (US Department of Education, 2003) will have little difficulty calculating effect sizes because there will always be a comparison or control group. The reported effect size will typically be the average score of the group not exposed to the technology intervention, subtracted away from the average score of the group that took part in the technology intervention, with the result divided by the standard deviation that would result when both groups were combined. This indicator is commonly called Cohen's d (Cohen, 1988).

One advantage of an effect size indicator is that it can be used to compare the magnitudes of an impact across different studies and on different measurement scales. This is very useful when conducting research on a topic such as ubiquitous computing, where math is the curricular focus in one location, while writing is the focus in another. It is especially useful when large amounts of data are gathered. Cohen's (1988) guidelines for effect size are small = 0.2, moderate = 0.5, and large = 0.8. Another general guideline often quoted in education is that ES ≥ 0.3 is usually considered to be educationally meaningful:

> According to Kulik and Kulik, an effect size of 0.30 constitutes a 'moderate but significant effect'; Ryan notes that an effect size of 0.30 is equivalent to approximately three months' gain in student achievement. Thus, an effect size of 0.30 or better in favor of technology-based instruction suggests that such instruction is significantly effective. … (Bialo and Sivin-Kachala, 1996, p. 2).

The North Central Regional Educational Laboratory (NCREL) has reported that an effect size of 0.1 is equivalent to about 1 month of learning gain in student academic achievement and "… may be of important practical significance if the intervention is relatively inexpensive compared to competing options, if the effect occurs among all groups of students, and if the effect accumulates over time" (NCREL, 2007). NCREL has also reported that effect sizes for educational interventions are rarely as large as +1.0.

Note that studies with highly significant differences (e.g., $p < .001$) within large samples can have small effect sizes, and studies with educationally meaningful effect sizes may not reach $p < .05$ significance. Reporting both effect sizes and significance levels adds useful information. For the findings regarding attitudes and competencies reported in this chapter, significance levels have typically been omitted in the narrative but studies with statistical research designs have been prescreened to those reaching a significance level of at least $p < .05$. Studies reported with effect size indicators are also listed only if $p < .05$ significance was achieved. Unless otherwise indicated, effect sizes reported are in terms of Cohen's d (Cohen, 1988).

Findings

Teacher Attitudes and Competencies

Researchers have known for decades that IT attitudes and beliefs have powerful influences on actions. Loyd and Gressard (1986) showed that positive attitudes toward computers are positively correlated with teachers' experiences. With familiarity, anxieties and fears tend to decrease and confidence increases. Lillard (1985) found that knowledge has a positive impact on teacher attitudes toward technology. Summers (1990) stated that one of the most common reasons for teachers' negative attitudes toward technology is the lack of knowledge and experience in this area. Competencies and attitudes are clearly interrelated.

Researchers have developed models that have components believed to be necessary for successful integration of technology into the classroom (e.g., Rogers, 1999). The will, skill, tool (WST) model (Knezek et al., 2000; Knezek and Christensen, 2008) includes classroom technology integration as a key intervening variable. The model includes three key elements for successful integration of technology: will (attitude) of the teacher, skill (technology competency), and technology tools (access to technology tools). In this chapter we focus on the will and skill as reported by the users.

Importance of Attitudes. Much research in the latter part of the twentieth century focused on teachers' attitudes toward computers and the factors that affected those attitudes (Savenye, 1993). As observed by Tsitouridou and Vryzas (2003), teachers' attitudes are known to play an important role in the effective use of technology. They affect the teachers' level of confidence in computers (Delcourt and Kinzie, 1993), as well as their personal use and adoption of computers for use in class (Hignite and Echternacht, 1992). Teacher attitudes often determine the final success or failure of an initiative to introduce computers into the classroom (Woodrow, 1991).

Gressard and Loyd (1985) also established that perceptions of the potential usefulness of computers can influence attitudes toward computers. The amount of confidence a teacher possesses in using technology may greatly influence his/her effective implementation in the classroom. Positive teacher attitudes toward computers are widely recognized as a necessary condition for effective use of IT in the classroom (Woodrow, 1992).

Attitudes and Use. A positive attitude toward computers is associated with greater computer use. The relation between attitudes and computer experience appears to be strong and positive (Dupagne and Krendl, 1992; Potosky and Bobko, 2001; Necessary and Parish, 1996). Research has shown that as experience rises, anxiety declines (Reed and Overbaugh, 1993).

Computer Anxiety and Related Attitudes. Computer anxiety is the fear or apprehension an individual may feel toward computers, their use, and effects (Leso and Peck, 1992; Loyd and Gressard, 1984; Marcoulides, 1989). Resistance to the use of computers can occur from insufficient knowledge of computers and from a general fear of computers and technology (Harrington et al., 1990). Technological changes sometimes cause adverse emotional responses, such as anxiety. Teachers who are anxious about computers tend to develop negative attitudes toward computers and express opposition to their use (Corston and Colman, 1996; Hohmann, 1994). While computers can be highly effective tools for teaching and learning, resistance and anxiety will have adverse effects on learning and on computer use (Marcoulides, 1989).

Many teachers experience a feeling of anxiety when they confront the prospect of using computers in the curriculum (Woodrow, 1991). Negative attitudes (lack of confidence) and the teachers' lack of skills with computers constitute a serious obstacle to the introduction of computers into the classroom. The less anxious teachers are about computers, the more likely they are to implement computers in the curriculum (Dupagne and Krendl, 1992).

Computer anxiety has been found to be a consistently measurable construct since the earliest reliable attitude scales were developed by Loyd and Gressard (1984). Christensen and Knezek (2000, 2001a,b) have found it to be consistently present in teacher data sets used to derive the Teachers' Attitudes Toward Computers (TAC) Questionnaire. Anxiety (coded as Lack of Anxiety = Comfort) is one of the TAC's nine factor-validated constructs: Interest/Enthusiasm, Comfort (Lack of Anxiety), Accommodation, Interaction (Electronic Mail), Concern (Negative Impact), Utility/Productivity, Perception, Absorption, and Significance.

Christensen and Knezek (2001a) have also been able to show a consistent decline in computer anxiety as educators advance to higher stages of adoption of technology(Christensen, 1997, 2002; Russell, 1995). The six stages measured by this instrument are as follows:

- Stage 1: Awareness
- Stage 2: Learning the process
- Stage 3: Understanding and application of the process
- Stage 4: Familiarity and confidence
- Stage 5: Adaptation to other contexts
- Stage 6: Creative application to new contexts

Figure 1 illustrates the relationship between lack of computer anxiety (Comfort) as well as other attributes measured by the TAC, as teachers advance from lower to higher Stages of Adoption of Technology. This strong linear relationship of an increase in comfort (decrease in anxiety) as teachers advance through higher stages of adoption of technology has been found in multiple studies (Christensen and Knezek, 2001a,b).

Similar trends have been found for concerns-based adoption model level of use (CBAM LoU) and Apple classrooms of tomorrow (ACOT) teacher stages (Christensen and Knezek, 2001a). CBAM LoU (Hall et al., 1975) separates the continuum of use into eight levels and ACOT (Dwyer et al., 1989) defines educator progress in terms of five stages.

Hancock et al. (2007) confirmed that Stages of Adoption of Technology, CBAM LoU, and ACOT together can serve as strong indicators of technology integration.

Attitudes and Demographic Characteristics. Researchers have also examined many demographic variables that have been conjectured to influence the attitudes of teachers toward IT. These factors include the number of years of previous service and the age of the teachers, their use of a computer at home, their inservice training,

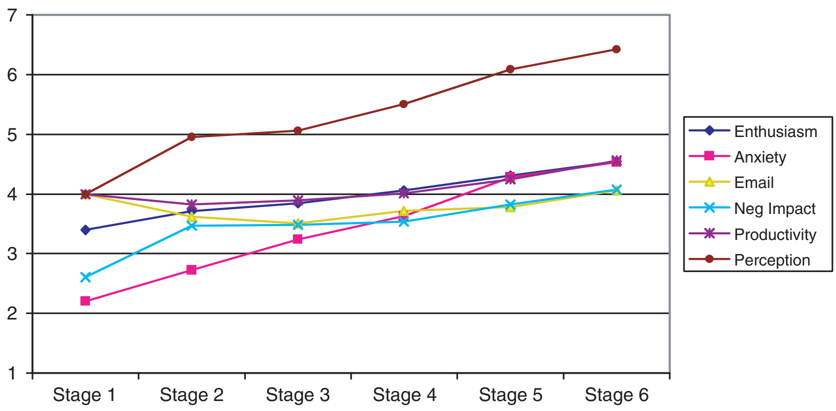

Fig. 1 Teacher attitudes toward computers by stage of adoption of technology

previous experience, and willingness to use computers in their classrooms. The length of a teacher's teaching experience and the age generally appeared to have little impact on the teacher's attitude toward computers (Smith, 1985), although more recent studies have found that younger teachers coming out of traditional university teacher preparation programs typically are more confident in their technology abilities than are their older peers (e.g., Christensen and Knezek, 2006).

Other Factors Related to Attitudes. Piper and Austin (2004) examined the relationship between leadership, experience, and attitudes toward teachers' self-efficacy of using computers in the classrooms. In the models that examined teachers' self-efficacy of Internet use and software use, the variable of experience demonstrated significance. However, in the model that examined self-efficacy in instructional use of computers, the variables of attitudes toward computers, perception of leadership, and professional development demonstrated significance.

> In essence, this means that despite extensive professional development opportunities, if the teachers ultimately have a negative attitude about the use of computers in the classroom or feel the building leadership isn't supportive of the initiative, or the teacher, then it is likely that the teacher's self efficacy in using the computer in the classroom will be negatively influenced (Piper and Austin, 2004, p. 1640).

Riel and Becker (2008) studied the relationship between teacher leadership and use of technology in the classroom. A typology of teachers included those who have a private orientation to teaching, viewing their job as solely in the classroom, known as "private practice teachers." Another type is those who are "professionally engaged teachers" who view their responsibilities to include those beyond the classroom, collaborating with other educators to continually look for ways to improve their teaching. Riel and Becker reported that in the multiple ways these types of teachers differed (background, teaching practices, teaching experience, etc.), none of the differences were on the order of magnitude as the measure of "exemplary computer use." This suggests a strong connection between teacher leadership and use of computers, in both teaching and professional life. Riel and Becker concluded that teacher leaders are much more likely than the typical teacher to have incorporated a wide variety of computer applications into their instructional practice (Riel and Becker, 2008).

Preservice Teacher Attitudes and Competencies. The relationship between anxiety, competency, and computer use appears to extend to preservice teachers as well. Peters (2004) found that preservice teachers who use the computers more frequently are more competent, have better attitudes, and also judge that using technology in the classroom will make them better teachers. Milbrath and Kinzie (2000) found that teachers must have positive computer attitudes and feel self-efficacious in using them to be effective users of computer technologies and be models for students' computer use. The computer training that teachers receive through their teacher education program is likely to foster positive computer affect, yet the change may require time and development. Their longitudinal study examined prospective teachers' changes in perceived anxiety/discomfort with and usefulness of computer technology, frequency of using word processing, e-mail, spreadsheets, database management, statistical packages, and CD-ROM databases, and perceived self-efficacy with the six selected computer technologies over 3 years of study.

Bai and Ertmer (2005) conducted a study that examined teacher educators' beliefs and technology use in relation to preservice teachers' beliefs and attitudes toward technology. The results indicated that teacher educators' learner-centered beliefs about teaching, learning, and learners were significant predictors of preservice teachers' learner-centered beliefs about teaching, learning, and learners. The frequency that teacher educators had students use technology in both constructivist ways and traditional ways predicted the affective aspect of preservice teachers' attitudes toward technology use in instruction.

Evidence is beginning to accumulate that well-designed training for IT in education can be efficiently delivered at the preservice teacher education stage of a teacher's career, before the educator is absorbed in the daily activity of managing a classroom. Christensen et al. (2005) found in a two-university, 4-year study of technology integration preservice teacher preparation methods courses that weekly, 3-hour, hands-on classes and homework, over the span of 15 weeks, resulted in Stage of Adoption of Technology gains in the range of effect size 0.62–1.02. Pre-post gains on self-efficacy measures of the Technology Proficiency Self-Assessment (TPSA; Ropp, 1999) Questionnaires were also recorded for the preservice educators from 2001 to 2003, across multiple offerings of the classes with different groups of students. Pre-post effect sizes ranged from a low of 0.41 (for e-mail skills) to a high of 1.41 (for teaching with technology) (Christensen and Knezek, 2006). These are in the range of moderate to very large according to guidelines provided by Cohen (1988).

Inservice Teacher Attitudes and Competencies. A body of literature on the subject of teachers' attitudes toward computers shows that teacher training programs can play a vital role in making teachers less anxious and more confident about the use of computers (Pina and Harris, 1993). Teachers who have had computer training are more likely to show positive attitudes toward computer use in the classroom (Burke, 1986). Thus education can help teachers to feel less anxiety and more confidence, and generally value computers more highly (Savenye, 1993).

Teachers who are more familiar with computers are more confident about using them for instruction and report more positive attitudes about the instructional effectiveness of computers (Dupagne and Krendl, 1992). Tsitouridou and Vryzas (2003) investigated the attitudes of early childhood teachers toward computers and IT. The subjects of the survey were inservice female early childhood teachers, taking part in a 2-year program of inservice training in Greece. The results show that early childhood teachers' attitudes appear to be influenced significantly by computer use at home, experience with computers, and inservice training. Yaghi (1997) found that teachers with Internet access at home demonstrate more positive attitudes toward computers, and feel a greater need for computers in their lives. Christensen and Knezek (2001b) found a similar trend and further confirmed that teachers without access to the Internet at home seldom become high integrators of technology when working with students in their classrooms.

Student Attitudes and Competencies

Attitudes, Access, and Use. Several studies involving students have addressed attitudes or competencies or both on a multinational basis. In 1992, the Computers in Education Study (CompEd) found that student attitudes toward computers were generally positive in that computers were perceived as relevant to school and later careers, and that student competences on the Functional Information Technology Test were surprisingly similar regardless of home or school access, as long as the student was not lacking in both (Pelgrum and Plomp, 1993, 1996). CompEd also found that while infusion of technology had increased somewhat from 1989 to the 1992 follow-up study, the types of IT implementations were still mostly "easy" applications that might not be expected to bring about systemic change (Pelgrum and Plomp, 1996). The 2003 Program for International Student Assessment (PISA) report (Organisation for Economic Cooperation and Development (OECD), 2005) evidence confirms previous studies showing the particularly strong association of performance with home access and usage. In an age in which computers are a prominent aspect of everyday life and of education, the minority of students who have little access to them, who use them little, and who are not confident in using ICT are not performing well. The disadvantages faced by students whose parents have low educational or occupational status are likely to be exacerbated where they also do not have access to computers (OECD, 2005, p. 66).

Meelissen (2008) provided a comprehensive assessment of student attitudes and competencies worldwide. In her appraisal she concluded that with regard to IT self-efficacy, boys tend to overestimate and girls tend to underestimate their own abilities. In general, gender differences in computer attitudes are very small, and often girls do not show negative attitudes toward computer, but are (a little) less positive. She also noted that different cultural and socioeconomic backgrounds appear be just as or even more relevant than gender from the perspective of forming a "digital divide."

Novelty Effect. In Wilder et al.'s (1985) study involving 1,600 K-12 students in the USA they found that students' liking of computers decreased with increased age. Another study of 339 US students in grades 4–10 confirmed the previous study (Krendl and Broihier, 1992). However, Knezek et al.'s (1994) study of first through fifth grade students in Japan, Mexico, and the USA did not find the same "novelty effect" with respect to attitudes toward computers. They found that Computer Importance did not decline as much as other dispositions related to school and Computer Enjoyment declined little if at all. It was hypothesized that attitudes toward school are what pulls attitudes toward computers down, although not at the same rate of decline as other dispositions. A similar decline across all attitudes related to school was found in US students in grades 1–5 with attitudes toward computers showing the slowest decline (Christensen, 1997). A study of more than 1,600 US students in grades 1–6 also supported this finding (Knezek and Christensen, 2000).

IT Confidence and Academic Performance. IT access is known to affect attitudes and competence, and there is growing evidence that confidence in IT competence (self-efficacy) can be an indicator of academic achievement. Many new research findings are beginning to emerge in this area. For example, the 2003 Program for

International Student Assessment (PISA) report (OECD, 2005) contained many findings related to attitudes, competencies, and self-efficacy that were derived by looking across many nations. Two relevant conclusions regarding student attitudes, student competencies in mathematics, and self-efficacy were as follows:

- In 15 countries, more positive attitudes toward computers were associated with improved performance in mathematics. However, the association was not large.
- The relationship between student confidence in ICT and performance was more clear-cut. Students' confidence (self-efficacy) in performing routine tasks on a computer was a relatively strong predictor of student performance, explaining 10% of the variance in mathematics performance on average across OECD countries (OECD, 2005, p. 66).

Effect of Internet Use. Researchers in Japan have conducted many studies since 2000 examining the impact of Internet use at home and in school on attitudes and competencies. Most of these were conducted using a technique called panel analysis (Markus, 1979), a time-lagged regression technique in which the directionality of impact is inferred by the direction and strength of association. One of the instruments developed and validated during the course of these studies was The Practical Use of Information Scale, which is a 58-item self-report scale which measures the skills of practical use of information – one major component of information literacy as it is defined in Japan. Reliability was reported as 0.90 (Takahira et al., 2001). Findings can be summarized in categories.

Internet use can increase international understanding among students. A panel survey of high school students showed that for male subjects the amount of Internet use heightened (a) the respect of human rights and (b) the sense of international solidarity, while for female students, it increased (c) the understanding of foreign cultures, and (d) the understanding of foreign languages (Suzuki et al., 2001).

Internet usage can have positive effects on student dispositions. A panel study of junior high school students found that frequent e-mail use reduced loneliness in friendships, and longer Internet use increased social support from cyber-friends and off-line friends. Longer Internet use in many tools and for many purposes increased social support from cyber-friends (Ando et al., 2005).

Internet use does not appear to have negative effects on elementary students' attitudes toward learning. A panel study conducted with elementary school students indicated that the use of the Internet for interpersonal exchange significantly enhanced motivation for learning. However, the effect was not large, which led the authors to interpret the findings in the more conservative light of "no negative effects" of Internet use were found (Ando et al., 2004).

Internet use at home or in school increases student information literacy and readiness for an information society. A quasi-experimental study (Kashibushi et al., 2003) involving high school students confirmed that greater use of the Internet in school increased students' readiness for an information society. Another quasi-experimental study (Naito et al., 2003) showed that the self-reported ability in the practical use of information and its four components (the abilities of collection, judgment, processing, and communication) were more greatly improved in schools in which the Internet was used.

Discussion

What Have We Learned About IT Attitudes and Competencies Through Self-Report?

Much has been learned through self-report about IT attitudes and competencies in the past three decades, and especially since the late 1990s, when online survey administration has made large-scale data acquisition more economical.

Self-report is accepted. Historical concerns regarding reliability (consistency) of data and intentional dishonesty do not seem to be well founded with respect to self-report for IT attitudes and competencies. The words of Northrup (1997) in his critique of self-report survey research seem to apply: "Misreporting is negligible for non-threatening questions … " (Northrup, 1997). Reliable and well-validated instruments are now frequently reported in the literature. Benefits of the technique as well as limitations (in comparison to observation and laboratory experiments) are widely accepted.

Attitudes are important. Both positive attitudes and lack of negative attitudes are important for adoption. Computer anxiety was once a serious problem but seems to be less serious now. (However, it is still very serious for teachers who are true novices with respect to IT.) Over time the focus has shifted from anxiety to other indicators such as interest and usefulness.

Self-Efficacy is a bridge between attitudes and competencies. This is critical for teachers. They have to believe they can perform in the classroom. This requires both the training/practice and belief in oneself. Self-efficacy is rarely an issue with students.

Home access is a key to high competency. This is true for teachers to reach high stages of adoption and students to reach high performance. For students, combined lack of home access and lack of school access is a serious problem for attitudes and competencies.

What Still Remains to be Learned?

Is IT a "new toy" and will it become old? Early studies expressed these concerns but so far (into the twenty-first century) interest and enthusiasm do not appear to have waned. This is certainly true at the level of the student learner. Teachers appear positive as well.

What does it mean to be competent? Children seem to be able to reach a high ability level quickly. Teachers and other educators often simply do not have the time to master one technology before another arrives. Will the new generation of teachers who grew up as digital natives be as comfortable with IT when teaching as they were as learners? The answer remains to be seen.

Summary and Conclusions

Teacher beliefs about the worth of technology in education have been consistently high across nations and cultures for several decades. Specific attitudes toward various aspects of IT in education generally have been positive during the late twentieth and early twenty-first centuries and have continued to become more positive overall, as concerns such as computer anxieties and fear of negative impact on society have lessened with increased training and experience. Of course training and experience also increase competence, and a new generation of teachers who have always known computers is becoming a major portion of the workforce. The high confidence this generation possesses in the use of IT in education is also clear. Because of these trends, we contend that the issue of whether teachers and students should become competent users of IT is not something we should continue to debate. Rather the focus should be on finding ways to most effectively teach students how to use the tools necessary for becoming a part of the twenty-first century work force.

Student perceptions of technology are generally positive and the competencies of students with access to technology are high. Student competence in ICT is positively associated with student performance in some content areas. While student dispositions toward school in general decline as they advance through school, attitudes toward computers do not appear to decline at the rate of other measured dispositions. Internet usage at home or in school can increase student information literacy and readiness for an information society.

The WST model mentioned earlier in this chapter provides an organizing framework addressing the impact of teachers' attitudes and competencies, as well as IT access, on student learning. The model is not intended to encompass the numerous other home and classroom variables that influence learning, but rather to narrow the scope to the study of IT in the classroom learning environment. As shown in Figure 2, attitude scale scores from the Teachers' Attitudes Toward Computers (TAC) Questionnaire can be viewed as indicators of teacher will, while scores from the Technology Proficiency Self-Assessment (TPSA) Questionnaire can be viewed as indicators of teacher skill. When combined with indicators of level of technology access (technology), measures of attitudes (will) and competencies (skill) are able to account for greater than 90% of level of classroom technology integration (Morales, 2006).

Research has shown that on the student achievement side of the WST model, level of classroom technology integration has been able to account for ~10% of the variance in school year gains on standardized measures of reading achievement (Knezek and Christensen, 2003, 2007; Knezek, Christensen and Fluke, 2003; Morales, 2006). It is hypothesized that these magnitudes of annual gains would have compounding effects over consecutive years. Hancock et al. (2003) have proposed an expanded WST model that includes attitudes and competency components for students as well as teachers. If these components were included in the equation, then the expanded WST model would encompass most of the attitude and competency measures addressed in this chapter. While it is likely that the resulting model would explain a greater proportion of student achievement than does the existing formulation, the major advantage of an expanded, fully encompassing approach is that it would provide a unified conceptual framework from which to address the interrelationships of isolated research studies and findings. Additional research is needed to test the explanatory/predictive power of this and other unifying models.

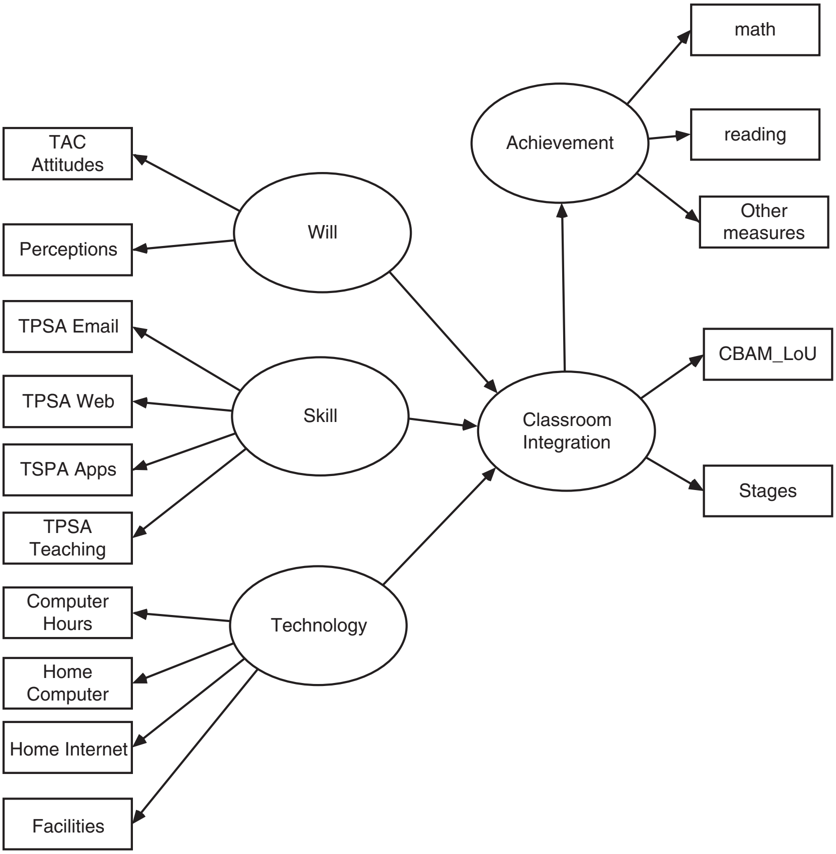

Fig. 2 Will, skill, tool model of technology integration. Adapted from Christensen and Knezek (2001a)

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4.4

OBSERVATION MEASURES FOR DETERMINING ATTITUDES AND COMPETENCIES TOWARD TECHNOLOGY

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Introduction

During the past quarter century major investments have been undertaken in most OECD (Organisation for Economic Cooperation and Development) countries to bring computers into classrooms. As a result of this effort a rapid improvement in student–computer ratios could be seen (see OECD, 2004, 2006). In most OECD countries primary as well as secondary schools have access to computers and educational software applications in their classes or in specially facilitated computer classrooms.

In the United States the *No Child Left Behind* legislation puts forward the need to continue these efforts in the information technology (IT) sector and makes substantial funds available through a performance-based grant program (The White House, 2001). However, the grant program will also shift emphasis from ensuring access to IT to assessing the impact that technology has on classroom practices and on how much students learn at school (Dirr, 2003).

Until recent years empirical research on the effects of IT on students' attitudes and competencies could not provide a clear picture about the relationship between IT access and student academic achievement. The research studies show controversial results: For example, the 2006 OECD PISA report on computer attitudes declares an important effect on the extent of computer use and student performance in mathematics (OECD, 2006). Reanalysis of these results by the German PISA group showed

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that these effects are negligible if these analyses are controlled for context variables in a longitudinal data analysis approach (Senkbeil and Wittwer, 2006).

To address these controversies, alternative research approaches to determine the impact of IT on classroom practice and student achievement need to be considered. The challenge is to assess not only the extent of technology in the classroom but also the appropriate use of technology to facilitate student learning and to relate these observations to student achievement.

One family of approaches is observation techniques. The main advantage of observation techniques is that research objectives can be studied in their natural field settings (such as classrooms) and thereby provide a richer understanding of the topic under investigation. These techniques allow an alignment of classroom observation with the instructional context and the evaluation goals. According to Dirr (2003), observation protocols – or forms of observation techniques – serve as valuable tools in order to:

– evaluate the effectiveness of a school program.
– assess the performance of a teacher or a school.
– provide feedback to teachers for professional development.
– conduct basic research on classroom practices.

These functions make observation a useful component of educational research. For example, observation protocols can serve as a tool to measure whether the use of IT programs achieved anticipated changes in teaching practice and how these changes are related to student performance.

In this chapter we describe different observation techniques, present the rationale for observation techniques, and discuss their unique characteristics as well as advantages and challenges of this research approach. In addition we present examples of how observation techniques can be used to study IT attitudes and competencies and we report a synthesis of findings. We conclude the chapter by discussing how observation research techniques can be enriched and combined with quantitative research approaches.

Observation as an Approach to Researching IT Competencies and Attitudes

In general, observation is regarded as a "primary" data assessment technique because of the closeness to everyday (nonscholarly) techniques in order to acquire information. In comparison to this "naive" kind of observation, the systematic form of observation takes place in an instructional context as a formative assessment tool. Data are gathered under controlled conditions by means of structured observation criteria. In the following section different types of classroom observation measurement instruments are introduced, and advantages as well as limitations of these data assessment techniques are discussed.

Use of Observation Techniques as a Tool of Research

Observation measures in educational research have been used for decades. Substantial research focusing on tracking classroom management and interactions that occur between students and teachers has taken place since the 1970s.

Observation measures for determining attitudes and competencies toward technology include a wide range of approaches, e.g., checklists, inventories, time interval ratings, holistic ratings, narrative descriptions, and logs. Some of these approaches have been built on the prior work of others, but according to Dirr (2003), there is little evidence of any attempt to bring cohesion to these efforts.

Observation techniques allow a systematic, structured data collection process, using well-designed observation record forms. Compared with large-scale summative evaluation tools, the main advantage of these techniques is that data are collected in their natural setting, thereby providing a richer understanding of the subject under investigation. In the instructional educational research context these techniques allow a researcher to view and monitor processes that lead to student comprehension. The data can be used to explain students' performance.

Observational studies in general go through several stages. The Center for Development Information and Evaluation (1996) named a step-by-step list for observational techniques that can be used to judge quality. These steps are named in logical order of the data collection and analysis process.

Step 1: Determine the Unit of Instruction Being Studied

The first step is to decide which unit of instruction is to be studied. This consideration is especially important when the protocol involves third-party observers. Will they observe an entire class period, a segment, an entire day, an entire course, or program? Different protocols are used to observe different units of instruction. Because of resource constraints, the observational approach has to be selective, looking at a few activities, events, or phenomena that are crucial to the research questions. A good example of this point is the study of Wecker et al. (2007). The research team chose an observation method that focused on the activities on the computer screen and the users' spoken comments regarding those activities (see Chapter 3.2).

Step 2: Select or Develop an Observation Form

Observation record forms help to standardize the observation process and to ensure that all important items are covered. They also facilitate aggregation of data gathered from various sites or by various investigators. Closed response categories (yes or no answers, check boxes) help to minimize observer variation, and improve the quality of data. If the number of items in a form is limited, then the observation process is more manageable. One important question concerning this step is how the prior work form of other scholars can be integrated into one's own research questions.

Step 3: Specify a Sample

Once the forms are ready, the next step is to decide where the observations will be carried out and whether it will be based on one or more schools or classrooms. A single site observation may be justified if the class or school can be treated as a typical case or if it is unique. However, single observations should generally be avoided. As a rule, classes from several schools are needed to obtain a reasonable understanding of a situation (see Stigler and Gallimore, 2000). In SITES-M2 (Second Information Technology in Education Study – Module 2), for example, the countries selected one or more of the primary, lower secondary, or upper secondary levels, with four cases for each level (Kozma, 2003). The cases were selected by a national panel for their "innovativeness" and for what could be learned from them about how technology is being used to support educational change.

Step 4: Decide on Timing

Timing is a crucial point in the observational process, especially when events are to be observed as they occur. Classes normally follow a fixed sequence. Poor timing can distort findings (see Petko et al., 2003). Because most studies observe classes continuously with at least two observers who record their findings independently on a form or by the help of video technology or both (see Schaumburg, 2001), the probability of missing the key moments when events occur can be decreased.

Step 5: Conduct the Field Observation

As previously mentioned, an observation team can provide more comprehensive and reliable data than can a single observer (see Schaumburg, 2001). If many classes are to be observed, nonexperts can be trained as observers, especially if observation forms are clear, straightforward, and mostly close-ended.

Step 6: Complete Forms

The observer should take notes as inconspicuously as possible. The best time for recording is during observation; however, it is not always feasible because it may disturb the situation. In such cases, recording should take place as soon as possible after observation. For example, McInerney et al. (1996) used a procedure in which the instructor also took the role as an observer and recorded his observations in a weekly tutorial diary (see Chapter 3.2).

Step 7: Analyze the Data

Observation data from close-ended questions can be analyzed using basic procedures such as univariate and bivariate statistics. Qualitative observations need to be coded in reference to specific categories with respect to the research questions. Finding these aspects and arranging them together in a system of codes is an important process. The "cyclical analytical process" includes viewing, coding, and analyzing the data aimed at transforming the video images into objective and verifiable information (Jacobs et al., 1999). Usually the coding process is repeated several times because in viewing the videotaped material new aspects might occur important from the researcher's perspective (also see Stigler et al., 2000; Dirr, 2003; Petko et al., 2003; Horsley and Walker, 2003). For the coding itself software such as videograph (http://www.ipn.uni-kiel.de) or ATLAS.ti (http://www.atlasti.com) can be used.

Step 8: Check for Reliability and Validity

Observation techniques are susceptible to error and bias that can affect reliability and validity. Errors can be minimized by following some of the procedures suggested, such as checking the representativeness of the sample of schools or classes selected; using close-ended, unambiguous response categories on the observation forms, recording observations promptly, and using teams of observers at each site (see Wecker et al., 2007).

Video-Supported and Audio-Supported Observation

In the early twentieth century, one can find the roots of present observation approaches. However, early twentieth century approaches are now supported by high-end technical devices. Video was originally used as a stenographic recording method (Stevens, 1910, as cited by Stigler et al., 2000). The video-supported observation was used more than 40 years ago for the first time in the context of educational research. Now this research approach receives much attention (Leinhardt and McCormick, 1996; Stigler et al., 1999; Aufschnaiter, 2001; Ulewicz and Beatty, 2001; Petko et al., 2003; Seidel et al., 2005). Recording audio data is another observational method. Depending on the research questions, a combined use of videotaping and audio-recording can be useful since multiple types of data enable the data to be triangulated and thereby increase confidence in the conclusions drawn.

A recent approach to recording observational data is to record user activities on a computer screen (Wecker et al., 2007). This approach can be adequate, for example, for investigating students' competencies while using a computer. Compared to videotaping teachers' or students' behavior, screen recording captures all desktop activities. It can deliver more data about the individuals in detail because of the separately recorded data on each computer. In contrast to the observation with a single video camera, this approach can deliver data from every single computer and its user(s). For capturing the activities on a computer screen, software such as Snapz Pro (MAC) (http://www.ambrosiasw.com) or Camtasia and SnagIt (PC) (http://www.techsmith.com) has to be installed. If a microphone is installed near the computer the software is able to record the subjects' spoken comments during their activities with the computer.

The latest approach to gaining data on attitudes is the implementation of Face Reader-Software (http://www.noldus.com). This software automatically recognizes specific properties in facial images, including the following emotional expressions: happy, sad, angry, surprised, scared, disgusted, and neutral. The emotions are represented as bar graphs and as a continuous signal. An additional gauge display analyzes how negative or positive the emotion is. This software is currently not a substitute for a human coder, but it might be a good support for precoding video data in respect to specific aspects. A human coder/researcher can select such precoded video sequences and analyze them more deeply in the context of the whole video. The classifications made by the Face Reader can be exported to analytical and database programs for further analyses.

Advantages and Challenges of Observation Research Techniques

Observational data deliver a much wider spectrum of information, which expands the researcher's ability to analyze complex human interactions such as those in a classroom setting. When using a video-supported observation approach, the analysis of complex human interactions can be conducted more easily because the recorded video data can be analyzed again and again. Through this set of techniques unanticipated ideas and alternative analytic categories can also be discovered. The same set of video data might provide a focal point for interdisciplinary collaboration. In addition, data gained from video-supported observation allow the integration of qualitative and quantitative methods of analysis (Stigler et al., 2000).

When conducting an observation in a classroom, there are also challenges (Dirr, 2003). Each observer approaches the classroom with his or her own experiences and biases. As a result, two observers may focus on different aspects of the classroom and thus they may record different phenomena for the same lesson. Also every school environment provides a different context in which the observations take place. This variation can affect the record-keeping behaviors of the observers. One or more observers may have an effect on classes, e.g., on the behavior of teachers and students. The observed lessons can vary from the "normal" situation and thus lead to a falsification of the data. Unless the observers and coders are given extensive training, reliability among their observed and rated data can be low.

Classroom observations, data recording, and data analysis are very time-consuming. Therefore the researcher has to carefully consider which data are needed with respect to the research questions.

A Synthesis of Empirical Research Results

The US No Child Left Behind Act (The White House, 2001) emphasizes that the use of technology in the classroom can be a tool to improve academic achievement. Such legislation emphasizes the fundamental need to gain more knowledge about how integration of IT in classrooms can be realized. In this respect, research on attitudes and competencies toward IT is a major topic for study. Observation techniques may provide a deeper insight into learner attitudes, compared with standardized questionnaires.

In the following section we present the results of an ERIC search of studies on attitudes and competencies toward information technologies that used observational techniques. Our major goal is to provide insight into the kind of observation techniques that exist and how they are implemented in studies. Furthermore, we will give examples of findings attained by the use of observation measures and advantages that accrued compared to other methodological approaches. We will synthesize the findings of these studies to put together a picture of what we can learn from using observation techniques in understanding teachers' and students' attitudes and competencies toward technology.

We followed Whitley's (1997) approach to locate studies. As a first step, we conducted a computerized search of the ERIC database from their inception through abstracts available as of June 1994. We conducted the search using the term "comput* and attitud*," in which "*" is a wild-card character that institutes a search for any word having the designated stem. As a second step, the reference lists of prior literature reviews were examined for relevant sources. Finally, we searched the reference lists of articles located by the other means.

The ERIC inquiry results on this issue produced a few results based on the keywords observation/measurement, qualitative research, participant observation, data collection, and social research. The search also produced a small number of results for the keywords attitudes, students, and observation. The largest number of hits was reached with the keywords *computer capabilities*, *attitudes*, *computer use* in combination with a second set of keywords *computer attitudes*, *computer literacy*, *computer uses in education*, that were added to the search by using OR-operators.

Review of Researches on Attitudes Toward Information Technology

Many studies have used the "traditional" observation method, conducted by one or two persons who joined the observation group and filled out observation forms. This approach of investigating attitudes is still quite common, although the influence of new observation technologies is continuingly growing. A more elaborate way to gain data on attitudes is to use a triangulation approach. This means the interpretation of the acquired data through observation methods by involvement of other qualitative data (e.g., interviews) or quantitative data (e.g., questionnaires) collected in parallel. Several studies used mixed methods in order to capture the richness, complexity, and interdependence of events, actions, and conditions in the real classroom. Observation methods were also applied to corroborate interview or survey data. Combining data from more than one source helps to detect possible biases in subjective reports. By using triangulation for the interpretation of data, the probability of getting objective, reliable, and valid results is much higher than by simply using a single approach.

In the following, the methodology and findings of selected studies that use a triangulation approach will be presented. It should be mentioned that in several studies research on attitudes is just one aspect of the research goals. In many studies research on attitudes is also combined with research on competencies.

One study carried out by Schulz-Zander and Preussler (2005) at the upper secondary level used a triangulation approach to evaluate a new state program in North Rhine-Westphalia, which combined self-regulated learning methods with a problem-oriented approach to mathematics. Data were gained from principal, teacher, and student interviews, a student survey, and classroom observations, conducted by two persons and videorecorded.

Students' attitudes toward information and communication technology (ICT), cooperation, independent learning, academic, computer-related, and mathematic-related self-efficacy were gathered from questionnaires combined with interview data. The observations were used to support information gained from these data. The triangulated data indicated increased self-regulated learning in general, caused by the new developed materials and learning arrangements. In addition, the study showed significant gender differences. More male than female students assessed the digital media as supportive for their learning processes. Males also preferred ICT for self-learning, and felt mathematics more interesting and better visualized through digital media than did females, who preferred traditional media. More females had problems with self-regulated learning or functioning as a tutor. Females felt overly challenged to master the difficulties, especially when they did not collaborate with others. Thus, more support was required from the teacher. Also, significant gender differences related to the academic, mathematic-related, and computer-related self-efficacy were found. Males had a significantly higher self-efficacy than did females. High-performing students (mostly males) coped better with the new concept of mathematics problem orientation, self-regulation, and ICT use than low-performing students did. The findings indicate a cumulative effect for low-performing students (see also Preussler and Schulz-Zander, 2004).

Schaumburg and Issing (2002) carried out a study with a longitudinal pretest–posttest control group design to investigate the impact of personal mobile computers in the classroom of a German grammar school ("Gymnasium") (see also Schaumburg, 2001, 2002). Subjects covered were mathematics, German, and English as a foreign language. To investigate changes in teaching strategies and classroom practices, the observational data were collected to confirm data (e.g., attitudes toward ICT, teachers' and students' roles, self-efficacy) gained from teacher and student interviews and student surveys. Researchers observed the same classes (grades 7–9) and the same teachers in lessons with and without laptop use. A randomly selected sample of lessons of the laptop classes was videotaped over 2 ½ years. The video-supported observations were conducted by two persons, one who did the videotaping and a second person who simultaneously conducted a nontechnical unstructured observation of what was happening in the class. For each interval of 5 min length, two trained observers recorded the dominant media use and form of instruction. Schaumburg and Issing combined their observations with interviews of the teachers from their observed lessons to corroborate the information they would get from their observational data (triangulation).

Using teacher interview data, Schaumburg (2002) identified five types of teachers, based on their attitudes toward teaching with laptops: type 1 focused on teacher-centered instruction, type 2 focused on media literacy/techniques, type 3 focused on curricular/content, type 4 focused on didactics and methods, and type 5 supported a constructivist approach. Teachers of types 4 and 5 composed the minority.

Results gained from questionnaires and interviews were confirmed through observations with respect to increased independence of students' work during laptop lessons. But, the study could not confirm increased collaborative classroom activities in the laptop lessons for all three cohorts, when compared to lessons without laptops.

The same was true for the shift from teacher-centered instruction to student-centered learning through laptop use. Video analysis showed that the change was less profound than the teacher interviews and student survey data indicated. The amount of independent student work increased significantly during laptop lessons, but for teamwork, pair work, lectures, and teacher-guided discussions no significant differences were ascertained. Yet, teachers and students felt that the laptops were valuable tools for teamwork and facilitated collaboration. With respect to the different types of teachers, Schaumburg found that only teachers of types 2–4 displayed a change in their teaching style. Types 2 and 4 increased the group work in their classes. Type 2 teachers exhibited a more effective acquisition of computer competency. Only type 4 teachers practiced collaboration related to content. Solely type 4 could be identified as having made a substantial change of their teacher roles. These findings should be considered in the context of the investigated school type which in general is more focusing a teacher-centered instruction and independent learning and less on cooperative learning.

Another study using the triangulation approach was conducted by Jaervenoja and Jaervelae (2005). They came to the conclusion that an observation on its own cannot tell enough about the students' attitudes toward a computer-supported inquiry learning setting. The authors used interviews with the students to support their observational data.

In contrast to the ordinary interpreting process (see Schaumburg, 2001), Jaervenoja and Jaervelae used a modified approach. By the help of the Noldus Observer software (http://www.noldus.com) they transcribed their video data as a first step. In a second step, they watched the transcripts again and wrote specific descriptions regarding the students' emotional and motivational expressions as well as volitional behavior. During the second phase the researchers were more familiar with the data, and looked again at the videotapes with the transcriptions they had made during the first phase and wrote specific descriptions of the students' emotional and motivational expressions and their volitional behavior.

The aim of Jaervenoja and Jaervelae was to understand how students describe their emotional experiences and their attitudes in computer-supported collaborative inquiry.

The results show five main sources for student's attitudes during the computer-supported inquiry learning. Self- and context-driven emotions were the most frequent sources of emotional experiences, but task-, performance-, and social-driven emotions also were identified. Jaervenoja and Jaervelae conclude that these results are in accordance with the idea that individuals bring their prior learning experiences and assumptions to the learning situation (Higgins, 1990; Salonen et al., 1998).

Review of Researches on Competencies for Information Technology

In this section we will give an overview of ERIC-referenced articles concerning the research on competencies for IT.

The studies of Schaumburg and Issing (2002) and Haeuptle and Reinmann (2006), both were the same in design (multimethodological approach), data interpretation (triangulation), and medium of intervention (notebook computer). The study of

Haeuptle and Reinmann (2006) is also a case study, carried out at a German secondary general school ("Hauptschule") in grades 7–10. One of their research questions aimed at clarifying how the implementation of notebook computers into classes in a school can contribute to improvement of student competencies. In their study they used the observation approach to support the information that they received from student interviews. Especially when trying to gather information about competencies, the observational approach can deliver data to make visible processes of acting and reacting. The study concludes that the implementation of notebooks into the classroom improves the student IT and social competencies. The students also developed different strategies in working with and using the notebooks. Furthermore, the students showed their willingness to learn more about ICT.

The purpose of the study of Ilomäki and Rantanen (2007) was to examine the development of students' high-level computer skills and competency (student expertise) in ICT. Design (multimethodological approaches), data interpretation (triangulation), and also the medium of intervention (notebook computers) were the same as in the previously presented study. In combination with other methods, classroom observation was used in this study to describe the classroom activities concerning ICT and student participation in them. This study used a longitudinal design. Data collection (e.g., observational data, questionnaires) was repeated several times, mostly with duration of at least 1 year in between. Through this approach it became possible to see changes happening over a longer period, e.g., in the students' ICT competency caused by the implementation of notebook computers.

Similar to Haeuptle and Reinmann (2006), Ilomaeki and Rantanen also came to the conclusion that student ICT competency increased through the use of notebook computers in the classroom. But in addition they identified differences in the students' degree and type of ICT competency during their 3 years of research. They identified a subgroup of students with a special technical interest in ICT but also a subgroup that used ICT as a tool for their own creativity and human interests. Ilomaeki and Rantanen also came to the conclusion that the degree of student ICT competency depended on the students' personal interest and motivation – for instance, the time the individual student spent using the Internet at home.

McInerney et al. (1996) conducted research on the question of how a cooperative group setting influences a student's computer competency training, in comparison to a direct instruction setting. The instructor, who was teaching both groups, also was the observer who provided observational data. After the lessons, the instructor recorded his observational findings in a weekly tutorial diary, which contained several categories of interest. This tutorial diary was analyzed in a qualitative/intuitive way. Findings were supported by student interviews (triangulation). The study concluded that an instructional setting that boosts the development of self-regulation and peer support reduces the students' anxiety and increases their motivation by enhancing a sense of control and competency.

Finally, we present a technical state-of-the-art observational approach. This research, conducted by Wecker et al. (2007), tried to clarify the question of whether higher computer competency – more specifically, greater procedural computer-related knowledge, higher familiarity with computers, and higher self-confidence in using a computer – might be associated with greater acquisition of knowledge. They collected data by using questionnaires in combination with a screen observation. Screen observation means observing all the activities that occur on the computer screen by using screen-capturing software. Wecker et al. also recorded audio using an integrated microphone in the computer. It then became possible to interpret what is seen on the screen by combining these data with the information that the computer users provide by commenting consciously or unconsciously on their activities. Wecker et al. did the transcription/coding of the video/audio data with the help of the Videograph software. This technically supported observation approach provides new and innovative possibilities for conducting nonparticipating observation.

The findings of this study do not indicate significant positive relations between procedural computer-related knowledge or self-confidence in using the computer and knowledge acquisition. Notably, students having a greater familiarity with IT achieved significantly less knowledge. Wecker et al. interpret these findings in the context of the patterns of media use by different navigation styles adopted by students having high and low familiarity with computers. Students having high familiarity with IT exhibited more shallow processing strategies ("browsing"), which were less functional for learning.

Conclusions

The use of observational methods has changed during recent decades from nonsystematic and nontechnical to a more objective and reliable, technically supported method. Based on the review of research on attitudes and competencies of the ERIC database, it can be stated that most studies used other methodological approaches (e.g., questionnaires or interviews) as well as observations.

For measuring attitudes and competencies the main value of observational measures is added capability for clarifying explorative research questions. Observational methods can deliver meaningful, unique data. Especially when using observational data in the context of data triangulation in combination with other methodological approaches (qualitative as well as quantitative approaches) – as was practiced in all our reviewed studies – observational investigations are able to provide valuable information about the conditions of the natural field settings, teaching arrangements, classroom activities, and the individuals in detail, which helps to make an overall interpretation of the results more objective, reliable, and valid.

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4.5

COMPUTER ATTITUDES AND COMPETENCIES AMONG PRIMARY AND SECONDARY SCHOOLSTUDENTS

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Introduction

Research on students' use of information technology (IT) often results from concerns about the so-called "digital divide." The digital divide refers to differences in computer use, attitudes, and competencies with regard to gender, age, ethnicity, or social economic status (Broos and Roe, 2006). In most western countries the participation of females in IT professional careers and pathways is not only low but also still falling (Anderson et al., in press). Therefore, in the last 30 years, the most frequently reported sociodemographic parameter of the digital divide has been gender. One of the main topics in this field is girls' and boys' attitudes toward IT (which is mostly referred to as "computer attitudes"). In the United States in particular, differences between female and male students in attitudes toward computers have been the subject of many studies since the 1980s (Volman, 1994). At first, the interest for computer attitudes was mainly directed to being one of the influencing factors explaining gender differences in computer use and in computer competencies. During the last 20 years, computer attitudes have become the main focus of study by itself. Nowadays, the number of studies on the "gender gap" in computer attitudes exceeds the number of studies on computer competencies and abilities by large (Imhof et al., 2007; Kay, 2006). Studies on computer attitudes, competencies, or use among students with different cultural or social economic backgrounds are also still scarce, although the differences between these groups seem to be substantial as well (Volman et al., 2005).

This chapter provides an overview of the main research results of studies on (gender) differences in computer attitudes (including computer anxiety) and studies on (gender) differences in computer competencies during the last 15 years (for summaries of earlier studies, see Volman, 1994). Although the majority of studies are conducted

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among university and college students or among adults, the main focus in this chapter will be on students in primary and secondary education.

The first and major part of this chapter is directed to studies on computer attitudes. Despite the large interest of researchers for students' computer attitudes, the results of these studies are often inconclusive or sometimes contrasting. Therefore, the benefits as well as the limitations of these studies will be discussed in the first section. An overview of the main results and outcomes is provided in Section 2. Section 3 focuses on research on students' computer competencies, including their own perceived competencies. The last section (4) summarizes the main results and addresses possibilities for future research in this field.

Measuring Computer Attitudes

As stated earlier, despite the large number of studies on students' computer attitudes, the results of these studies are often inconclusive or even in contrast to each other. For example, although the majority of studies show less positive computer attitudes of girls compared with those of boys, the difference is often very small or negligible (Meelissen, 2005; Whitley, 1997). Furthermore, some studies show no gender differences in computer attitudes at all or find more positive attitudes among girls than among boys (King et al., 2002; North and Noyes, 2002; Whitley, 1997). One of the explanations could be related to the measuring of the construct "computer attitudes" in those studies. The research literature on attitudes toward computers shows a large variation in the use of computer attitudes scales (Christensen and Knezek, 2000; Dryburgh, 2000; Durndell Haag and Laithwaite, 2000). In general, the operationalization of computer attitudes is based on the attitude theory of Fishbein and Azjen (1975), in which three aspects are distinguished. The first aspect is the affective aspect and refers to someone's feelings about the subject. In terms of computer attitudes, the affective aspect can be measured by statements about liking computers or enjoyment in computer use. The perceived relevance of computers could be an operationalization of the cognitive aspect of attitudes or in other words, someone's perceptions and opinions about the subject. The last aspect refers to the behavior toward the subject. In computer attitudes research, this aspect can be measured by instruments measuring computer anxiety or self-confidence in computer use.

Often, only one or two of these aspects are measured in computer attitude studies. One of the most used instruments (or versions of this instrument) is the Computer Attitude Scale (Gressard and Loyd, 1986). In this scale three subscales are distinguished: enjoyment in computer use, computer anxiety, and self-confidence in computer use. The first scale refers to the affective aspect; the other two refer to the behavioral aspect. However, computer anxiety could also be regarded as a potentially influencing factor on students' attitudes (e.g., Durndell and Haag, 2002; King et al., 2002). The same goes for concepts such as gender-stereotyped views on computers, self-efficacy, or self-confidence. These concepts are used as subscales of computer attitudes or as potentially influencing factors on the dependent variable computer attitude (e.g., Comber et al., 1997; Levine and Donitsa-Schmidt, 1998). The large variation is discussed by Kay (1993):

> *One method of developing a common language among attitudes scales is to develop a composite of the various constructs already identified. This process is hindered somewhat by a noticeable absence of theoretical justification provided by researchers in support of their constructs. In a number of studies independent constructs are identified in a post hoc fashion. Without some theoretical substance, it is difficult to pick and choose from the computer attitudes grab bag* (Kay, 1993, p. 372).

Researchers in this field seem to pay little attention to the effects of their choice for an attitude instrument. In the research of Levine and Donitsa-Schmidt (1998) and Pope-Davis and Vispoel (1993) it turned out that self-confidence, which is often used as a subscale of computer attitudes, fits better as a subscale of computer anxiety and that anxiety and attitudes are two different concepts. Gender differences seem to be much more substantial for computer anxiety (girls are more anxious than boys) than for liking computers and relevance of computers (Charlton, 1999). On the other hand, a Scottish study among primary school children shows that gender differences occurred only in enjoyment and relevance of computer use and not in self-confidence (Todman and Dick, 1993).

There is variation not only in the operationalization of computer attitude, but also in the actual measuring. In most cases, computer attitudes or subscales of computer attitudes are measured by presenting students with statements on computers and asking them to what extent they agree with these statements (e.g., Meelissen, 2005; Shashaani, 1994). In the study of Whitley (1996), gender differences occurred only for the negative statements (female students agreeing more with negative statements about computers than did male students), while there were no differences regarding the positive statements. Therefore, Whitley (1996) emphasized that negative and positive statements in a computer attitudes scale should be well balanced. Often this is not the case.

Another possible explanation for the lack of agreement in the research literature on computer attitudes has to do with the meaning of the word "computer" in the computer attitudes scales. If it is presented just as "computer," the respondent could associate the computer with a variety of attractive or less attractive hardware devices, software, and uses. Including a distinction in the different uses of computers in the attitude scale is not that common in the research literature (Richter et al., 2000; Van Eck, 2002). Volman (1994) measured the attitudes of Dutch secondary school students before and after a computer literacy course. Students who finished the course no longer associated computers with playing computer games, but regarded computers mainly as an instrument for teaching and learning. According to the research of King et al. (2002), students in lower secondary education regarded computers above all as an instrument for playing games. Their attitudes changed during secondary school, as computers were used more seriously for educational purposes and the use became more vocationally oriented.

Differences in associations with the word "computer" could lead to differences in attitudes. In other words, the interpretation of the results of many studies is hindered by the fact that the researcher does not really know what each respondent is thinking of when the respondent gives an opinion about "the computer." The lack of this distinction could be a threat to the validity of the computer attitudes scale used.

Finally, in terms of generalization of the results for the research population, the eloquence of the outcomes of studies on computer attitudes is often not that strong (Dryburgh, 2000; Meelissen, 2005). Although a case study approach with in-depth interviews or lessons observations seems to be less common in this research field than a survey approach, survey instruments are frequently administered among convenience samples of students from a few classes or schools. But also in the case of larger, random samples, the possibility to generalize to the research population is often not addressed in the research design. Very few studies recognise the limitations of their sample and incorporate these limitations in the interpretation of their results (e.g., North and Noyes, 2002).

Taking into account these limitations of computer attitude studies, the main theories and research results on (gender) differences in computer attitudes are described in the next section. The section gives an overview of the main and recent publications on students' computer attitudes in primary and secondary education. As stated earlier, computer attitudes are often analyzed from the perspective of gender differences in computing. Therefore, a substantial part of the studies described in this article are carried out with this perspective in mind. Often, these studies do provide insight into the factors influencing computer attitudes in general as well.

In the next section, the research literature is summarized on the basis of three main topics. These are the socialization processes, gender-specific behavior, and the influence of schools and teachers.

Students' Computer Attitudes

The Socialization Theory

Perceived "Masculinity" of Computers

The rationale for research on the digital divide between males and females is often based on females' low participation rates in computer science courses and IT-professional careers (Anderson et al., in press). IT professions and computers are assumed to be unattractive for females because of their "male image." It is argued that this male image has a negative effect on the attitudes of girls as a result of gender differentiated socialization (e.g., Brosnan and Lee, 1998; Charlton, 1999). Children are taught by their environment (parents, other family members, peers, and in the media) what "correct" behavior is for boys and what "correct" behavior is for girls. Knowing a lot about computing and liking computers has a different meaning for girls and boys. For example, boys with high computer interest and skills have historically received more appreciation from their environment than girls have with the same skills and interest.

Some researchers have found evidence that it is not the physical attributes traditionally associated with gender (being male or female) that determine student computer attitudes. To a large extent, their attitudes are determined by the gender with which the child identifies him- or herself (e.g., Brosnan and Lee, 1998; Charlton, 1999; Todman and Day, 2006). In other words, not the sex of a child but the "psychological gender" is regarded as the main factor determining students' computer attitudes. Because computers are often seen a male domain, children who identify themselves as more masculine may have more positive attitudes toward computers, as opposed to children who identify themselves as more feminine.

In the 1960s, females were just as involved in the area of early computer science as males. Females played an important part in the introduction of the binary system and in the development of the computer language Cobol (COmmon Business-Oriented Language) (Corston and Colman, 1996). Female computer programmers were even preferred to male programmers because of their supposed "accuracy" and "patience." This changed completely during the 1970s and 1980s in most of the industrialized western countries. Computers and computer science became associated with more typically "male" areas, such as mathematics, science, and technology. For example in the Netherlands, the introduction of computers in secondary schools was often initiated by mathematics and science teachers. Those teachers also became responsible for the computer science lessons (Beentjes et al., 1995). A study carried out among secondary school females in the USA showed that negative attitudes toward mathematics are strongly related to negative attitudes toward computers and that girls are less positive about mathematics than boys are (Shashaani, 1995).

Not only the association of computers with mathematics and technology was responsible for the male image of computers, but the use of the first personal computers at home played a role as well. In the beginning of the 1980s almost no (user-friendly) software was available, which meant that computers were predominantly used for programming and playing games (Teague and Clarke, 1995). Males spent considerably more time than did females with these computers. According to Teague and Clarke, males are more interested in experimenting with new techniques, even when the practical use of that technique is not clear. For females, the direct practical use is much more important than it is for males. Furthermore, most of the computer games that were available were more directed to the interests of boys than to the interest of girls, which emphasized the male image of computers (Charlton, 1999).

However, Charlton (1999) also argues that the male image of computers is no longer a valid explanation for gender differences in computer attitudes. Nowadays, computers are widely available, have become more user-friendly, and computer use has become much more varied. In 2003, in most western and also some nonwestern countries both girls and boys spend more than an hour per day playing computer games and more than half an hour per day using the Internet (Mullis et al., 2004). The variety of available computer games and the intensity of gaming have increased enormously. Among English primary and lower secondary school students, playing computer games turns out to be the favourite out-of-school activity for both girls and boys (Mumtaz, 2001; Colley, 2003). In the Netherlands, primary school boys (grade 5) reported more intensive computer use outside school hours than girls did. However, although boys spent on average 5 h per week, girls still spent on average 3 h per week with the computer (Meelissen, 2005). Both girls and boys spent most of that time gaming.

Empirical evidence on how the image of computers is perceived by girls and boys is not widely available. In 1994, Shashaani collected data about gender-stereotyped views on computing among almost 1,800 American secondary school students. It turned out that only boys regarded computers as a typically male domain, while girls did not. In 1997, an English study among primary and secondary school students showed that on average, girls explicitly disagreed with gender-stereotyped statements about computers and that most of the boys were neutral toward this subject (Comber et al., 1997). However, the majority of Dutch boys in grade 5 (in 1999) were convinced that boys knew more about computers than girls did (Meelissen, 2005). Furthermore, about a third of the girls agreed with them. Girls with less gender-stereotyped views on computers were expected to have more positive computer attitudes. However, gender-stereotyped views on computers turned out to be unrelated to either girls' or boys' computer attitudes (Meelissen, 2005).

Another method for finding out whether computers are (still) regarded as typically masculine is applied in a study by Mercier et al. (2006). With surveys, drawings, and interviews, sixth- and eighth-grade students were asked to generate representations of computer users in pictures or in words. Both girls and boys were more likely to draw a male user. Frequently, the drawing showed a boy wearing glasses and sometime the word "nerd" was written under the drawing. When asked whether these students saw themselves as such a "computer-person," around 80% of the students disagreed. There were, however, no significant gender differences.

It is also not yet clear whether the male image of computers can be regarded as a worldwide phenomenon or just as a characteristic of western industrialized societies. In the beginning of the 1990s, an international study called COMPED *(COMPuters in EDucation)* included questions about computer attitudes in the student questionnaires (Pelgrum et al., 1993). COMPED showed that in most western countries boys in primary and secondary education were more positive about the relevance of computers when compared with girls. However, Japanese girls in upper secondary school regarded computers as more relevant to themselves than to their male classmates. With regard to enjoyment in computers, these gender differences were even more substantial (girls were less positive). In Japan and India these differences were less convincing, compared with the differences in the western countries. The absence or the smaller differences in attitudes between girls and boys in Japan and India could indicate that the male image of computers is not a worldwide phenomenon. A study supporting this assumption is a small-scale survey among primary and secondary school students in South Africa. It showed no gender differences in computer attitudes, nor did students perceive computers as a typically male domain (Bovee et al., 2007). According to the majority of both male and female students, females have the same abilities in computer use, in learning computer science and in pursuing a computer-related career.

The Influence of the Social Environment

According to the socialization theory, parents, other family members, friends, and also teachers are expected to have a substantial influence on students' computer attitudes (e.g., Shashaani, 1993). A Dutch study from 1995 analyzed the relation between computer use of parents and that of their primary school children (Beentjes et al., 1995). Fathers and brothers spend more time with the computer at home than do mothers and sisters. In general, the amount of time that parents spend together with their children at home with the computer was positively related with out-of-school computer use of those children. For girls, the frequency of the use by their mother turned out to be more important than that of their father. More recently, a Dutch study of the computer attitudes of primary school children showed no relation at all between the intensity of computer use at home by the parents and the computer attitudes of their sons or daughters (Meelissen, 2005). However, the support of parents with regard to the computer use of their children turned out to be very important for children's attitudes. Although boys experienced more encouragement from their parents to use computers than girls did, the effect of encouragement was stronger for girls' computer attitudes than for boys' computer attitudes. In an earlier study of Shashaani (1994), a similar relation was found; the computer attitudes of girls in secondary school were less positive if their parents were convinced that "knowing a lot about computers" was less important for girls.

In the same study, the relation between socioeconomic status (SES) (educational level and profession of the parents) of the student and computer attitudes was also analyzed. This study showed a very modest positive influence of SES on computer attitudes of students (Shashaani, 1994). However, these results were not found in a more recent Flemish research among upper secondary school students. In this study, no relation between SES and computer attitudes was reported (Braak and Kavadias, 2003).

The socialization theory assumes that older students are more exposed to the influence of the social environment than are younger students, and therefore gender differences in computer attitudes increase with age (Shashaani, 1993). This could explain why the low interest of girls in computers is mostly visible in the under representation of girls in computer science courses and IT-related professions. Several studies have found that gender differences in computer attitudes and computer anxiety increase with age (e.g., Chua et al., 1999; Comber et al., 1997). Analyses of data from about 10,000 grade 3–12 students in the USA revealed that in grade 4 and grade 5 girls enjoyed computers even more than boys did, but in the higher grades of primary school these differences were the other way around (Christensen et al., 2005). There are also studies showing a less linear correlation between attitude and age. A Scottish study showed that, in general, students' attitudes toward computers became less positive during primary school years (Todman and Dick, 1993). Girls enjoyed computers less than boys did; however, the extent of these gender differences stayed the same throughout primary school. A small-scale study among 5- to 13-year-old students in the USA revealed a remarkable relation between age, gender, and gaming (Cherney and London, 2006). Boys' out of school activities, such as gaming, became a little more "masculine" with age, but girls' leisure activities became less "feminine." With age, girls became more interested in playing computer games that could be regarded as masculine, such as action adventures, human and fantasy violence, or sports.

Compared with younger girls, older secondary school girls in Australia indicated that computers were more interesting and more relevant, because the computer use at school has become more serious and useful in the higher grades (King et al., 2002).

As stated earlier, males seem to be more interested in experimenting with new techniques, even when the practical use of that technique is not clear (Teague and Clarke, 1995; Christensen et al., 2005). For females, the direct practical use is much more important than it is for males. For secondary school students, this difference between males and females seems to become more apparent during their school career.

Gender-Specific Behavior

Studies on computer attitudes from the 1980s and 1990s are often reporting about the importance of computer access for the explanation of (gender) differences in attitudes. The assumption was that more access would lead to more experience, which in turn would lead to more positive attitudes (e.g., Comber et al., 1997). However, there are also indications that persons with a negative reaction to computers will feel even worse when they are reinforced with repeated exposures to them (Garland and Noyes, 2005).

In many western countries, access to computers seems to be no longer a relevant issue. According to the latest *Trends in International Mathematics and Science Study* (TIMSS-2003), more than 75% of the primary school students from 25 nations have access to a computer at home (Mullis et al., 2004). Therefore, the discussion about the relation between computer access, computer experience, and computer attitudes seems to have been shifted from computer access and experience to the "quality" of computer experience (e.g., McIlroy et al., 2001). Girls and boys experience computer use differently because of gender-specific behavior (e.g., Bamossy and Janssen, 1993; Volman, 1997). Especially the differences in the way girls and boys interpret their own performance in computer use could be an important factor explaining the lower interest of girls for computers. Some observational studies show that girls and boys attribute success and failure in computer use very differently. Girls blame themselves for failure and attribute success to external causes such as "luck," or "easy task." For boys, it is the other way around. They blame the situation in case of mistakes and "boast" about their successes. Boys show the teacher what they can do with computers while girls show the teacher what they cannot do with the computer (Bamossy and Janssen, 1993). In her study among Dutch lower secondary students, Volman (1994) called this behavior of boys in the classroom during computer literacy lessons "the expert repertoire." Girls showed the "outsider repertoire," which not only included reservations about their own computer competencies, but also avoided any signs of computer expertise.

In research about gender differences in mathematics achievement the same line of reasoning is applied. The "learned helplessness paradigm" states that gender differences in mathematics achievement and in affective factors can be explained by psychological differences in attribution styles between boys and girls (Boaler, 1997). Compared with boys, girls are much more likely to blame themselves for failure in mathematics, and as a consequence, show less confidence in mathematical tasks and enjoy mathematics less. Boaler (1997) argues against this paradigm, because girls themselves are seen as the main factor causing the inequity. She also refers to it as "blame the victim paradigm." Although the differences in success attributions between girls and boys with regard to computers seem to be empirically supported, this paradigm has one important weak point. It is not clear whether and why this behavior is specific for "male" subjects like mathematics and computer literacy. The international comparative study of reading literacy (Progress in International Reading Literacy Study), for example, showed that in most countries girls are more confident than boys in their reading abilities (Mullis et al., 2003). Obviously, this is influenced by girls' higher achievement in this subject compared with that of boys. It is however unclear whether and to what extent the described gender differences in success attributions are also playing a role with regard to self-confidence in reading.

The Influence of Schools and Teachers

In general, it is assumed that computer use for educational purposes is not only important for (improving) teaching, but teaching is important for students' attitudes toward computers as well. Several authors suggest that the teaching approach could play an important role in reducing gender differences in computer attitudes (Brosnan and Lee, 1998; Comber et al., 1997; McIlroy et al., 2001; Mumtaz, 2001). Volman (1994) showed in her study the importance of "gender inclusive" teaching methods. In her research she found that the computer literacy lessons she observed in Dutch secondary schools were nowhere near gender inconclusive education. Teachers treated girls differently from boys. When girls needed help, teachers were much more inclined to help them by demonstrating how it should be done than they were inclined to help boys in that way. Boys were more stimulated than girls to find it out for themselves. Boys were also asked more questions by the teachers and teachers had higher expectations of the computer knowledge and skills of boys.

It is assumed that the students' computer attitudes are partly determined by the attitudes, confidence, and abilities of the teacher to integrate technology in a meaningful way in the lessons (McIlroy et al., 2001; Torkzadeh and Dijke, 2002). For example, primary school students in England found computer use in school not attractive because of the limited use of computers in the classroom; computers were mostly used for traditional drill and practices programmes or word processing. The use of computer(s) at home turned out to be much more advanced (Mumtaz, 2001). Some authors argue that especially female teachers have a positive influence on the computer attitudes of girls, because a female teacher could be regarded as a role model for girls (Brosnan and Lee, 1998; Janssen Reinen and Plomp, 1993). A Dutch study on gender differences in attitudes in primary education (grade 5) showed that the computer experiences (number of years using computers) of the teacher had a small positive effect on girls' computer attitudes, but only if the teacher was female (Meelissen, 2005). However, although female teachers assessed their own computer skills considerably less positively than male teachers did, their perceived computer competencies turned out to be unrelated to the computer attitudes of girls. Therefore, it was not confirmed in this study that the gender of the teacher is really important for the computer attitudes of girls and boys.

Students' Computer Competencies

The limited interest in the research field for students' computer competencies, also indicated with the terms computer performance, computer ability, or computer achievement, is in big contrast to the large attention of researchers in computer attitudes (Imhof et al., 2007; Kay, 2006; Tsai and Tsai, 2003). Furthermore, for measuring competencies an even wider range of measures is used, often specially directed to the target group. This makes it very difficult to compare the results of these studies and draw general conclusions from them. Studies in which computer competencies are measured are mostly targeted at university or college students or other groups of (young) adults and not at primary or secondary students (e.g., Garland and Noyes, 2005; Imhof et al., 2007; Kay, 2006). In this section, a few examples are discussed of research in which student competencies, in general computer and Internet skills, were studied. Furthermore, this section will provide some theories about students' own assessment or expectations of their success in performing computer-related tasks. This assessment perceived by the students is often indicated with the term "self-efficacy."

Competencies

One example of a study measuring general computer knowledge and skills of primary and secondary school students is the international comparative COMPED study (Pelgrum et al., 1993). In 1992, these students were tested in the domain of "functional computer knowledge." In all ten participating countries (including Japan and Indonesia) boys outperformed girls in this test. An updated version of this test was used in a Dutch large-scale study in primary (grade 5) and lower secondary school (grade 8), called the ICT monitor (ten Brummelhuis, 1998). Unfortunately, possible gender differences in the tests scores were not reported, but this study indicated that most of the computer skills were learned outside school and not in the classroom. It turned out that the differences between primary (grade 5) and lower secondary students (grade 8) in computer competencies were rather small, although the tested students in secondary education just finished a compulsory computer literacy course at school. The achievement test addressed most subjects of the course.

A more recent study among Taiwanese grade 8 students looked at the relation between students' learning strategies and computer achievement (Tsai and Tsai, 2003). It was concluded that the so-called higher-order learning strategies (as well as metacognition, or "thinking about thinking") resulted in higher computer achievement. Especially the role of study aids (e.g., "I compare class notes with other students to make sure my notes are correct") turned out to have a positive influence, not only on computer achievement but also on computer attitudes and confidence in computer use. Students who are aware of and are able to use helpful learning resources (other students or online resources) seem to become more successful and confident computer users, compared with students with limited use of such study aids.

Self-efficacy

With regard to computer competencies, the main interest seems to be directed to self-efficacy: student's own assessment or expectations of their success in performing a computer-related task. This concept was introduced halfway through the 1970s. According to Bandura (1986), self-efficacy refers to "people's judgements of their capabilities to organize and execute courses of action required to attain designated types of performances" (p. 391). Sometimes self-efficacy is regarded as a subscale of computer attitudes (Kay, 2006).

Just as the concept computer attitudes, the concept self-efficacy can be operationalized in many different ways. Often it is a list of questions referring to the respondents' confidence in carrying out general computer tasks (e.g., Durndell et al., 2000; Torkzadeh et al., 2006). Another example is asking students whether they are able to do a whole range of computer activities without help from others (e.g., Meelissen, 2005). Other self-efficacy instruments are task-specific measures for a specific target group (Torkzadeh et al., 2006).

Just like studies on computer attitudes, self-efficacy is often studied from a gender perspective. Girls seem to show a lower self-efficacy compared with boys, especially in the more complex computer tasks (e.g., Meelissen, 2005). In a Dutch study among grade 5 students, the majority of both girls and boys indicated that they were able to perform the most common computer activities such as copying text and saving documents, word processing, or using a drawing program (Meelissen, 2005). Boys showed more self-efficacy than did girls in tasks that were (in 1999) less common and more complicated such as sending an attachment with an e-mail, forwarding an e-mail, and downloading programs or documents from the Internet. Furthermore, it turned out that self-efficacy had a small effect on computer attitudes in general, but the effect on the attitudes of girls was more substantial than the effect on the attitudes of boys.

Another Dutch study measured the skills of IT of primary and secondary school students from different ethnic backgrounds (Volman et al., 2005). Although the instruments used were not intended as an operationalization of self-efficacy, the study did not measure students' actual computer skills, but reported students' own assessment by asking them how good they consider themselves in the presented general computer tasks. The gender differences in this study turned out to be very small. Compared with boys, girls in primary schools considered themselves less good in surfing and downloading files from the Internet. Girls from secondary schools considered themselves also less equipped with skills for downloading from the Internet and they were less handy with burning CDs. No significant differences were noted with respect to all other computer tasks. The differences between ethnic-minority students and majority students were much more extensive than the gender differences. For example, ethnic-minority students reported fewer skills in word processing, working with illustrations, and using the Internet.

Summary and Prospects for Future Research

Owing to a lack of agreed-upon instruments for measuring students' attitudes, self-efficacy, and computer competencies and the shortage of studies using representative, random samples, the results in this research field are often inconclusive or are based on limited empirical evidence. One of the most addressed topics in computer research is gender differences. Although in most studies girls show less positive attitudes, lower self-efficacy, and less frequent use of computers, the statement that there is a gender gap in computing and girls are behind boys is less straightforward than it seems to be. In general, gender differences in computer attitudes are very small, and often girls do not show negative attitudes toward computer, but are (a little) less positive. With regard to self-efficacy, boys tend to overestimate and girls tend to underestimate their own abilities (Comber et al., 1997). More important, gender differences in attitudes, out-of-school computer use, and self-efficacy in computers can only be described as "being behind" if use and attitudes of boys are regarded as "the norm." There is an increasing gender gap with regard to the participation of women in IT courses and professions, but to what extent this is related to or caused by the reported differences between primary and secondary school girls and boys is not clear. Other factors such as the attractiveness of IT professions or the unavailability of female role models in the IT field could be just as or even more important. The question remains whether the supposedly lower interest of girls in primary and secondary education for computers is really such a major problem that it justifies the ongoing large interest of researchers for this subject. The study of Volman et al. (2005) showed that research among students from different cultural and socioeconomic backgrounds seemed to be just as or even more relevant from a digital divide point of view.

To strengthen the foundation of theories such as the socialization theory, the "learned helplessness paradigm" or the assumed influence of school and instructional characteristics on computer attitudes, it would be useful to measure computer attitudes and competencies of students in large-scale international comparative studies, such as the COMPED study. These studies have several advantages over small-scale, often explorative studies that are now most common in this research field. First, they provide the possibility to develop (internationally) reliable test instruments to measure student achievement (among students from different age groups) in basic knowledge and skills in information and communication technology, as well as theoretical-based and empirically valid attitude scales. In those scales, distinctions should be made in the different uses and purposes of computers, and the positive and negative statements should be well balanced. Second, the COMPED study collected data at three levels: school, class, and student. This makes it possible to analyze non-school-related and school-related factors in conjunction with students' computer literacy. Finally, the international comparison provides the opportunity to find out whether (gender) differences in computer attitudes and competencies are a characteristic of the western culture, or are more a worldwide phenomenon.

The design envisioned is close to that of TIMSS (Trends in Mathematics and Science Study; Mullis et al., 2004) and PIRLS (Progress in International Reading Literacy Study; Mullis et al., 2003). Especially the ability to analyze trends turned out to be very important for the success and participation of countries in these studies. Therefore, it would be an important addition for this research field to include students' computer literacy achievement tests and computer attitudes instruments in future COMPED studies, and repeat those studies regularly, to analyze and compare developments in all parts of the world. Furthermore, with this design it is possible to find more conclusive evidence of the presumed influence of the social environment (including schools and teachers) on the interest of girls in pursuing an educational and professional career in information and communication technology.

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4.6

CHARACTERISTICS OF TEACHER LEADERS FOR INFORMATION AND COMMUNICATION TECHNOLOGY

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Introduction

At about the same time that the idea of teacher leadership was emerging as a professional development strategy, desktop "microcomputers" had begun to have a significant presence in K-12 schools. An increasing number of teachers had become intrigued, and even excited, by the possibilities of improving motivation and learning in their classroom through the use of computers and their software. This led to a rapid growth of teacher networking around computers in education, which in turn developed into formal educator-based organizations at varying levels of geographic inclusiveness, from regional and state organizations (e.g., computer-using educators) to national and even international organizations (e.g., the International Society of Technology in Education). With the expansion of the World Wide Web in the mid-1990s, geographically dispersed teachers began using the communications affordances of the Internet to develop informal networks of common professional interests. Through these informal networks and through teachers' involvement in educational computing organizations and conferences, computer-using teachers gained a sense that they belonged to a community of innovators at the leading edge of change in educational practice.

Although some teachers in this new educational computing subculture focused their attention almost exclusively on using technology in their own classrooms, a significant number became strong advocates and leaders for establishing a wider role for computers in the instructional practices of their colleagues. In that way, teachers personally excited by the possibilities of computers for their own teaching entered the broader realm of teacher leadership.

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In this chapter, we define teacher leadership more precisely as behavior reflecting a high level of engagement with the *profession* of teaching and with other teachers, both locally and at a distance, who constitute a teacher's professional colleagues. Teachers with *minimal* professional engagement focus on the routine practice of instruction in their own classroom – perhaps *not ignoring* other teachers, but at least not attempting to influence their teaching practices. In contrast, teachers with *strong* professional engagement across a range of activities and domains are the teachers whom we regard as the leaders of their profession.

After reviewing the literature on teacher leadership, we present a model of four dimensions of teacher leadership – each reflecting a high level of professional engagement in a particular domain: classroom, school, professional organizations and networks, or the profession as a whole. We summarize U.S. national data that we collected on the extent of teachers' professional engagement and on the content of teacher leaders' teaching philosophies and instructional practices, including their use of computers. We show that teacher leaders, a group *defined independently* of their teaching philosophy and pedagogical practices, are in fact (a) more constructivist than other teachers of the same subject and level, and (b) use computers substantially more than other teachers do. Then we apply our general model of teacher leadership to technology leadership in particular, showing how one might reasonably expect teacher *technology leaders* to incorporate Information and Computer Technology (ICT) into their professional practice in ways that parallel the actions of teacher leaders more generally and thereby foster exemplary practice among other teachers.

Teacher Leadership and Professional Engagement

Paralleling the use of teacher leadership as a strategy for professional development is a substantial research literature that seeks to understand it. In their recent *Review of Educational Research* article, York-Barr and Duke (2004), proposed a conceptual model of teacher leadership using teacher characteristics and dimension and conditions of teacher leadership work. They highlighted three characteristics of teacher leaders: respect among their school peers, an orientation towards continuous learning, and a personal capacity to influence others' practices; four characteristics of leadership work: valued in their school's culture, visible, negotiated, and shared. Finally they include four conditions required for teacher leadership to flourish: supportive principal and colleagues, time for collaborative work, resources, and opportunities for professional development.

Instead we find it useful to view teacher leadership primarily in terms of how teachers conceptualize their role – their duties and responsibilities as teachers. Some teachers view their work as taking place solely within their classrooms in what is essentially a private, individual practice. Teachers with a private practice orientation have little time for meetings, conferences, or other forms of professional engagement. They use the textbooks, other supplied teaching resources or created materials and orchestrate their own instructional practices without significant input from others. They may do this because of perceived disagreements between their own perspective and those of their peers or because of a sense that the norms of their craft do not permit admitting that one needs help from peers in order to do one's work. In either case, their choice is to engage in a private practice. They are content to let educational decisions about curriculum, policies, or standards be made by outside experts, and they accept that different teachers choose to teach in ways that they themselves believe are less likely to be effective than other approaches. Instead, they focus on trying to be the best teacher they can be with the students in their own classroom. Of course, all teachers focus on their own practice, but for some it is their *only* focus.

Other teachers, though, view their responsibilities as extending beyond classroom teaching to include participation in the larger community of educators and administrators. They see their role as trying to help other teachers be more successful and to influence how teaching occurs in other places. Teachers with this *leadership* orientation not only work in collaboration with other teachers at their school to improve teaching and learning, they also see their responsibility in terms of the larger community of educational practitioners (Glazer, 1999). Their concern about what happens in other classrooms becomes part of their own definition of being successful. In its most profound manifestation, teacher leaders influence the practice of teaching in the profession as a whole. Over time, a teacher attains the perspective of a teacher leader as a result of taking on increasing responsibility for the success of the teaching enterprise. We see the following set of practices as collectively describing the expertise embedded in teacher leadership, in which a teacher moves from classroom activities to knowledge-building within the larger profession:

1. Learning from One's Own Teaching: Maintaining a disposition to improve their teaching, and in particular, developing innovative "adaptive" pedagogical expertise.
2. Collaborating and Sharing Responsibility for Student Success: Promoting and employing a public rather than a private practice of teaching; encouraging and accepting collective responsibility for student learning across their school site.
3. Participating in Geographically Diverse Communities of Practice: Engaging actively in regional and national teacher professional organizations and networks and actively seeking out and using ideas, information, and expertise beyond the practitioner community.
4. Making Personal Contributions to the Teaching Profession: Communicating their learning to peers through conference presentations, university teaching, and publishing.

Although we describe each of these domains of teacher leadership separately, they represent overlapping and interrelated practices. Just as the underlying dimensions of professional engagement are multidimensional, teacher leadership is manifested in different forms, varying both by *breadth* of engagement across these four domains and by *extensiveness* of involvement in any one domain. Referring to someone as a "teacher leader" is a shorthand way of saying that, relative to most other teachers, this individual engages significantly in some combination of these four domains of leadership. As discussed in the next section, the four domains can be seen in *developmental* terms, in which engagement in one domain would typically, but not necessarily, precede engagement in the succeeding domains. Finally, while we recognize that principals and other administrators play a central role in creating the conditions that either foster or inhibit the development of teacher expertise and leadership, our focus in this description is on the actions or practices of teachers.

Describing a Route to Teacher Leadership

Learning from One's Own Teaching

When teachers use the context of their own classroom to reflect upon and systematically inquire about the learning that is taking place, they are taking a necessary step for improving their own practice (Ball and Cohen, 1999; Feiman-Nemser, 2001). Unfortunately, many teachers do not prioritize their own learning in a way that advances their expertise (Bereiter and Scardamalia, 1993; Darling-Hammond, 2000; Elmore, 2002). Some teachers use their experiences to perfect a set of routines and strategies that seem to "work" for them – adjustments that can be rapidly and effortlessly employed in the classroom, but that are based only on the narrowest criteria of "improvement." For example, these teachers may not attend to the variety of ways that different students think about the same presentation of ideas, or be alert to how new tools might reshape practice. For these teachers, skill at teaching is having taught the same lesson so many times that they can teach it with their eyes closed. In contrast to this habitual approach to teaching, "adaptive expertise" describes a different approach (Hatano and Inagaki 1986). Using a specific set of cognitive, metacognitive, and dispositional strategies (Bransford et al., 2000), teachers employing adaptive expertise engage in a process of progressive problem-solving that enables them to continually learn from practice. Adaptive expert teachers also reuse lessons, but they continue to be attuned to the nuances of context with a readiness to experiment and innovate with new content, tools, and strategies (e.g., see Tsui, 2003).

Adaptive expertise involves a purposeful and attentive orientation to novelty (Chi et al., 1988). This form of expertise evolves from a process of progressively transforming problems of practice into questions, using these questions to shape action, and reflecting on the results to frame new questions (Allen and Calhoun, 1998; Coghlan and Brannick, 2005). Teachers who learn from practice in this way often move into positions of teacher leadership when they share what they are learning with their peers.

Collaborating and Sharing Responsibility for Student Success

Teacher leaders not only learn from teaching, but they redefine teaching as a public act inviting others to observe, participate, and discuss teaching practices. In many schools, norms – informal expectations and sanctions – governing conversation strongly discourage substantive discourse about teaching methods during lunch or in the teacher lounge (e.g., see Little, 1990; Wasley, 1991). Public teaching involves changing the pervasive norms of privacy and autonomy so that teachers actively engage their colleagues in dialogue, formally and informally, about the practice of teaching (Meier, 1995). In Lortie's classic study of the vertical and horizontal isolation of teachers, he highlighted schools' unmet need for "greater adaptability, more effective colleague relationships, and more sharing in the issues of knowledge and expertise" (Lortie, 1975, p. 221).

Teacher leaders strive to make teaching more public by encouraging their colleagues to engage in activities that examine and critique different approaches to teaching. These include "cycles of inquiry" about teaching (McLaughlin, 2004), lesson study (e.g., see Fernandez, 2002), collective analysis of videorecorded lesson examples (van Es and Sherin, in press), collaborative unit design (Wiggins and McTighe, 1998), mentoring and coaching (e.g., see Carroll, 2005), and collaborative forms of evaluating student work (Blythe et al., 1999). What is common to these different types of activities is that all engage teachers in making their everyday work public and the focus of dialogue (Little, 1982; DiPardo, 1999). Although many of these approaches were organized by outside educators and researchers, effective implementation often involves developing informal teacher leaders who help develop and refine the techniques for the local context, and in doing so sometimes move into more formal leadership positions.

Teacher leaders use public teaching as a means to build a community orientation to teaching in a school and for developing a sense of trust and collective responsibility for student learning in schools (e.g., see Riel and Fulton, 2001). The notion of teacher professional community (e.g., see Riel and Fulton, 2001; Westheimer, 1998) suggests a concern with developing not just collaborations among a few teachers but of teachers taking on shared responsibilities for success of all students in the school. Frank (in press) suggests that a strong identification with a larger collective can result in the formation of "quasi-tie" which increases the tendency of members to share resources with others in the community even where there is no close personal tie. These weak ties (Granovetter, 1973) are often the way new information travels from one subgroup to another.

In one sense, teacher leadership is a partial usurpation of the traditional responsibilities of school administrators. However, Spillane et al. (2001) refer to this development not as usurpation but as "distributed leadership" – a fluid and empowering concept akin to the earlier term "shared decision-making," a feature of earlier efforts to engage teachers in leadership roles within the school (e.g., see Weiss, 1993). In this newer formulation, teacher leadership is thought to be primary in areas related to pedagogy and implementation of instruction while administrators' responsibilities are focused on strategic planning and external relations (Crowther et al., 2002). The ideas of professional communities and teacher leadership are joined by the recognition that professional communities cannot develop by fiat from above but require indigenous intellectual leadership to emerge within the teaching staff (Grossman et al., 2001; Hargreaves, 1994; Westheimer, 1998).

Strong collegial relationships allow for more frequent interaction about ideas and thus promote critical reflection and deep learning about practice (Cochran-Smith and Lytle, 1999; Grossman et al., 2000; Little, 1990; Westheimer, 1998). Teacher leaders actively foster the continuing intellectual development of teachers and work collectively with shared responsibility and commitment (Grossman et al., 2001; Darling-Hammond and Bransford, 2005).

Participating in Geographically Diverse Communities of Practice

Schools vary in terms of the norms and social structure for supporting the flow of ideas from outside of the school building. Teacher leaders not only play a role in sharing problems of practice, and learning from each others' experiences and ideas at the school level, but are often the conduits for the movement of new ideas between schools. They do this by joining professional organizations, attending conferences, and participating in "communities of practice" (Lave and Wenger, 1991) with teachers in distant places. This type of professional engagement with networks of other teachers beyond the local context can bring value to a teacher's own school culture by invigorating the school conversation with important new ideas and expertise (DiPardo, 1999; Little, 2003).

Teacher leaders serve this role by pursuing connections with university professors and researchers, attending professional conferences, and actively searching for published educational materials, software tools and application, and making use of the Internet to bring to the internal conversation information and scholarship that might otherwise be missing. It is true that outside information can increase conflict among ideas circulating in a school building, but teacher leaders can play a valuable role in resolving this conflict in productive ways (Achinstein, 2002). In this way, teacher leaders broker knowledge. They serve to help bring expertise and resource from the district, network communities, or professional organizations and conference back to the school, and in doing so increase the social capital of the school (Penuel et al., 2008).

Making Personal Contributions to the Teaching Profession

Thus far, we have been talking about the role that teacher leaders play at the building level in working collaboratively with peers and bringing new ideas from the world of research and professional writing to bear on teaching in their common setting. But leadership involves going beyond improving understanding to actually *influencing* common understandings held in the professional community writ large – i.e., the knowledge base of teaching. As teachers' skills and abilities develop, they may contribute to this knowledge-building activity as professional developers, authors of articles or books for educators, or designers or evaluators of curriculum or software. Their contributions shape the professional dialogue for others in distant contexts. Schon (1983) hoped that reflective practice of the form we have been describing could lead the way to a new epistemology of practice. Action research advocates also look to deep contextual knowledge of practice to provide the insights that will lead to more general understanding of pedagogy through praxis (Allen and Calhoun, 1998; Coghlan and Brannick, 2005).

A number of publications, such as the *National Writing Project Quarterly*, have evolved to support national efforts at teacher knowledge building. In the American Educational Research Association, special interest groups have formed around

Teacher as Researcher and *Action Research* to encourage teacher leaders to participate in shaping the knowledge base for learning and teaching. Ultimately, this form of teacher leadership challenges traditional roles and power relationships and argues for a stronger relationship between teaching and research, theory and practice (Bereiter, 2002).

Teachers Leaders Represent the Highest Level of Professional Engagement

Bass (1981, as cited in Wasley, 1991) suggested that the essential characteristic of teacher leaders is that they "enable their colleagues to do things they would not ordinarily do on their own to improve their professional practice." If that is so, then these four processes of engagement in the profession – (1) an intellectual approach favoring innovation and divergent thinking; (2) the move of teaching from a private to a more shared space and shared professional commitments in the workplace; (3) access to important sources of ideas and resources through teacher networks, academia, and elsewhere; (4) and participation in knowledge-building in the profession as a whole by taking on roles of presenter, teacher, and author – represent the kinds of leadership acts that seem likely to result in the outcomes suggested by Bass. As shown in Figure 1, we see these practices as forming a pyramid of the

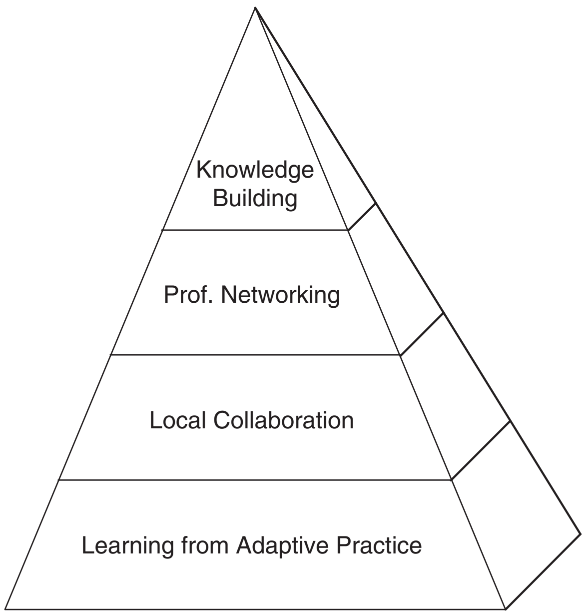

Fig. 1 Teacher leadership practices

growth of teacher leadership. Informal teacher leadership operates at the base and as teachers increase their expertise in each of these practices – employing adaptive expertise in their teaching, providing support to their same-school colleagues, participating in professional communities and networks, and contributing to the knowledge base of the profession – they are more likely to move into more formal leadership roles.

Variation in Professional Engagement: Findings from the TLC Study

We measured the distribution of levels of teacher professional engagement across a broad national sample of U.S. teachers (Becker and Riel, 2000). Findings from that study, known as the Teaching, Learning, and Computing: 1998 National Survey, or "TLC" for short, have been published in a number of venues, but we concentrate here on findings about teacher professional engagement. See also http://www.crito.uci.edu/TLC.

In the TLC study, professional engagement was measured from answers to three survey questions, comprising a total of 15 separate response opportunities. One question measured the frequency of six types of teacher collaboration and collective responsibility for teaching in their school (four types of substantive discussions and two items about mutual observation of classroom teaching). A second question measured the frequency of three types of participation in communities of practice beyond the school (workshops, committees, and electronic mail). The third question obtained information about the teacher's involvement in six types of leadership activities, including mentoring, speaking at workshops, college-level teaching, and publishing articles for a teacher audience. For each of the three survey questions, criteria were defined to indicate "high" and "medium" levels of engagement in that particular area. For example, a "high" level of within-school interaction was indicated by an average frequency midway between "several per month" and "one to three times per week" for the six types of discussions and classroom observations (e.g., discussions about how to teach a particular concept, or visits to another teacher's classroom to observe teaching). Teachers who scored "high" in all three areas (within-school, beyond-school, and leadership) were designated as "teacher leaders." Those who had scores of at least "medium" in each area were designated "teacher professionals." The remaining teachers were designated either "interactive teachers" or "private practice teachers" based on their combined score on the three indices.

Overall, 13% of 4th through 12th grade teachers in the nationally representative sample met the "high" within-school interaction criterion and 27% others met the less rigorous "medium" criterion. However, because teachers who collaborate within their school do not necessarily collaborate beyond their school and do not necessarily engage in leadership activities, only a small minority (16%) of teachers who met the "high" criterion for within-school interaction also met parallel standards on the other two aspects of teacher professional engagement and thus became classified as teacher leaders. Similarly, only about one fourth of those who met the less rigorous "medium" standard in terms of their within-school interactions also met at least a medium standard in both of the other two aspects of professional engagement. The percentages of teachers responding in particular ways to each of the 15 survey responses are omitted here for lack of space but can be found in Becker and Riel (2000).

Using these three sets of questions to create a high standard for leadership, we found that in the representative sample of teachers, only 2% were teacher leaders, with another 10% classified as teacher professionals. These two groups of teachers represent a range of teacher leadership skills and together we refer to them as "professionally engaged teachers." The majority of teachers (58%) were classified as representing the traditional norms of limited interaction with other teachers, that is, "private practice teachers." "Interactive teachers" (29%), an intermediate category, represent teachers who collaborated with their peers either in their school (for example, by engaging in substantive discussions or by mentoring younger teachers) or beyond (e.g., attending workshops), but did not meet the moderate standards on all three dimensions – in-school, beyond-school, and leadership activities.

As a group, professionally engaged teachers were somewhat more experienced than private practice teachers, with about 5 years more teaching experience. However, more significant than their slightly greater teaching experience was that professionally engaged teachers had been distinctly more invested in their *own* education, with nearly twice as many reporting college grades above 3.5 on a 4-point scale (50% vs. 28%) and half-again as many having a master's degree (64% vs. 42%).

Teacher Leaders' Beliefs About Teaching and Learning

If teachers are to lead other teachers in changing practice to improve student learning, it is important that teacher leaders' educational beliefs be consistent with the best ideas for educating children. What beliefs do teacher leaders hold, and in what direction might they lead other teachers?

As a group, professionally engaged teachers were philosophically in a different place than private practice teachers were. Teachers' responses to individual TLC survey questions suggested that they were more likely than other teachers to see good teaching in terms of facilitating student inquiry rather than directly transmitting knowledge. They were more likely to emphasize student engagement in learning and the "meaningfulness" of content than to be concerned about disseminating a specific externally mandated curriculum to unmotivated students.

The TLC study's measure of teaching philosophy came from three survey questions, incorporating 13 individual prompts. In one question, teachers were asked to compare the likely effects on student learning of two teachers' contrasting approaches to classroom discussion. One approach represented traditional teacher-directed questioning based on prior reading; the other represented teacher-led discussion that provoked questions from the students themselves, which the teacher then reflected back to them for further research. A second set of four questions presented paired comparisons of contrasting teaching philosophies. Each item presented a hypothetical personal statement of beliefs around issues such as curriculum coverage vs. "meaning-making" and alternative classroom activity patterns (i.e., teacher-directed vs. varying group activities). The third question involved seven agree vs. disagree statements (6-point scales) about, for example, whether the need for direct instruction can be justified by the importance of providing students with background knowledge; or how important was building instruction around problems with "clear, correct answers and…ideas that most students can grasp quickly"; or how valuable was student freedom of movement in the classroom for facilitating student initiative to learn.

An index was created by taking the mean of these 13 prompts, after equalizing item standard deviations (effectively creating standard scores for items). The alpha reliability for this index was 0.83, suggesting that a strong single dimension underlay these specific beliefs about good teaching. We term that dimension a "teaching philosophy," and the contrast represented by the scale being one between a "transmission" view of good teaching (direct instruction and repetitive skills practice around a fixed curriculum) and a "constructivist" view (knowledge construction through collaborative projects, and problem-solving tasks). The index was divided roughly into quartiles, with teachers in the lowest quartile classified as "most transmission-oriented" and those in the highest quartile as "most constructivist."

Table 1 shows the percentage of teachers at each level of professional engagement who fell into each quartile in terms of teaching philosophy. Only 3% of the teacher leaders were in the most transmission-oriented quartile, compared with 32% of the private practice teachers. In contrast, 58% of the teacher leaders defined their overall beliefs about good teaching in ways that suggest a strongly constructivist philosophy, compared to only 20% of private practice teachers. These are striking differences, suggesting that to the degree that professionally engaged teachers influence other teachers, either through dialogue or by modeling these beliefs in the teaching practices that they discuss, the impact of teacher leaders would be to move other teachers in a more constructivist direction.

Leadership-Inspired Instruction

Of course, if teacher leaders influence other teachers through their practice, their practice would need to reflect their teaching philosophy to begin with. It is well

Table 1 Teaching philosophy by professional engagement

Professional engagement	% Most transmission-oriented	% 2nd Quartile	% 3rd Quartile	% Most constructivist	% Total
Teacher leaders	**3**	9	30	**58**	100
Teacher professionals	14	20	26	40	100
Interactive teachers	19	24	24	32	100
Private practice	**32**	25	23	**20**	100
All teachers	25	24	24	27	100

Sample: Probability and purposive samples understood that teaching from a constructivist perspective is more demanding on teachers; perhaps there are no actual differences between teacher leaders and other teachers in classroom practices – only in espoused beliefs.

The TLC study investigated that question as well. First, we present some illustrative findings drawn from the TLC report on teacher leaders (Becker and Riel, 2000) that highlight the kinds of instructional practices that are most relevant to teaching in specific subject areas.

Professionally engaged teachers of English were more than twice as likely as private practice English teachers to have students work in teams to complete assignments (78% vs. 36%). They were also much more likely to have students write in a journal on at least a weekly basis (67% vs. 45%), and they were somewhat *less* likely to introduce a new unit by having students do introductory drills on background facts or skills. Among social studies teachers, professionally engaged teachers were much more likely than private practice teachers to have students work on long projects (72% vs. 33%) and to do metacognitive assessments of their own work (61% vs. 23%), while they were much *less* likely to lead their class in frequent whole-class recitation activities (27% vs. 61%) or to ask their students questions for the purpose of seeing whether their students knew the correct answer (22% vs. 61%).

Professionally engaged science teachers were almost twice as likely as private practice science teachers to ask students questions in order to get students to relate their school work to their own personal experiences (74% vs. 40%) and they were more than twice as likely to have students work in small groups on a weekly basis to collectively solve a problem (66% vs. 28%). Secondary math teachers falling into the professionally engaged group were more likely than private practice math teachers to report that they had students work on problems with no obvious solution (54% vs. 35%). Professionally engaged elementary teachers (grades 4–6) were substantially more likely to have students decide on procedures for solving problems and more likely to introduce their current unit by having students discuss the topic in small groups.

All of these differences suggest that, consistent with differences in their teaching philosophies, professionally engaged teachers were more likely than other teachers to emphasize teaching toward higher cognitive processes, to use active learning strategies such as projects and group work, and were less likely to use direct instruction and skills-practice strategies. This was confirmed by analyzing an index of the entire group of 27 item prompts about teaching practices contained in the survey, an index with an alpha reliability of 0.86. Divided into quartiles, just as with the teaching philosophy index, a clear majority (57%) of the teacher leaders fell in the quartile that most reflects a knowledge construction approach to teaching while only 2% of the teacher leaders were located in the direct instruction quartile. In contrast, among private practice teachers, twice as many fell into the most direct-instruction-oriented quartile as fell into the most knowledge-construction-oriented quartile (see Table 2.)

The relationship between professional engagement and constructivist teaching practice was quite strong across teachers of every subject-matter category analyzed in the TLC survey. For all seven subject-matter categories, the scores for professionally engaged teachers were more than two thirds of a standard deviation higher, suggesting that they were far more constructivist in their teaching than were private

Table 2 Constructivist pedagogy by professional engagement

Professional engagement	% Direct instruction	% 2nd Quartile	% 3rd Quartile	% Knowledge construction	% Total
Teacher leaders	**2**	16	25	**57**	100
Teacher professionals	11	20	23	47	100
Interactive teachers	16	22	29	33	100
Private practice	**33**	28	23	**16**	100
All teachers	24	25	25	26	100
Sample: Probability and purposive samples					

practice teachers of the same subject. The largest difference was in the field of social studies, where professionally engaged teachers scored an average of 1.35 standard deviations higher in the direction of constructivist practice than did private practice teachers.

Teacher Leaders' Use of Computers: TLC Study Findings

We now turn to a discussion of teacher leaders' use of computers. Using the TLC data, we address the question of whether teachers who are professionally engaged use computers more frequently than other teachers do, and whether they use computers in ways that reflect their more constructivist orientation. Our main focus in this section is on instructional use by students during class time – how frequently teachers ask students to use computers and what types of software they have students use – but we also would want to consider teachers' own professional uses of computers and their expertise in doing so.

In nearly every subject area of instruction, teacher leaders and teacher professionals were more likely to have their students use computers on a regular (i.e., weekly) basis during class time than were private practice teachers. This was especially true for math teachers (five times as likely), but was also true for English and science teachers. Also, professionally engaged teachers had their students use every type of software asked about in the survey more than private practice teachers did, even when the comparison was limited only to teachers who used computers. The greatest differences between professionally engaged teachers and private practice teachers were in students' use of electronic mail, multimedia authoring software, and presentation software, where computer-using professionally engaged teachers employed these resources three to four times as much as computer-using private practice teachers, but it was also true to a lesser degree for word processing software, CD-ROMs, and even drill-oriented game software.

Another analysis was about a type of teacher we called an "exemplary computer user." This construct was measured by combining information about teachers' instructional and professional uses of computers and their technical expertise in ICT, including self-reported changes in the role of computers in their teaching practice over the previous several years. Professional use, for example, included such activities as accessing lesson materials from the Internet, using digital cameras for lesson preparation, corresponding with parents, and posting student work on the Web. Technical expertise concerned both specific computer skills (self-reported) and experience with both Mac and Windows platforms. An index construction process (involving three subscales and described in more detail in Becker and Riel, 2000) produced a measure on which 10% of all teachers were judged to be "exemplary" computer-using teachers. Similar percentages (9–12%) at each school level (elementary, middle, and high school) and in subject areas (other than computer and business education) were identified as exemplary.

Yet when we disaggregated teachers according to their level of professional engagement, rather remarkable differences appeared. In particular, teacher leaders were ten times as likely as private practice teachers to be designated as exemplary computer users. Forty percent of teacher leaders were classed as exemplary users, compared to only 4% of private practice teachers. About one fourth of teacher professionals were classed as exemplary, six times as many as among private practice teachers. Of the three component factors of this measure, teacher leaders were most different from other teachers in having students use constructivist-oriented tool software (mean z-score of +0.88), and least different from other teachers in terms of frequent use of simple software (still more than one-half standard deviation higher than average, $z = +0.52$). On professional use and expertise, their superiority was extremely high ($z = +0.67$), but not as high as on constructivist instructional use.

Of all the ways in which professionally engaged and private practice teachers might differ – in their backgrounds, teaching responsibilities, teaching philosophies, and teaching practices – none of them produced differences on the order of the magnitude of this measure of exemplary computer use. This suggests that there is a very strong connection between teacher leadership and sophisticated use of computers, in both teaching and professional life. Teacher leaders are much more likely than the typical teacher to have incorporated a wide variety of computer applications into their instructional practice and they are much more likely to have become competent users of computers themselves.

The magnitude of this association suggests that several different causal forces are operating – that teachers who act in professional ways are more motivated to master new technologies and more easily see the utility of computers in their work; that accomplishment in using technology in student lessons and in class preparation motivates teachers into sharing with peers their new skills; and, in a complementary way, that teachers seeking to learn to exploit computers in their work also seek out professional contacts as a means of attaining those skills. The huge association between computer expertise and professional leadership among teachers also helps to explain why the excitement about using computers one sees at professional meetings of teachers does not translate into widespread improvement across the board in teachers' use of technology: The participants at such conferences are professionals who are exploiting computers in their work, but they are an unrepresentative subset of purveyors of their craft. The real challenge for such technology experts is to transfer their excitement and expertise to their peers who lack the same interest for involving themselves either in professional activities or in learning to master the application of computer resources to their instructional and work tasks.

Studies of Teacher Leadership Among Technology-Expert Teachers

The Teaching, Learning, and Computing Survey did not specifically focus on *technology* leadership among teacher leaders. Instead, the findings we cited here dealt with the technology proficiency of teacher leaders in general. However, there have been a number of other studies whose focus was on technology-specific leadership and the ability of technology-utilizing reform efforts to change schooling and teaching more generally.

Perhaps the most influential research on reforming teaching through technology has been Sandholtz et al.'s (1997) study of the Apple Classroom of Tomorrow (ACOT) project. That study is most well known for its typology of stages of developing teacher expertise around technology – from entry to adoption to adaptation to appropriation to invention. Other researchers have produced similar stage models of expertise development, and with some of these models, "technology leadership" is presented as a final stage in personal development (e.g., see Sherry and Gibson, 2002).

The ACOT researchers devoted a substantial part of their book to discussing collaboration among technology-using teachers and diffusion of computer use. They reported a bidirectional influence between the level of teacher collaboration in a school and the extent of diffusion of technology applications. In other words, preexisting levels of collaboration influenced the amount of technology diffusion, but also the relatively dense infusion of technology itself led to more collaboration among teachers. They suggested that over time, collegial sharing around technology moved from emotional support (e.g., sharing frustrations and successes and providing encouragement) to technical assistance, to sharing ideas around instruction (including observing the use of computers in other classrooms), and then to what they called "team teaching" (e.g., joint planning and curriculum development, and interdisciplinary alignment of instructional lessons and projects).

A later development within the ACOT project was the implementation of a constructivist-oriented program of summer institutes for selected teachers at non-ACOT schools (that is, schools without the technology infrastructure provided by Apple in ACOT schools) who were expected to go back to their schools and provide technology leadership. The researchers found that several problems were endemic to these newly trained teachers providing effective leadership – e.g., a density of technology too low to be practical for teachers, insufficient technical support for what they did have, and not enough free time to provide peer leadership. What did change was the teaching of the participants in the summer institutes – their own pedagogy became more constructivist and their own use of technology became more innovative. Anecdotal evidence did suggest that "some" of the workshop participants were effective in getting broader participation in technology use among their peers and in taking on a leadership role with respect to technology at their school. It is difficult to say how broad this outcome was since the researchers' orientation to this study was qualitative and illustrative rather than statistical, even to the extent of failing to provide descriptive statistics about the frequency that various outcomes characterized individual teacher-participants.

A second program of research on teacher technology leadership identifies teacher technology leaders as those who became "active researchers who carefully observed their own practice, collected data, shared their improvements in practice with their peers, and taught new members of their virtual learning community" (Sherry and Gibson, 2002, p. 182). The challenges identified for the successful promulgation of this role included the fact that teacher leaders with formal peer-leadership responsibilities often lost the release time that had been granted to them, and, over time, experienced reduced support from school and district administration for their own continued professional growth (e.g., attendance at technology conferences, etc.). In fact, Sherry argues that from a systems theory point of view, the principal impediment to maintaining the momentum of teacher leadership around technology is that three "critical processes" must all be present:

– "Convergence": Resources for technology must be dense enough at the classroom level for practical use.
– "Mutuality": Benefits for technology investment must be perceived both by the user of these resources and the administrators responsible for funding and providing them.
– "Extensiveness": A high density of technology must be present throughout a school building, enabling both broader administrative support and backup expertise in the likelihood of a technology leader taking their own expertise with them when others entice them with new career opportunities.

This suggests that there is a high bar in terms of local resources and support before teacher technology leadership will have staying power in any school.

One other study of technology leadership identified here focused specifically on technology expert teachers, and essentially turns the presumed temporal direction – from expert use of technology in teaching to technology leadership – on its head. This is a recent study of technology use in teacher education (i.e., in tertiary rather than primary or secondary education). Drent and Meelissen (2006) asked how we can account for innovative information and computer technology (ICT) practices among teacher educators. They identified "personal entrepreneurship" as a significant trait in influencing innovative use. Personal entrepreneurship was defined in this study to refer to the number of contacts, both inside and outside their own university, that the teacher educator maintained to assist in her own professional understanding of ICT. It was measured by several indicators of the strength of external networking – ties to organizations and individuals – that the teacher educator maintained, and the frequency of contacts with colleagues around ICT issues. By using path analysis software the authors identified personal entrepreneurship as a critical factor – existing very early in the chain of variables influencing innovative ICT use, not only having a direct influence on innovative ICT use, but also affecting the teacher educator's ICT attitudes and their ICT competence, which in turn also affected their propensity to innovate with technology.

Dimensions of Teacher Technology Leadership

Innovative or exemplary use of technology in a teacher's own teaching practice is one of only a number of conditions that would qualify someone as a *technology leader*. Applying the model of teacher leadership proposed in the first section of this chapter, teacher technology leaders are conceptualized here as incorporating a parallel set of activities into their professional practice:

1. Teachers Learning with Technology: Technology leadership evolves from an interest in and ability to incorporate new tools in innovative ways, coupled with a highly reflective and analytic focus on the relative merits of the technology. These teachers constantly explore and refine new ways of making technology useful to their teaching and their students' learning.
2. Teachers Collaborating Around Technology: Technology leadership involves frequent exchanges of ideas about educational applications of ICT with other teachers at their school through formal and informal mentoring and coaching and other informal leadership activities.
3. Teachers Networking in Technology-Active Communities: Technology leaders participate in networks of technology-using teachers around their district, region, state, and nation, particularly around innovative ways to use technology resources and tools and would have links to sources of expertise about educational technology through their reading and through personal associations with researchers and developers of educational technology products.
4. Teachers Contributing to Knowledge About Educational Technology: Finally, technology leadership implies taking an active role in organizations to share knowledge formally through presenting, teaching, and publishing on educational technology issues.

Here we briefly illustrate how these interrelated and overlapping practices around the use of technology collectively describe a form of teacher leadership in the use of technology.

Teachers Learning with Technology

To assume the role of leader and affect the technology use of others, teachers must be able to learn to use technology in a generative manner and engage in a process of continual learning in and through practice. Technology changes so rapidly that efforts to create a stable set of lessons that relies on computer tools are challenging. Shifts in platforms, software versions, and peripheral tools will frustrate anyone who is not looking to continually adapt practice. So it is likely that teachers who are attracted to working with technology are more likely to be teachers who approach teaching from an adaptive stance. This high level of need for continual learning is likely to explain the high correlation between teacher leadership and innovative computer use (Becker and Riel, 2000). Teachers who focus only on how to teach, to the exclusion of an adaptive inquiry process, are less likely to become involved with technology because, by its nature, use of technology requires a high commitment to continual learning.

Teachers Collaborating Around Technology

In order for expertise of technology-proficient teachers to be shared with other teachers, there has to be motivation on both sides – expert teachers have to want to share their knowledge and other teachers have to want to receive it. Expectations, social processes, school networks, principal leadership, and communication technology all help shape the way in which teacher technology leaders influence the practice of others.

One element that may have made leadership in this area promising, and yet difficult at the same time, is that for many years educators have felt pressured to use computers in their teaching, even before computers were widely accepted as valuable instructional tools. For example, Zhao and Frank (2003) found that more than 80% of the teachers in their Michigan sample believed that "others in this school expect me to use computers." More than 70% reported that "I need to use computers to keep up in this school." High expectations might result in a level of tension that would make sharing of expertise difficult. But at the same time, such a climate could be thought of as an inducement for teachers to be open to peer expertise. On balance, Zhao and Frank found that the *more* the teachers reported high expectations for their use of computers, the *greater* was the teacher use of computers.

Further study by these researchers suggested that technology use within a school was promoted primarily by "help and talk" – social processes by which effective leadership is manifested. It is through these mechanisms that the social capital of technical expertise is made useful (Frank et al., 2004). "Help and talk" can involve sharing personal experience with similar technologies, software, websites, and teaching strategies, or it can be based on wider knowledge about how information and communication technology has been successfully used in other places. It can be pedagogically focused or it can involve technical troubleshooting. But two key points are that the communication has to be based on actual expertise and that it must be relevant to the specific needs and instructional context of the technology leader's peers. However, even that may not be enough. Frank and his colleagues concluded that for technology leaders' expertise to be broadly influential, the sociometric pattern of communication among teachers in a school was critical. "The distribution of technology implementation is very much a function of the distribution of social relations within the school" (Zhao and Frank, 2003, p. 830).

Teachers Networking in Technology-Active Communities

The importance of teacher technology expertise extends well beyond providing leadership among the peers with whom that expert has potential day-to-day in-person contact by virtue of working in the same school. Technology leadership is also manifested in a variety of online, at-a-distance, and in-person episodic encounters. The Internet has made it possible for teachers to exchange expertise with other through social ties of online communities. The largest and longest-standing online global communities of teachers sharing of expertise around technology – International and Education Resource Network (http://www.iearn.org) and Global SchoolNet (http://www.globalschoolnet.org) – were both started by teacher leaders in technology. Teachers assume a high degree of responsibility in the distributed leadership of these organizations and in doing so extend the reach of new forms of teaching with technology to peers in developing countries. Technology teacher leaders play central roles in many other Internet-based communities, including discipline-linked organizations (e.g., Math Forum, National Writing Project), professional development communities (Tapped In, Knowledge Loom, Teacher.net, and Teacher Network), and student learning activities (ThinkQuest and Globe).

Teachers Contributing to Knowledge About Educational Technology

Profiles, videos, lessons, and reflections of teacher leaders in technology, both on the Internet and in print, extend their ability to shape educational practice. Education with New Technologies at Harvard features five "pictures of practice" (http://learnweb.harvard.edu/ent/gallery/) highlighting teachers who have published extensive descriptions of how they have used technology tools to reach and adapt their teaching goals. On Indiana University's Inquiry Learning Forums (http://ilf.crlt.indiana.edu/), the virtual classroom visits link to dozens of teacher leaders who use technology to share videos of a lesson with extensive analysis and reflections about classroom practice. The George Lucas Education Foundation has created Edutopia (http://www.edutopia.org) for publishing the stories of teachers who are using technology in inspirational ways. They feature teacher leaders with technology in videos on the Web, which are also included in instructional modules, on compact disks, and in print magazines. Teachers increasingly publish their work on the Web and in teacher magazines and professional journals.

Other means for extending the reach of teachers' knowledge, expertise, and leadership come from opportunities to present at annual conferences such as, in the United States, the National Educational Computer Conference and many state-sponsored computer-using educators conferences. Journals such as *Learning and Leading with Technology* and *Technology and Learning* (and its online companion, http://www.techlearning.com) search out and feature innovative teacher leaders, and in doing so create bridges that extend the reach of innovation with technology.

Toward a Culture of Teacher Leadership with Technology

In this chapter we have suggested that teachers who become leaders – either with technology or more generally – approach teaching in a specific way. We have characterized teacher leadership in terms of a path from learning to teach adaptively to contributing to the knowledge base of the profession. Although clearly the skills that enable one to become a fully expert teacher leader develop over time, we would argue that the *disposition* to lead may need to be instilled early in a teacher's career. We propose that during preservice education the cognitive and metacognitive skills and dispositions that *lead to adaptive expertise* ought to become part of a novice teacher's repertoire (e.g., see Bransford et al., 2000). This process of learning from practice requires teachers to be engaged in acquiring deep knowledge by paying increasing attention to the contextual, situational, and interactive dimensions of teaching (Darling-Hammond and Bransford, 2005).

Yet that is only the first step toward teacher leadership. Teachers who develop deep understanding of teaching but who remain isolated in their classrooms will not affect what is taught or learned in other classrooms. Effective leadership requires personal effort to overcome norms within teaching that discourage substantive and productive exchanges of ideas among practitioners. The current structure of schooling inhibits rather than supports teacher leadership. Changes in the structure of work are required to make teaching more public, to give teachers more opportunities to learn from and teach each other. To accomplish this, schools must develop a structure that supports collective responsibility for student learning and distributed learning opportunities for teachers. A critical aspect of that structure is attention to the social and professional networks that connect teachers to one another and to the resources and expertise embedded in the network. When access to relevant knowledge is severely restricted, the result is that not only is teacher expertise lost to professional practice but teachers who hold that expertise fail to develop as leaders. This is a huge loss of talent and results in lower teacher quality over time. Mentoring, although helpful for novice teachers, is often only a bridge to a disconnected island, helping a new teacher accommodate into a dysfunctional structure. To reach every child will take a structure that develops not just the technical ICT skills of teachers but their leadership skills as well. The speed of change in technology makes effective use impossible if each teacher has to learn to use it alone. Without developing and capitalizing on forms of distributed expertise of teacher leadership, schools will simply be unable to cope with the rapid rate of change that is required for the use of technology.

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Section 5

IT, PEDAGOGICAL INNOVATIONS, AND TEACHER LEARNING

5

IT, PEDAGOGICAL INNOVATIONS, AND TEACHER LEARNING

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The integration of IT in education can take on very different forms for very different purposes ranging from technologizing education (i.e., replicating traditional, non-IT using educational practices in digital media with technology tools) to transforming education (i.e., using IT to bring about new learning goals and pedagogical innovations). The purpose of supporting teacher learning in the latter context is not merely to impart knowledge and skills, but more importantly, to bring about pedagogical innovation and change in classroom practices. This section addresses issues related to teacher learning for using IT in educational practice.

The section starts with Law's chapter, Chapter 5.1, that explores what capacities a teacher would need to have in order to engage in pedagogical innovations using IT. The chapter begins by making a distinction between the use of IT to support prevalent curriculum goals and pedagogies, and leveraging the potential of IT as a *disruptive* force for the introduction of new pedagogies and new curriculum goals that are compatible with the demands of the knowledge society. Building on the literature on teacher knowledge for IT integration in teaching, teacher learning for educational change, and analyses of case studies of technology-supported pedagogical practices, the author argues that teacher learning needs to go beyond knowledge. A teacher who is able to initiate and maintain technology-supported innovations also needs to develop socio-communicative, metacognitive, and socio-metacognitive capacity. The chapter ends by proposing a framework for conceptualizing teacher learning for IT-supported pedagogical innovation that highlights the need for teacher learning to take place in a social, institutional, or professional milieu. Teacher learning needs to be conducive to the cultivation of the educational values and epistemological beliefs to provide the disruptive drive for teachers to innovate and take risks, as well as a socio-technological infrastructure conducive to supporting collective learning in a network of innovators.

In Chapter 5.2, Kirschner, Wubbels, and Brekelmans present nine benchmarks for teacher education programs on the pedagogical use of IT for both preservice and

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inservice teacher education and training based upon a review of the literature on effective teacher education and an analysis of international exemplary teacher education programs. Four of the benchmarks relate to the competence of the teacher at the individual level and include personal IT competencies, the use of IT as mind tools in professional practice, knowledge of and experience with social aspects of IT use in education and the use of IT in teaching. Some benchmarks relate to program design, which point clearly to the need for effective teacher professional development programs to involve institutional and workplace learning, foster development of communities of practice (CoP), and use learning environments that are rich in IT, open, and flexible. Teacher-education pedagogy benchmarks highlight the need to integrate IT in structured, experiential learning embedded in different content domains in the teacher education program rather than as a separate component.

Chapter 5.3 discusses the factors affecting teachers' pedagogical adoption of IT. In this chapter, instead of addressing this topic by examining factors at school, classroom, and teacher levels that inhibit or facilitate adoption as is commonly found in the literature, Somekh develops a new analysis of the process of teachers' pedagogical adoption of IT, based on sociocultural theories, to draw attention to factors beyond the school. Technology adoption is always carried out in the context of complex cultural factors and regulatory frameworks, such as organizational structures, social contexts, and established mechanisms of control, such as national curricula and assessment regimes, which in turn enables or constrains the process. The chapter provides examples of transformative pedagogies with IT and draws attention to the common factors that have enabled their success.

In Chapter 5.4 McDougall addresses the topic of models and practices in teacher education programs for teaching with and about IT. Teacher education and professional development is critical to the effective use of IT in education. It is at the same time complex as significant pedagogical change may be needed to exploit the potentials offered by the fast developing learning technologies. This chapter reviews a variety of teacher education programs, ranging from award-bearing courses for preservice education and professional development in tertiary institutions to less-formal programs initiated from within and outside schools, outlining their goals and purposes, as well as describing the models, structures, and strategies used. The chapter also considered the evaluation of IT teacher education programs.

Hypermedia platforms can be used to integrate visual, audio, graphical and textual information into an advanced technological learning environment. Such platforms can be used to represent classroom practice as multimedia case studies. In Chapter 5.5, van den Berg, Wallace, and Pedretti explore the potential and current practice in the use of multimedia cases as vehicles to support the four processes in teacher learning: thinking, acting, reflecting and transferring. They identified three ways through which teachers make use of multimedia cases: (1) teachers videotaping their own lessons for case construction and self analysis; (2) teachers learning new principles and practices directly from finished, exemplar cases; and (3) teachers using existing cases to stimulate discussion and action. The authors suggest that to effectively anchor multimedia cases in teacher education programs involves several considerations: intentionality, creating context, scaffolding, quality conversations, and praxis.

CoP for continuing professional development in the twenty-first century is the theme for Chapter 5.6. Based on the literature on CoP as a pedagogical approach for teacher professional development, Looi, Lim, and Chen identify CoP as a constructivist, in-situ social approach to teacher learning that provide opportunities for individual advancement whilst progressing the collective. They propose design tenets for supporting and sustaining CoP in the twenty-first century: foregrounding practice, relying on existing social networks, building on strengths of diversity in membership, task practices that require collaboration, and peer and leadership mentoring. The authors further propose six technology architectural considerations for the development of an online learning environment that supports the continual professional development of teachers.

In the final chapter, Chapter 5.7, of this section, Davis addresses the question "How may teacher learning be promoted for educational renewal with IT?" from a systemic, ecological perspective. The purpose of this chapter is to give teachers and other leaders in the education system an understanding of the ecology of educational renewal with IT. The different factors influencing teacher's adoption of IT are envisioned in layers that frame perspectives of the classroom as nested within the school, local area, region, and the global biosphere of education. Starting with a global perspective, diverse socio-technical forces are mapped with illustrations and evidence of their impact. Davis advocates the simultaneous renewal of teacher education and K-12 schools, which involve overlapping ecologies in multiple organizations, leading to additional challenges for teacher learning with IT in preservice teacher education. Models of the adoption of IT in a classroom should emphasize each teacher's ownership of the innovation process. The chapter concludes with a recommendation to incorporate ecological perspectives in the design and reporting of research in this area.

5.1

TEACHER LEARNING BEYOND KNOWLEDGE FOR PEDAGOGICAL INNOVATIONS WITH ICT

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Introduction

Teacher professional development has long been identified as critical to the successful adoption of ICT in schools. Starting from the early 1980s when computers were introduced into schools, the issue of helping teachers to learn the prerequisite knowledge and skills have attracted the attention of those interested in promoting the integration of computers in the curriculum. The kind of professional development required depends on the nature of the adoption targeted for ICT in the curriculum. Law and Plomp (2003) categorized the role of ICT in the curriculum into *learning about ICT* (as a subject), *learning with ICT* (as a medium to support or enhance existing instructional practice), and *learning through ICT* (which involves a full integration of ICT to bring about learning experiences that would otherwise not be possible). With the exception of the first kind of ICT adoption, which only comprises a very small part of the curriculum focus in most countries, the acquisition of technical knowledge and skills is only one component in the teacher professional development needed (Law and Plomp, 2003).

Mishra and Koehler (2006) argue that the lack of theoretical grounding for educational technology is the prime reason for the lack of significant changes in the way teaching and learning is carried out in schools, even when digital technology is used. They propose technological pedagogical content knowledge (TPCK) as a framework for conceptualizing the complex systems of knowledge underpinning expertise in teaching with digital technology. The TPCK framework is built on Shulman's (1986, 1987) conception of PCK, a term introduced to conceptualize teacher knowledge underpinning teaching expertise. PCK lies at the intersection of content and pedagogy, encapsulating a competent teacher's knowledge. PCK blends knowledge from both domains into an understanding of how particular aspects of

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subject matter can be organized, adapted, and represented for instruction. In addition to technological knowledge, Mishra and Koehler's (2006) TPCK framework introduces, three new kinds of knowledge for teacher competence in integrating ICT in instructional practices: TCK (technological content knowledge), TPK (technological pedagogical knowledge), and TPCK. The framework emphasizes the situatedness and interactive nature of the development of TCK, TPK, and TPCK.

The importance of considering the context dependence and interactive nature of teacher learning has not been overlooked in the research literature (e.g. McDougall and Squires, 1997; Watson, 2001; Schlager and Fusco, 2003). In terms of the actual policies and practices regarding ICT-related teacher learning, there is a wide variation across countries and localities (see Plomp et al., 2003). In some countries, teacher learning provisions are mainly focused around the development of technical knowledge and skills in isolation of pedagogy and curriculum content, as identified by Mishra and Koehler (2006). Policies and practices in developed countries where schools have had a longer history of ICT integration in the curriculum do focus more strongly on linking teachers' learning of ICT skills to content and pedagogy (Law and Plomp, 2003). For example, the National Educational Technology Standards for teachers published by the International Society for Technology in Education (ISTE, 2002; Thomas and Knezek, 2008) is a relatively comprehensive list describing the performance required of teachers in relation to the use of technology in six domain areas: technology operations and concepts; planning and designing environments and experiences; teaching, learning and the curriculum; assessment and evaluation; productivity and professional practice; and social, ethical, legal, and human issues. It is clear from this list that with the exception of the first domain, the other domains involve the intersection between technology, curriculum content, and pedagogy. There are also many examples in the teacher professional development literature on technology that have taken a holistic perspective and address both the content (what is to be learnt) and the process (how the learning takes place). The United Nations Educational Scientific and Cultural Organization (UNESCO) document, *Information and Communication Technologies in Teacher Education: a Planning Guide* (Resta, 2002), is a fine example. In this document teacher education is situated in a framework of professional practice that requires attention to four themes: leadership and vision, lifelong learning, context and culture, and planning and management of change.

On the other hand, as Kirschner et al. (2008) point out, the mainstream teacher education research does not pay much attention to ICT, while researchers studying ICT pay little attention to research conducted on teacher education. Mishra and Koehler's (2006) TPCK framework provides a more abstract level of conceptualizing teacher knowledge and serves to provide a link between the two bodies of literature. However, it is argued here that to encompass what implies for a teacher to engage in ICT-supported pedagogical innovations, a conceptualization of what it takes for teachers to effectively integrate the use of ICT in pedagogical practice is needed. This conceptualization needs to go *beyond* a focus on knowledge necessary *during* classroom practice.

Teacher learning should prepare teachers not only for any kind of ICT integration, but should equip teachers for "best practices" in ICT integration that contribute to improving existing teaching practice to achieve the goals of school reform (Holland, 2001). Hence it should contribute to the development of new, innovative teaching practices (Kirschner et al., 2008; Davis, 2008). Teacher learning for pedagogical innovation is becoming increasingly important in the twenty-first century when the focus in education shifts toward lifelong learning and knowledge creation, demanding changes in educational goals, as well as curriculum and pedagogical processes (Pelgrum and Law, 2003).

In this chapter, an analysis has been made of the roles played by technology in pedagogical innovations, the kinds of challenges faced by teachers when innovating with ICT, and the kind of abilities (including knowledge) required to do so, drawing largely on findings from SITES M2, an international comparative study of innovative pedagogical practices using technology conducted under the auspices of IEA (Kozma, 2003). The innovative pedagogical practices using technology collected in the SITES M2 study were identified as outstanding examples of ICT-supported pedagogical innovations in their own national contexts from the 28 educational systems participating in the study (see also Voogt, 2008; Nachmias et al., 2008).

ICT as a "Disruptive" Force in Pedagogical Innovations

In the book *The innovator's dilemma: when new technologies cause great firms to fail,* Christensen (2000) introduced the concepts of sustaining and disruptive technologies. The former refers to technologies that foster improved performance of existing, established products while the latter refers to technologies that are less well-developed and weaken established products in mainstream markets but have features that address specific needs in a newly emerging, fringe market. The distinction between sustaining vs. disruptive technology lies in the market to which the technology serves. The concept of disruptive technology so defined may not immediately apply to education since we are interested in exploring the impact of ICT in publicly funded schools, and not the impact of ICT on a different "education market" such as home schooling, learning centers, etc., as referred to in Halverson and Collins (2006). Instead, the relationship between technology and pedagogical practices can be conceptualized as *sustaining* or *subversive*, depending on whether the use of the technology is aimed to strengthen existing pedagogical processes to better achieve existing curriculum goals or to bring about new goals, new processes, and new relationships. It is important to note here that the categorization of sustaining or subversive uses of technology does not depend on the technology alone, but also on the intended use of the technology in the specific educational context.

In analyzing the case studies collected in the SITES M2 study from the perspective of teacher learning, Law (2003) identified six dimensions (or aspects) of change of classroom practices: intended learning objectives of the classroom practice, pedagogical

Cooperative project using telecommunication tools to study the climate and weather

Students from four schools conducted, in collaborative teams, scientific inquiry on questions related to climate and weather that they identified for themselves. Every weekday, pupils from different schools had to collect meteorological data and share them with their partner schools via the Internet and to conduct comparative research projects using the weather variables. Teachers provided suggestions and guidance for the pupils but it was the pupils working in groups who made the final decisions on what they wanted to learn and how they were going to do it. Technology played an important and pervasive role throughout the whole learning process in supporting communication and collaboration among students and between teachers and students, in providing access to information and data through the Internet, and in data collection and analysis during the inquiry process,

(http://sitesdatabase.cite.hku.hk/M2/case2/ES001/Index.asp?case_ID=ES001)

Fig. 1 Example case study from the SITES M2 database

role(s) of the teacher, role(s) of the learner, nature and sophistication of the ICT used, connectedness of the classroom, and learning outcomes exhibited by the learner. Each innovative pedagogical practice in the SITES M2 study may involve different extents of change along these different dimensions. Figure 1 provides a summary of a highly innovative pedagogical practice from the SITES M2 database.

What is new in this example is not just the technology, but also the other five dimensions identified above. In fact, the selection and deployment of technology were subservient to the changed curriculum goals and pedagogical approach. Hence the use of technology was not to sustain prevalent pedagogical practices, but to create new practices. Not only has the purpose of school education changed, the process through which learning takes place and the relationship between learners and teachers as well as the nature of schools as an institution and how it relates to the wider community have also changed. Learning no longer takes place within the classroom as the latter becomes connected to the wider world beyond the school walls, allowing students to learn from peers and experts around the world. Hence it is not just the technology, but the innovation as a whole that can be considered a *disruption* to prevalent practices.

What is the role of technology in the process of innovation (or disruption)? In analyzing the characteristics of the innovative practices in SITES M2, Owston (2003) identified four important features: need as defined by Fullan (2001) and compatibility, relative advantage, and observability as defined by Rogers (1995). There is no apparent evidence that technology was the motivating or initiating force driving the innovative practices. Rather, technology facilitated the realization of the innovative practice. This resonates with the conclusion drawn by Venezky and Davis (2002) in the study of ICT-supported school wide innovations of the Organization of Economic Development and Co-operation (OECD) – that technology plays the role of a lever rather than a catalyst in the process of change. Hence technology is leveraged by teachers as a disruptive force (or resource) in realizing pedagogical innovations.

To understand the kind of abilities required of teachers to engage in ICT-supported innovations, one needs to find out what constitute the necessary qualities of a teacher to be able to leverage ICT as a disruptive pedagogical resource.

Teacher Learning for Pedagogical Innovation with ICT: Beyond Knowledge

What does it take for a teacher to be able to leverage ICT for pedagogical innovations such as the one described in the previous section? Clearly there is a lot of new knowledge involved. However, this definitely does not only include technological knowledge – TCK, TPK, and TPCK – but also encompasses the other kinds of knowledge in Mishra and Koehler's framework – CK, PK, and PCK. The example provided in Figure 1 is a multidisciplinary project involving science, languages (Catalan and English), and plastic art. While the teachers for these respective subjects were involved in this innovation to provide guidance to the students, each teacher still had to learn something about the involved disciplines other than their own in order to design and implement such an interdisciplinary project. Further more, the project involved students inquiring authentic problems related to weather, which do not have standard answers. In achieving these new curriculum goals, the teachers had to grapple with new *content knowledge* (CK).

Two further dimensions of innovation involved in this example are the changed roles of the teachers and the students. The "teaching" was accomplished through close collaboration among teachers such that they could be working together with all the students in the same classroom or separately with groups of students in different locations. Instead of playing an instructional role as teachers often do in traditional classrooms, in this innovative practice teachers guided the inquiry through helping students to identify worthwhile questions, as well as the various ways to tackle problems, collect data and conduct inquiry. Students may be more knowledgeable than the teacher, particularly in the area of ICT, and the teacher may learn from and learn with students. The teachers also introduced greater flexibility into the learning process so that low-performing pupils could find a task which they feel comfortable with and achieve a more successful result. Hence the teacher had to master new *pedagogical knowledge and skills* (PK) in the implementation of this innovation. Furthermore, facilitating inquiry in the area of climate and weather also required new PCK.

The need to learn within all the seven kinds of knowledge in Mishra and Koehler's (2006) TPCK framework is not unique to the particular example of innovation discussed above, but in all ICT-using pedagogical innovations that exhibit change in the curriculum goals as well as teacher's roles or students' role or ways of assessing students. Furthermore, as was the case in the example quoted, many of the innovative practices in SITES M2 involved change along the connectedness dimension such that teachers had to liaise and collaborate with parties outside of their school who may even be in other countries, speaking other languages. To connect up and work with other parties to extend students' learning opportunities and experiences require the capacity to "know-who," which does not only involve information about who knows what and who knows what to do, but also the social ability to cooperate and communicate with others (Hargreaves, 2003). This goes beyond the TPCK framework of teacher knowledge.

To be an agent of disruption (or innovation) and to leverage ICT as a disruptive force requires courage and motivation. Teacher learning in the various knowledge domains alone is not sufficient to stimulate the emergence of pedagogical innovations. There is a whole body of literature on conditions for innovation and change in schools (e.g. Fullan, 2001; Senge, 2000), which clearly indicate that leadership and institutional factors are critical to the emergence and sustainability of innovations. The question that is explored here is what kind of teacher learning will be necessary so that teachers can develop a new professionalism to be able to play the role of catalysts in the knowledge society, where they:

– promote deep cognitive learning;
– learn to teach in ways they were not taught;
– commit to continuous professional learning;
– work and learn in collegial teams;
– treat parents as partners in learning;
– develop and draw on collective intelligence;
– build a capacity for change and risk; and
– foster trust in processes (Hargreaves, 2003, p. 24).

It is clear that to build up the capacities listed above requires teacher learning to go beyond knowledge. Teachers need to develop the metacognitive ability as an autonomous learner to identify problems and knowledge gaps, monitor and review their own professional learning, and to assess the extent to which the problems are resolved or targeted goals are achieved. Working in teams to achieve new goals and tackle new problems may not always arrive at productive outcomes. In fact, as Scardamalia and Bereiter (2003) pointed out, knowledge building is not something that happens naturally, but requires shared intentional efforts from members of the community. Hence teachers need to develop the socio-metacognitive capacity (Scardamalia, 2002) required for knowledge building through professional development efforts that engage them as contributors in a knowledge-building community (Oshima et al., 2003). Furthermore, teachers need to build the socio-emotional capacity to engage in change, take risk, and foster trust.

By now, the magnitude and scope of a teacher's learning for pedagogical innovation must look so enormous that it may seem to be almost insurmountable. Obviously, the magnitude and scope of the challenge depends on the extent of the innovation. Even among the collection of case studies in the SITES M2 study, the example given above is exceptional and the collection as a whole do exhibit wide diversities in the extent of innovativeness along the six dimensions (Law, 2004). Teacher learning is an emerging process and in the SITES M2 study there was clear evidence that the prior experience of the teacher and the school involved contribute to the nature as well as the sustainability and transferability of the innovative practices (Owston, 2003). However, a more important issue to be addressed in relation to teacher learning for pedagogical innovation is not what needs to be learnt, but why a teacher would want to learn? What motivates a teacher to put in so much cognitive, metacognitive and socio-emotional energy to make the change happen? The answer has to lie in the professional value and epistemological belief of the teacher.

To be willing to take risks and be committed to continual change and improvement, the motivation has to be a set of *professional values* that focus on social justice and care as well as a strong *epistemological belief* about how learning takes place. Oakes's (2002) research shows that the failure to address the values and beliefs underpinning change, and hence the deep-seated controversies that the change inherently invoke, would ultimately undermine the success of many reform efforts. Pedagogical innovations are disruptive precisely because they challenge long-standing values and beliefs in education. Professional development efforts that do not address these aspects of teacher learning will not measure up to the demands of preparing teachers for the twenty-first century.

Teacher Learning Through Innovations – Conceptualization of Support for Teacher Learning Beyond Knowledge

As discussed earlier, teacher learning for ICT integration need to prepare teachers to engage in pedagogical innovation that leverages on the disruptive potential of ICT. The TPCK framework proposed by Mishra and Koehler (2006) is not adequate as a conceptualization for teacher learning as a preparation for incorporating ICT in pedagogical innovations. Four kinds of capacities need to be developed through teacher learning: cognitive, metacognitive, social, and socio-metacognitive. Further, educational values and epistemological beliefs underpin and drive teacher learning. The educational values influence the teacher's perception of what are the important content goals (CK) as well as the pedagogical choices adopted. The teacher's epistemological beliefs about how learning takes place have an even greater influence on the pedagogical beliefs and orientations of the teacher, influencing what kinds of PK and PCK the teacher would want to become knowledgeable about. These pedagogical and goal preferences will also influence the teacher's selection of technology and how the technology is to be used in the pedagogical setting, hence influencing the teachers decisions on which TK, TCK, TPK and TPCK to learn about.

It is clear from the above discussion that teacher professional development for pedagogical innovation must address the issues of educational values and epistemological beliefs, which can only be cultivated through the social, institutional, and professional milieu within which the teacher lives and works. Values and beliefs cannot be learnt through instruction and changes can take place only through deeply engaging experiences over an extended period of time. Innovation is an emerging process both for the individual teacher(s) as well as the institution(s) involved. Initial steps of change leading to observed gains by students will reinforce the teachers' commitment to change through strengthening their beliefs and values. Pedagogical experimentation and sharing of experiences in a professional network of innovators will thus set up a reinforcing iterative cycle of learning in the different domains.

It was found in the SITES M2 study (Owston, 2003) that the development of the innovation ideas, process of change, and teacher learning were inextricably intertwined.

Innovations may be initiated by teachers themselves or by other agents within or outside the school. Innovations can only be successful if there is teacher buy-in to the innovation ideas. Hence there needs to be an alignment of the educational values and epistemological beliefs between the innovation concerned and the teachers involved. The innovation process itself needs to strengthen these alignments and provide a supportive social and technological infrastructure to support teacher learning and professional collaboration. Law et al. (2005) examined whether there were systemic differences in the change mechanisms and factors influencing change across the case studies of innovations collected from Hong Kong and Finland in SITES M2. They found that both the change processes, as well as the roles played by ICT in the change process were very different between these two educational systems. In all the Finnish cases, the teachers found collaborators and established a support network for technological, learning resources, and/or expertise (subject matter and pedagogical). Most of the Finnish innovations involved more than one school to become a networked project at local, regional, or national levels while the Hong Kong cases were all innovations involving single schools. The roles played by ICT were limited to being cognitive, productive, or as communication tools for use by learners or teachers in the pedagogical process in the Hong Kong cases. The Finnish cases, on the other hand, used ICT additionally to provide a supportive technological and socio-institutional infrastructure to support collaboration among teachers and to share resources and experience. Hence ICT was leveraged not only to bring about changes in curriculum goals and pedagogical processes, but also to support the establishment of a professional community that provided the necessary social milieu for teacher learning on pedagogical innovations. It is hence not surprising to note that all the Finnish cases were reported to have been sustained for more than one year while most of the Hong Kong innovations had yet to demonstrate their sustainability. Law et al. (2005) referred to the difference in change mechanisms between the two systems as "the standalone fragility versus a network of innovation." This finding provides evidence that teacher learning for pedagogical innovation is more effectively achieved if the innovation process itself integrates a design for teacher learning in a supportive network of innovators.

To conclude, teacher learning to build capacities for pedagogical innovation using ICT needs to go beyond knowledge to encompass the enhancement of metacognitive, social, and socio-metacognitive capacities. In addition, professional development must address issues of values and beliefs, which provides the orientation and motivation for teacher learning. Designs of professional development to build such orientations and capacities would be more effective if teacher learning is to take place in the context of a professional network of innovators sharing similar aspirations and challenges.

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5.2

BENCHMARKS FOR TEACHER EDUCATION PROGRAMS IN THE PEDAGOGICAL USE OF ICT

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Introduction

The 22-page subject index of the report of the AERA Panel on Research and Teacher Education (Cochran-Smith and Zeichner, 2006) has no entries referring to information and communication technologies (ICTs) and only two referring to computers. Several chapters remark that teachers should develop ICT skills, but what this actually means is not discussed to any substantial degree. This does not mean that there are no publications on the subject or that research on ICT and teacher education and teacher learning is non-existent. Two worlds seem to be on different sides of a divide: the main stream teacher education research does not pay much attention to ICT while researchers studying ICT pay little attention to research conducted on teacher education. This chapter attempts to bring these two worlds closer to each other, presenting benchmarks for both pre- and in-service teacher education programs. Benchmarking is a process through which organizations evaluate different aspects of their processes in relation to best practice with the aim of improving performance. The benchmarks, in this case, could be seen as standards demanded of teacher certification education programs.

Teacher education programs should stimulate the pedagogical use of ICT to improve existing teaching practice and contribute to the development of new, innovative teaching practices. Pedagogical use of ICT refers to how teachers use ICT to facilitate student learning. In referring to pedagogical use of ICT in this chapter, we include all three major perspectives on learning: (a) behaviorist-empiricist, (b) cognitive-rationalist, and (c) situative-pragmatist-sociohistoric (Dede, 2008; Greeno et al.,1996).

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In the context of everyday classroom practice, the behaviorist-empiricist perspective relates to learning environments where information is efficiently *transmitted* to students, with many opportunities to practice and individualize feedback. Facilitating these processes with ICT includes the use of computer programs for acquiring and practicing routine skills. The cognitive-rationalist perspective relates to learning environments that *connect instruction* to students' learned or intuitive conceptual understanding and facilitates active knowledge construction or reorganization. ICT could facilitate these processes by presenting learners with interactive environments or simulations that stimulate them to apply and expand their knowledge. Learning environments in the situative-pragmatist-sociohistoric perspective let students *interact* with each other and with their material environment and learn to *participate* in the characteristic dialogue and discourse of the community within a specific domain. Facilitation of these processes with ICT can be found in CSCL (Computer Supported Collaborative Learning) settings.

To develop benchmarks for teacher education programs, we used the analyses of exemplary teacher education programs included in Kirschner and Davis (2003), together with a review of the research literature on teacher education for the pedagogical use of ICT. Kirschner and Davis analyzed 26 good practices in ICT-supported teacher education, which were collected from five regions around the world and aimed at the preparation of student teachers for working in an ICT-rich environment. Based on the assumption that in exemplary teacher education practices one can observe what teacher educators consider to be the competencies that good teachers need to have, Kirschner identified a number of core competencies. In addition, he distilled from these cases guidelines for the pedagogy of teacher education. The exemplary practices were analyzed with respect to the emphasis they placed on different aspects of ICT-use in teacher education, the depth and the breadth of the practices, and the pedagogy employed. Based on these analyses Kirschner and Selinger (2003) composed a baseline for teacher education programs on ICT-related pedagogic benchmarks. They recommended that these benchmarks are only useful when integrated within a program of teacher education that models good pedagogical practice. The present chapter extends this earlier work on the "what" benchmarks with the "how" benchmarks.

In the rest of this chapter we will elaborate on the pedagogical characteristics of exemplary teacher education programs and their effects on teacher education and then present the benchmarks and discuss their status.

The Pedagogy and Effects of Teacher Education

Perhaps the best overview of the principles for effective teacher education programs for ICT stems from Reeves' (1994) 14 pedagogical dimensions. A slightly adapted version of these principles were used by Kirschner and Selinger (2003) and Boshuizen and Wopereis (2003) to present pedagogical aspects of the exemplary practices they analyzed. The programs chosen as best practices conformed largely to the ideas of modern constructivist education, where learning is seen as an active process and where a balance is required between learner support and teacher guidance.

The exemplary programs generally provided contextualized learning activities to enhance the possibilities of transfer and to help student teachers develop insight into underlying principles and conditions for their application. These programs were quite flexible, so that modifications could be easily introduced, a necessity in the ICT-field that changes rapidly in many directions. Most programs also gave learners a lot of autonomy to determine their own learning, supported a broad range of learner activities, and were sensitive to individual differences in skills, personal interests, and needs. The majority of the programs had built-in facilities to support co-operative learning. Sharing of experiences and actively learning from each other not only broadens and deepens learning outcomes, it also leads to reflection and development of metacognitive skills. When conducted in a CSCL environment, the students also learnt how to use such technology platforms in their own teaching practice. Finally most programs were characterized as having integrated culturally sensitive strategies (Boshuizen and Wopereis, 2003).

This description paints an optimistic picture of the current state of affairs but this does not necessarily mean that the overall impact of teacher education programs on achieving good pedagogical use of ICT is high. Ashton (1996) reviewed many studies conducted between the mid 1980s and the mid 1990s and concluded that student teachers do not learn everything we want them to learn, such as working effectively with students, dealing with ethic diversity, impacting the lives of the students, and "coping with the demands of today's classrooms" (p. 21). Richardson (1996) found that teacher education at the pre-service level did not impact highly on the attitudes or beliefs of student teachers. Skills and theories taught on campus were often not used in student teachers' practices. Many student teachers even had negative attitudes towards the theories encountered during their teacher education experience, feeling that the theories contributed little to good teaching or even worse, which were counterproductive to good practice. There was poor transfer of theories taught and of skills trained on campus to classroom teaching practice. This was called the theory–practice gap. Unfortunately, this situation was not much different ten years later. Clift and Brady (2006), summarizing what was known about the effectiveness of methods-courses and field experiences in teacher education, stated that short-term interventions through such programs have limited impact. Clift and Brady along with Grossman (2006) reported some discouraging results on the effects of specific strategies used in teacher education (e.g., use of portfolios, practitioner research and supervision). Research findings show that student teachers resist implementing what they have learnt when they find it difficult to engage in the recommended practices, even when their field experiences reinforce and support those practices. Beginning teachers are often socialized into the practices of their first job rather than grounding their practices on theories and recommended practices encountered during teacher education programs. Clift and Brady concluded that methods-courses and field experiences can affect prospective teachers' thoughts about practice and in some instances even affect their actual teaching practices, but practicing one's beliefs is neither linear nor simple.

Despite the discouraging results mentioned, both Grossman (2006) and Clift and Brady (2006) gave some recommendations on what could work. They mentioned, for example, microteaching, working in small student–teacher groups, and the inclusion of reflection activities in these groups. The powerful work by Joyce and Showers (2002) shows that a combination of elements such as theory, demonstration, practice, feedback, peer coaching, and a supervision approach has proven to be effective in many situations. Programs that stimulate close ties between teacher educators and actual practice in schools are also effective. Brouwer and Korthagen (2005) showed that although occupational socialization – defined as "socialization that initially influence persons to enter the field of [physical] education and that later are responsible for their perceptions and actions as teacher educators and teachers" (Lawson, 1986, p. 107) – in schools has a considerable influence on developing graduates' in-service competence, there was also evidence on the positive impact of specific strategies in the teacher education programs such as (a) alternating student teaching and college-based periods, (b) tripartite cooperation among student teachers, mentor teachers and university supervisors, and (c) gradual increase in the complexity of student teaching activities.

A reason for the low effectiveness of teacher education programs in general, and the scarcity of evidence for the effectiveness of separate elements of programs in particular, may be due to the thin theoretical basis of such programs (Grossman, 2006). Examples of approaches that start from a theoretical basis are *competence-based* teacher education and *concern-based realistic* teacher education. In Benchmark 8, we elaborate on one of these approaches.

The results on teacher education effectiveness suggest that what we want student teachers and in-service teachers to learn about ICT may have the same disappointing fate as many other earlier endeavours to educate them. With this caution in mind, we present ICT-related benchmarks for teacher education programs.

Benchmarks

We formulated nine benchmarks for teacher education programs on the pedagogical use of ICT. The first four benchmarks concern the "what" of teacher education programs; the last five concern the "how".

Benchmark 1 – Personal ICT-Competencies

A prerequisite for using ICT as a pedagogical tool is that the teachers themselves can use ICT as a work tool (e.g., posting course materials in an electronic learning environment), a communication tool (to liaise between school, parents, local community, and beyond) and an administration tool (Thomas and Knezek, 2008). Teacher education programs, pre- or in-service, should thus facilitate teachers to become competent personal users of ICT. Minimally, present-day teachers require basic competencies with:

– office applications – word processing, spreadsheets, databases, drawing packages, and a simple web page editor;
– resource tools – CD-ROMs, Internet, web-portals, different types of search engines, and
– communication tools – email, discussion lists and synchronous chat.

Further, these programs should develop the learner's ability to use ICT effectively for:

– communicating between and within student groups;
– communicating with other teachers, and
– lifelong learning, including self-assessment of learning and learning needs.

Some countries have introduced an "ICT driving license" for these competencies (e.g., Turcsányi-Szabó, 2008, in this book).

Benchmark 2 – ICT as a Mind Tool

Mind tools are computer applications that, when used by learners represent what they know, necessarily engage them in critical thinking about the content they are studying. Learning with mindtools depends "on the mindful engagement of learners in the tasks afforded by these tools and that there is the possibility of qualitatively upgrading the performance of the joint system of learner plus technology" (Jonassen et al., 1998, p. 30). Mind tools scaffold different forms of reasoning about content; they require students to think about what they know in different, meaningful ways. For instance, using databases to organize students' understanding of content organization necessarily engages them in analytical reasoning since creating the rule base requires them to think about causal relationships between ideas. At this point we must make a distinction between learning *with* ICT (i.e., as a productivity tool) and learning *through using* ICT (i.e., as a mind tool). In the former, ICT is the enabler, such as in using a project-planning program to help students plan their projects properly and hand in their projects on time. In learning through using ICT, the expected outcome is for ICT to bring about a change in the way one thinks and works. Going back to the planner, this can happen in the long run when the project planning program has taught the student to organize her thoughts, take critical paths and products into account, and plan her work efficiently (long) after having completed the project.

Programs should train teachers and student teachers to be able to use ICT as mind tools (see for instance van den Berg et al., 2008) to represent what they know as they transform information into knowledge and to engage in, and facilitate, critical thinking and higher order learning. Minimally, teachers should develop basic competence to use mind tools for ordering their own thoughts (e.g., through concept mapping) and those from colleagues, and modelling their own environment for optimal teaching.

Benchmark 3 – Social Aspects of ICT-Use in Education

ICT is having a profound effect on society (Thomas and Knezek, 2008). As a sociocultural phenomenon, ICT changes leadership and roles in organizations (Szewczak and Snodgrass, 2002), as well as teachers' and students' roles in schools. It creates opportunities for collaborative knowledge production and problem solving, breaking earlier limits of time, distance, and possession of knowledge. At the same time, it also creates new social dysfunctions, such as problems of privacy, escapism or anonymity, lack of commitment and false role images. Pre- and in-service teacher education must face these issues.

The introduction of ICT – including Internet, mobile phones, and SMS – is changing interpersonal relations. While 10 years ago telecommunication between teenagers was largely supervised by adults, in the sense that parents knew when someone was on the phone and often knew who it was, now many households have Internet access, allowing children and adolescents to communicate with friends (and even strangers) at any moment they like. The "disembodied nature" (Dreyfus, 2001) of ICT-use and the very fact that they enable unsupervised and unnoticed communication have a liberating and disinhibiting effect, which children and adolescents heartily welcome, but which also has some unpleasant side effects. Children can easily communicate with others about whatever topic they have a common interest in, but the disembodied nature of chatting makes it very easy to present oneself in a more favourable way, making it difficult for the other to discriminate between friend and foe.

Traditional normative concepts such as privacy, anonymity, and intimacy are changing. Norms and values have traditionally been passed from adults to children, but now children are also engaged at the cutting edge of societal change. With instant messaging they multi-task conversations in ways that adults are hard pressed to understand. It is important that teachers and teacher educators:

– engage as members of a (wired) school community;
– provide a role model of good ICT practice;
– learn to share and build knowledge;
– understand the implications of the information age on schools and schooling, and
– realise and discuss the impact of ICT on society.

Benchmark 4 – Adopting ICT in Teaching

Pre- and in-service teacher education and professional development programs should prepare teachers to use ICT in different educational or pedagogical settings. In other words, not ad*a*pting their teaching to ICT, but ad*o*pting ICT in their teaching.

Selinger (2001) noted that it is often the case that the increase in the use of ICT is little more than "more of the same." Learners are not given more autonomy; technology is not used to give students new ways of learning, and there is very little change in pedagogical practice. According to Cuban (1993), teachers tend to appropriate new technologies and incorporate them into their traditionally held views of teaching and learning. He argues that the overhead projector and video made very little impact on teaching styles, and so why should computers be any different?

Computers, however, are substantially different from previous technologies because they give students access to new ways of thinking through dynamic images, simulations and models, and a huge array of – worthwhile and worthless – information. Teachers must find ways of harnessing the power of the new technology. Their jobs will change but their role should become no less important in the same way that public libraries and books did not make teachers redundant.

There is also a growing, or possibly a renewed, interest in resource-based learning (Hill and Hannafin, 2001) that aims at achieving both subject and information literacy objectives through exposure to and practice with diverse resources. Students become active learners as they use a wide range of resources in different media formats to investigate subject matter prescribed within their classroom curriculum. Teachers become motivators and facilitators in learning processes and provide the initial impetus that drives students to seek information and become creative problem-solvers. The end result is that a "learning culture" is fostered as a climate of active and productive learning. Such an approach is flexible and emphasises complex skills important for the digital age, such as problem solving and critical thinking.

A note of caution needs to be made here. Teaching teachers to use ICT outside of meaningful educational contexts must be avoided. This means that aspiring teachers will not only come to know the theory behind why and how to use ICT, but will also develop competencies in:

– planning for relevant individual, group and whole-class activities;
– preparing and producing learning materials with the help of ICT;
– dealing with the possibilities and consequences of using ICT;
– teaching and learning specialist subjects with ICT, and
– team teaching in situ or at a distance.

Benchmark 5 – Cooperative Education: Combining Institutional Learning and Learning in the Workplace

While education-related theories are introduced to aspirant teachers during their formal pre-service education and professional development, most beginning teachers agree that they actually learnt the most during their practice teaching period. Optimising pre-service teacher education, thus, entails connecting and embedding learning such that the division between working and learning dissolves. In other words, teacher education institutions and schools need to make a transition towards becoming modern knowledge organisations, and thus place a premium on knowledge development and knowledge management. Learning is more than knowledge acquisition. It is an integral process of thinking, producing, communicating, cooperating and designing by learners, and of coaching, structuring, assisting, giving feedback, and teaching by teachers and support staff (van den Dool and Kirschner, 2003).

Hall et al. (2006), after analyzing professional development projects in the Preparing Tomorrow's Teachers for Technology (PT3) grant program, concluded that success depends on the quality of leadership, administrative support from departments and colleges, available resources and personnel, just in time learning, and faculty's understanding of the relevance of proposed changes. It is, thus, important for institutions to explicitly specify the competencies it wants its staff members to achieve or possess and to check whether they have been acquired or are present. Feedback (both peer and expert) must also be facilitated. Supervision, reflection, and co-operation within the school can positively influence teachers' beliefs and actions, but these activities are time consuming (Grossman, 2006). Thus, time must be explicitly allocated for reflection, monitoring, and evaluation of the teachers' personal and professional development in the use of ICT in their teaching.

Finally, Grossman (2006) stressed the importance of teacher educators having close ties to practice in schools. To this end co-teaching by teacher educators and student teachers would facilitate implementation of new educational strategies that are different from those in typical school settings.

Benchmark 6 – Communities of Practice

Communities of practice (Wenger, 1998) are places where a process of social learning occurs between people with a common interest in a subject or problem collaborate over longer periods of time to share and exchange ideas, find, solutions and build innovations. At the very heart of learning in a community of practice is discourse to build both personal and shared understanding. Such a discourse enables enquiry and encourages construction of personal meaning as well as shaping and confirming mutual understanding. When learners participate in such communities, they are allowed, and are even expected and encouraged, to make a different type of contribution than more knowledgeable and usually longer participating members, a concept known as legitimate peripheral participation (Lave and Wenger, 1991). Such a participation "provides a way to speak about the relations between newcomers and old-timers, and about activities, identities, artefacts, and communities of knowledge and practice. This social process includes, indeed it subsumes, the learning of knowledgeable skills" (p. 29). In the case of teacher learning for pedagogical use of ICT this would include getting the net-generation or student teachers to contribute as digital natives from their knowledge base on the use of ICT (and thus provide information to established teachers), while established teachers in the community can contribute their vast knowledge of teaching and learning praxis. Computer supported networked communities are, in the context of this chapter, an important example of such a community of learning or practice. De Laat's study of networked learning (2006) illustrated that engagement in collaborative learning processes does not automatically mean that participants strive for collective learning outcomes. His review of studies in networked learning found that individual interests and learning goals are the main drivers of learning and that feedback and guidance from peers and experts are appreciated for supporting learning. Students, especially in the earlier phases, welcome active pedagogical guidance by the teacher or expert, which can later evolve into a more facilitative approach. Because of the equal access of both teachers or experts and students to discussion and comments made by all the participants and the fact that there is no clear distinction between students and teachers or experts (i.e., in certain circumstances the learner can know more or have more experience than the "expert"), management of the learning process is a joint activity and responsibility.

Benchmark 7 – Embedding Learning About ICT in an Open, ICT-Rich and Flexible Environment

According to van den Dool and Kirschner (2003), a transparent, open, connected, well-resourced and flexible learning environment in teacher education is a precondition for learning about the pedagogical use of ICT. Student teachers and faculty use a wide range of electronic and human connections, have personalized access to human and electronic networks, and use tools such as PCs, laptops, handheld devices, digital cameras, MP3-players, and iPODs. Specifically designed and developed educational tools, applications and software (e.g., digital content, electronic learning environments, digital portfolios, electronic assessment programs) as well as tools, applications and software not specifically made for teaching and learning, but that can play a role in both processes, are plentiful. These learning tools and teaching aids are readily available and can often be integrated with each other. Examples of such tools are visualization tools, animations, simulations, knowledge networks and communities, mind maps, discussion boards, search engines, know bots, virtual environments, chat rooms, electronic whiteboards, tracking and reporting systems, teachable agents, applets, and widgets (see the experiences in PT3 projects such as Hall et al., 2006; Mims et al., 2006).

According to Simons (2002), such an ICT-rich environment offers extra potential to reinforce and promote learning. Examples are plentiful. ICT can be used for:

- making and building relationships with sources of information and with other persons;
- simulations, authentic tasks, games, case databases that help student teachers to actively create knowledge;
- supporting and fostering dialogue and learning through dialogue;
- promoting transparency (e.g., by making teacher–learner dialogues and dialogue patterns in collaborative learning experiences explicit and analysable);
- stimulating learning to learn (electronic tools for stimulating reflection, metacognition, peer feedback and peer tutoring);
- competence assessment (digital portfolios);
- dynamic task selection and feedback (pedagogical agents, expert systems);
- enhancing flexibility (with respect to place, time and pace of study, learner needs, learning style or preference, and just-in-time learning).

In sum, an ICT-rich environment in teacher education allows for increased communication, collaborative and cooperative learning, and individualisation.

Benchmark 8 – Learning About ICT Through Structured Experiences

Based on an analysis of the origins of the gap between the theory or skills taught in teacher education and teachers' practices, Wubbels et al. (1997) proposed that experiences should be taken as the starting point for learning. Similarly, van den Dool and Kirschner (2003) posited that the start of learning lies in the experience of the student teacher both as a student and a staff member. Starting from practical experiences can be a viable and fruitful avenue in teacher education to stimulate integration of theoretical notions in teacher actions with each other *and* with "reality." But to achieve this, careful planning, structuring and supervision is needed. Clift and Brady (2006) confirmed this, concluding that engaging in tasks associated with full responsibility may discourage or inhibit continuous attention to individual students.

Korthagen and Kessels (1999) offered a useful framework for thinking about learning from experiences in their *realistic approach to teacher education*, which focuses on the specific concerns, questions, and problems student teachers take with them to the teacher education institute today, on the basis of yesterday's experiences in the school. They considered this as a theory-based approach, integrating competency-based methods (Gage, 1978) and the reflection paradigm (Valli, 1992) in teacher education. Putting this approach into practice requires teacher educators to have special competences to guide the intended reflective learning process in student teachers. This process is described through the so-called 5-phase ALACT model of reflection: (1) action, (2) looking back on the action, (3) awareness of essential aspects, (4) creating alternative methods of action, and (5) trial, which is a new action and therefore the starting point for a new cycle.

Benchmark 9 – Embedding Learning about ICT in Other Content Domains of Teacher Education

Teacher education programs are usually structured around disciplines and courses such as educational psychology, foundations of education, teaching methods, linguistics and – unfortunately – multimedia and ICT. Such a structure promotes compartmentalisation of what is experienced and learned and, thus, inhibits student teachers from integrating insights from different disciplines for the solution of practical problems (Merriënboer and Kirschner, 2007). Taking student teachers' experiences as a starting point requires a holistic, integrated program structure rather than one that is broken down into distinct disciplines. Teachers who learn technology-skills in isolation from methods-courses may be competent in using technology but unable to use their technology skills to foster student learning (Mims et al., 2006).

A holistic approach can help teachers to deal with complexities that are often encountered in teaching without loosing sight of the separate disciplinary elements and the interconnections between them. It allows for the integration of knowledge, skills, and attitudes; the coordination of qualitatively different constituent skills and the transfer of what is learned in the taught courses to daily life and work settings.

Discussion

The above nine benchmarks are not exhaustive. Kirschner and Selinger (2003), for example, explained that additional benchmarks could be introduced to address issues related to ICT in learner assessment and ICT in educational and school policy. Learning to use ICT for assessment and understanding the policy dimension of ICT-use are not yet widely perceived as important components of good practice. In the opinion of the authors, this is shortsighted.

A benchmark on *educational policy* is needed because it would be strange for learners to remain ignorant of local standards regarding ICT in their educational system, especially where ICT was mandatory or integrated into mandatory standards for the subjects the individual is preparing to teach. In the United States, for example, most of the states and the US Council for the Accreditation of Teacher Education have adopted the ISTE standards for teachers (National Education Technology Standards for Teachers, NETS.T; see Thomas and Knezek, 2008) as mandatory.

A benchmark on ICT for *assessment* deserves full attention. Assessment via ICT and in particular new forms of assessment involving the learner as a collaborator in assessment (e-portfolios, learning diaries), peer assessment, and authentic assessment are of growing importance (Baartman et al., 2006; Gulikers et al., 2004; Reeves and Okey, 1996). The current trend towards competency-based education requires sympathetic testing and assessment that can both determine if the competencies have been achieved and stimulates – or at least not deter – that type of learning. It is noteworthy that most of the case studies of good practice reported by Kirschner and Davis (2003) used and modelled innovative approaches to assessment in line with their pedagogical approaches. We therefore conclude that this benchmark is emerging for teacher education initiatives that aspire to be good practices.

One of the six standards of the ISTE NETS.T (see Thomas and Knezek, 2008) is on assessment and evaluation. The remaining five standards closely resemble our first four benchmarks (on the "what" of teacher education). Our benchmarks differ from the US Standards in also including guidelines on the "how" of teacher education.

An unsolved issue is whether the attention on ICT in teacher education will be a continuing necessity or whether it is only a temporarily necessary topic. As we have seen and continue to see in educational research, attention for the use of written texts in education and their effects on learning is to be expected for a long time to come. Research on the use of ICT in education and learning through ICT will need to be carried out. For teaching on the use of ICT in teacher education, the necessary time period could be shorter, in particular, when ICT becomes a common tool such as books have been for a long time. When our benchmark 9 about embedding of learning about ICT in other content domains becomes common practice then teaching on the use of ICT will disappear (cf. Kirschner and Davis, 2003). Certainly ICT is not yet as common as books and it is not yet time to stop paying special attention to the topic.

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5.3

FACTORS AFFECTING TEACHERS' PEDAGOGICAL ADOPTION OF ICT

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Insights from Socio-Cultural Theory

Much of the research on teachers' use of information and communication technology (ICT) in their teaching describes low levels of usage and minimal pedagogical change. Around the world, when visionary policy initiatives have frequently resulted in minimal change in classroom practice, evaluators tend to blame teachers and urge more "training;" a consensus has developed for a deficit model that assumes failure to be caused at the levels of the school and the classroom, and teachers' "resistance" to be the core obstacle to be overcome. In this chapter I want to explore an alternative analysis. However, it is useful to begin by focusing briefly on some key findings derived from studies adopting these assumptions. An excellent review of the factors affecting teachers' use of ICT over the previous 20 years is provided by Mumtaz (2000). She provides summary lists of "inhibitors" to teachers' adoption, including "lack" of experience with ICT, on-site support, ICT specialist teachers, time, access, and financial support; and causes of "teachers' resistance" (outside intervention, time management, lack of administrative support or organisational change, and teachers' perceptions linked with "personal and psychological factors"). She provides a good overview of factors that encourage teachers to use technology drawing on surveys of teachers' perceptions and attitudes conducted in the USA (e.g. Hadley and Sheingold, 1993); and qualitative studies of teachers learning to integrate use of ICT in their teaching. Webb and Cox (2004) provide an extensive review of research into the relationship between pedagogy and ICT, drawing on the European tradition of pedagogy as "the science of teaching." They present a "framework of pedagogical practices relating to ICT use," which enables a sophisticated analysis of the relationship between teachers' knowledge and beliefs, pedagogical reasoning and behaviours; the affordances of technology; and students' knowledge, beliefs and

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behaviours – and how these impact on the learning activities which lead to the development of students' knowledge, understanding and skills.

The analysis presented in this chapter adopts a rather different framework, based on socio-cultural theory, which assumes that processes of change in schools and classrooms cannot be understood in isolation because they are necessarily co-constructed with students or local communities, and constrained or enabled by the regulatory frameworks and policies of national education systems and national cultures. Thus teachers' beliefs and attitudes, and their confidence and competence with ICT, remain centrally important in the pedagogical adoption of ICT, but teachers are not "free agents" (there is indeed no such thing) and their use of ICT for teaching and learning depends on the inter-locking cultural, social and organisational contexts in which they live and work. Although neither Mumtaz nor Webb and Cox adopt this approach, their reviews lend support to such a socio-cultural analysis of the process of ICT innovation. For example, Webb and Cox include students' values, beliefs and knowledge in their pedagogical framework and comment that "most of the studies considered in this article did not consider this issue specifically and there is a need for further research to address this" (Webb and Cox, 2004, p. 276).

Rather than teachers being somehow to blame for the lack of pedagogical transformation when ICT is introduced, this chapter will argue that the failure lies with both policy-makers and evaluators who have little understanding of the process of technological innovation. Drawing on socio-cultural theory, in particular, the insights it offers to the co-constructed, cultural–historical nature of social practices and the mediating role tools play in their development, the proposition will be made that radical structural changes to education systems and schools are needed if schooling is to be transformed by ICT. This approach draws on the insights of a number of other researchers (Cole, 1996; Crook, 2001; Saljo, 1999; Sutherland, 2004). What is argued is that the legislative frameworks and organisational structures of schooling often make it impossible for ICT tools to be explored and appropriated pedagogically. They severely constrain teachers' and students' agency, because they are in effect cultural tools that mediate pedagogies of blackboard and chalk. They reinforce teachers' traditional roles and beliefs. Education systems can be understood as outdated infrastructures resisting inevitable change. As McLuhan (1964, p. 379) argues, "Continued in their present pattern of fragmented unrelation, our school curricula will insure a citizenry unable to understand the cybernated world in which they live."

In this chapter pedagogy is defined as the interactive process by which a student's learning is mediated by teachers using a range of tools (Vygotsky, 1978, p. 27). These tools, including language, conceptual frameworks and artefacts such as books and computers, are continually developing and changing. As we become skilled in their use we develop social practices to incorporate them as extensions of ourselves (McLuhan, 1964, p. 7) and depending on how we use their affordances they shape and change the nature of those practices, empowering us to do things previously beyond our capability (Wertsch, 1998). Following Alexander (2000) pedagogy is conceptualised here as a set of culturally contextualised social practices, which requires holistic analysis: "Culture both drives and is everywhere manifested in what goes on in classrooms, from what you see on the walls to what you cannot see going on inside children's heads" (p. 266).

The specific focus of this chapter is how ICTs are being appropriated and used by teachers in many countries as pedagogical tools. The premise is that learning is a situated process (Lave and Wenger, 1991) mediated by the context of the classroom, school and larger society, and that teachers' pedagogical adoption of ICTs is driven by the values and assumptions embedded in routines of practice (Pearson and Somekh, 2006). Among these embedded values are teachers' beliefs about their own role in the pedagogical process. Bruner (1996, pp. 63–65) provides a useful analysis of four ways in which teachers orientate themselves towards learners: as fosterers of the child's learning process, skilled transmitters of specialist knowledge, expert manipulators of the child's psychological processes, or – in what he calls "modern pedagogy" – facilitators of *both* children's learning *and* the development of their metacognitive capability. It seems certain that teachers' pedagogical orientation is one of the crucial factors in their ability to appropriate ICTs. In a survey carried out in the USA (Becker, 2000), teachers who subscribe to Bruner's "modern pedagogy," believing teaching to be a process of co-constructing knowledge with learners, were predominant in the small group who used ICT for teaching academic subjects. I want to argue that this may be because digital technologies are tools that offer a new kind of control to learners, particularly because young people often acquire skills in their use more quickly than teachers. In effect, digital technologies in the classroom mediate the relationships between teachers and learners and are disruptive to styles of teaching where the teacher is either an authority figure or feels the need to be the centre or attention. To adopt Bruner's "modern pedagogy" teachers have to make a conscious effort to re-orientate their relationship with learners and to do this effectively they need to work within a community that actively supports both this new conception of childhood and the changes in pedagogical practices that concretise it. A second, very powerful factor that culturally shapes teachers' pedagogical adoption of ICT is the strong separation between the worlds of technology and the liberal arts in Western societies (Latour, 1996, pp. vii–x). Embedded in the culture of the classroom, which is itself embedded in a society dominated by the liberal arts, are the assumptions of adults (teachers and parents) about how technology may impact on their own identity and their assumptions about its (in)appropriateness for the study of many academic subjects. This separation between the worlds of technology and the liberal arts is powerfully explicated in Pirsig's *Zen and the art of motorcycle maintenance* (Pirsig, 1974). It is embedded in national curricula and assessment systems, and can be observed when the popular media express worries about the negative impact of ICT on children's literacy skills (Carrington, 2005).

The Processes of Pedagogical Adoption of ICT

How then does a teacher adopt ICT pedagogically? Starting inevitably without any skill in its use, humans explore the affordances of any new tool (what latently it makes possible) and develop the necessary skills *best* through exploratory play. This is how worldwide many children and young people have quickly become skilled users of technology. Indeed most highly skilled users of ICT describe themselves as self-taught through hands-on trial and error. However, those without the time – or often sufficient access to the new tool – to engage in exploratory play, invariably begin by trying to fit the new tool into existing social practices. This has certainly been the case for teachers and ICT. In subjects such as computer science, computer literacy and business studies (which has its roots in learning office practices such as typing) students were given hands-on access to computers in the classroom; but in other subjects, including science and maths, computers were not a good "fit" with the long-established pedagogic process of imparting conceptual understanding through exposition from the blackboard. A compelling example of the importance of "fit with existing practice" is the extraordinary speed with which interactive whiteboards (IWBs) have been adopted in primary schools in England (Somekh et al., 2007). IWBs include many features ideally suited to supporting the delivery of whole-class teaching, which is a requirement of the national numeracy and literacy strategies. The IWB makes it easier for teachers at the front of the class to engage the attention of thirty or so children, and provides an ideal medium for describing, explaining and exemplifying the complexities of reading and number work.

ICTs do not change pedagogic practices themselves. Watson (2001a) suggests that in seeing ICT as the means of transforming pedagogy politicians have "put the cart before the horse." It is teachers who change practices, co-constructing them to varying extents with their students (see Bruner's typology of pedagogies above). In this sense there is, as Fisher (2006) argues, no such thing as technological determinism and the term *affordance* is misused if it creates the suggestion that tools have any power of agency. However, the term *affordance* as a description of latent possibility is highly explanatory for the relationship between humans and ICTs. As we develop experience of using new tools we build mental models of their use – or secondary artefacts using Wartofsky's term (1979) – and these provide conceptual tools (tertiary artefacts) for imagining radically new ways of using them. By this means, a child who is already skilled in using powerpoint, and when using the Internet at home discovers "google image," is easily able to imagine new ways of using powerpoint incorporating images. Going back to powerpoint she may then investigate its menus and find the facility for importing images, and also perhaps digital video that further expands her power to envisage possibilities. Moreover, the affordances of ICT reflect the cultural assumptions of those who created the tools, in the sense that they provide a good "fit" with a social practice of exploratory, individual use, in which access to websites (information and potentially knowledge) is not controlled by a third party. This fits well with the independent young user of ICT working at home with a computer and broadband connections. By contrast, there is much research that describes the disruptive effects that ICTs appear to create in classrooms, for example Robertson et al. (2004) found that "ICT consistently destabilizes the established routines of classroom life including norms of time and space" (p. 179). Even when the "fit" is good as with IWBs in contemporary English primary schools, teachers, who have little time to "play" and explore new ways of using their boards, need continuing support and encouragement to make creative use of its affordances as a multi-modal portal and a shared resource with the children (Somekh et al., 2007).

Examples of Transformative Pedagogies with ICT

So how does pedagogical adoption of ICT occur? What are the features of policy and classroom implementation of ICT use that are indicative of success? This section describes three examples of ICT being used pedagogically in ways that transform schooling and draws out some of the features that distinguish them.

The Apple Classroom of Tomorrow (ACOT) Project in the USA (Sandholtz and Ringstaff, 1996)

Over a ten-year period from the mid 1980s Apple Computers financed a research and development project in which it worked closely with teachers in elementary and high-school technology-rich classrooms. The aims of ACOT were to put technology into the hands of teachers and students and radically change the learning experience. The researchers inspired ACOT teachers with a vision of constructivist teaching and supported them by funding training workshops and week-long "summer institutes" where they were introduced to the latest technologies. The visits of researchers to ACOT schools also "served as an indirect source of support" (Sandholtz and Ringstaff, 1996, p. 289). Sandholtz and Ringstaff describe and analyse the process of teacher change that resulted. They record that the introduction of technology brought teachers into conflict with their existing pedagogical beliefs, changing their relationships with their students, reducing their apparent "control" and making their classrooms noisier. At first they responded by imposing restrictions on students' use of technology, but over time they learnt new ways of working that turned technology to pedagogic advantage. Although the process was slow, it led to noticeable shifts in teachers' roles and the development of new practices. As radical pedagogic change developed, student motivation increased, and teachers developed new ways of assessing their learning that made creative use of technology. However, in relation to preparing students for standardised tests in traditional paper-based environments, teachers continued to have "serious concerns" and to "struggle." The ACOT project involved teachers actively in research through keeping regular audio-taped journals and writing reports, and this was an important strategy for professional development.

ICT-Initiated Development in Godøy Lower Secondary School in Norway (Krumsvik, 2006)

The innovative work at the school on Godøy island was part of the Norwegian PILOT (Project: Innovation in Learning, Organization and Technology) project aimed at "obtaining knowledge about how teachers accept and utilise technology over time and how this influences the school organisation" (Krumsvik, 2006, p. i). The principal established a partnership with Krumsvik, an action researcher who used it as a case study for his doctoral research. Two major innovations occurred in the school as a result of this work. The first was the development of a subject-portal (Themeweb) in which the teachers created and stored a large amount of curriculum materials.

Krumsvik describes the action research process over time: "Through contradictions and discussions in the school on questions of technology-use, the school experienced a process of small cycle forward movements, but also minor setbacks in this change-process" (p. 142). Systemic change began to take place when the teachers decided to integrate Themeweb into the syllabus. This had an impact on the school's structure, by leading to the second major innovation, the reorganisation of the school day with "study time every day" (90 min) in which students used Themeweb and other resources to pursue learning goals agreed with their teachers. As in the ACOT project the teachers' initial response was to focus on negative aspects of the work, which generated anxiety. This led to detailed discussions in regular staff meetings in which the school's educational philosophy and pedagogic practices were analysed and reconceived. There were also discussions with parents to allay their initial anxieties. The balance of power between teachers and students shifted with teachers' expertise in textbook knowledge being challenged by information available from the Internet. The school developed its own new understanding of "digital epistemology" and this led to the development of a new assessment framework. The teachers applied to the Directory of Education, and were granted permission, to develop a written ICT-based examination in English for 10th grade based on their framework.

The Enlaces ICT Initiative of the Chilean Educational Reform (Hinostroza et al., 2002)

The *Enlaces* ICT initiative is part of the national programme to improve the quality of education in 10,000 public schools throughout Chile. From the early 1990s schools were equipped with computers, local networks, educational and productivity software, and free and unlimited access to web-based educational content relevant to the Chilean curriculum. *Enlaces* provides on-going technical and pedagogical support, delivered locally to each school through a partnership of the Education Ministry with 24 universities. In 1999–2002, Chile participated in the SITES M2 international qualitative study of innovative pedagogical practices using ICT. Seven schools were selected as case studies using a local definition of innovative pedagogical practice as well as the SITES M2 criteria required of all countries (Law et al., 2005b, p. 178). Local criteria included flexible lesson planning, collaborative cross-curricula work using ICT, a focus on the process of learning rather than its products, increased student participation and control over their own learning and pedagogical planning that ensured "a correspondence between the goals, the evaluation and the 'success' criteria" (Hinostroza et al., 2002, p. 461).

Teachers and students reported that the main impact of *Enlaces* project work was on learning achievements and student motivation. Students (confirmed by parents) provided many examples of becoming fascinated by learning things directly relevant to their own lives and their local community and gaining new understanding of the relationships between knowledge in different subjects. Teachers across all the case study schools noted a marked improvement in students' motivation to learn. In terms of teaching and learning processes, students engaged in data collection, information processing and product development, as well as communicating with other schools (sometimes internationally) using email and video-conferencing. Teachers were aware that changes in their pedagogy led them to adopting new roles, particularly in "scaffolding" students' learning through assisting individuals and groups and in producing "activity guides" to provide structure for exploratory projects. Teachers perceived that the student's role had also changed to "learning on his/her own" (Hinostroza et al., 2002, p. 467). In terms of learning achievements, Hinostroza et al. record that these new kinds of learning were not captured by national tests, which showed little change in students' attainment. They conclude: "The challenge now is to deepen the identification and definition of these impacts and opportunities, and eventually include them as part of the national assessment tests" (Hinostroza et al., 2002, p. 468).

These three examples, drawn from different countries, show considerable similarities in the factors that enabled teachers to adopt ICT pedagogically. First, all the schools were well equipped with ICT and the focus was on changing the process of learning using ICT tools. Students and teachers acquired high-level ICT skills as a spin-off from using them purposefully to find things out and create products. Teachers were supported by facilitators (from industry, the ministry or a university, respectively) coming into their schools to provide expert knowledge on how ICT could be used for students' learning and how they could change pedagogical practices. This enabled them to make fundamental changes to how they constructed their own role, the student's role and their pedagogic relationship, becoming much more flexible in their teaching plans and giving students real agency as learners. In all three examples teachers had opportunities to discuss problems as they arose with peers and facilitators, and explore solutions over a long period of time. And in all three examples the nature of students' learning changed – both what they learnt and the process of learning itself – and the established epistemologies of the school also changed through the mediating effect of ICT and changing pedagogies. The focus and purposes of learning, teachers' beliefs, classroom organisation, tools used by students and teachers, their roles and the rules governing their interactive performance of pedagogy are all demonstrably inter-linked: changes in one mediate changes in all the others. Predictably, in all three cases, as pedagogical adoption occurred, a mismatch developed between learning outcomes and the requirements of national tests. New approaches to assessment, sensitive to new ICT-mediated learning processes, were needed to capture all aspects of student learning. The extent to which this remained an unresolved anxiety for the teachers or generated supportive action from policy-makers and education officials varied from country to country.

The Shaping of ICT-Mediated Pedagogies by National Culture

We know from Alexander's work (2000) that schooling is deeply embedded in national culture and that teachers and children bring into the school values and assumptions that strongly construct pedagogic practice. We would expect this to be demonstrated in comparisons of ICT-related pedagogy between countries. Law et al. (2005b) provide an in-depth comparison of the SITES M2 case studies of ICT-supported innovation in Finland and Hong Kong, placing these in the context of a more impressionistic analysis of the regional differences in innovation characteristics between case studies in Western Europe, America, Eastern Europe and Asia. The basis for comparison was a six-dimensional framework of innovation developed by Law et al. (2005a). Overall, the Asian case studies show low levels of "connectedness of the classroom" to other schools or external bodies, and the Western European schools score much higher on this dimension. The Finnish case study schools showed high levels of collaboration and teamwork. They were connected to other schools by means of on-line networks, and enjoyed considerable support from their local communities and the National Board of Education. For example, Netlibris is a "virtual school" project that schools can join with full funding from a partnership of the NBE and local municipalities. By comparison, case study schools in Hong Kong were not electronically networked with other schools. In Hong Kong schools, ICT was used mainly as a learning and productivity tool and the use of Internet was limited to information searching. Case studies of ICT-related pedagogies in Hong Kong were coded on levels of innovation and also categorized into "six types of pedagogical practice" (project work, scientific investigations, media production, virtual schools or on-line courses, task-based learning and expository teaching). This is a useful reminder that ICT can be used to support traditional pedagogies as well as innovative pedagogies. Many factors spring to mind as the drivers for the differences between ICT-related pedagogy in Finland and Hong Kong: the size of each country and density of its population; the dominance of the cell phone company Nokia in Finland; in Hong Kong the competitive ethic of a society with strong social class stratification; in Finland a society with little social class differentiation and almost no private schools. No one factor has clear significance, but together they build a portrait of national character and culture, which constructs how life is enacted in classrooms.

It may be relatively easy to identify cultural drivers which make schools in one country adopt ICT in very different ways from schools in another, but does this prepare students in one society better than those in another for life in the twenty-first century? What is particularly interesting about the comparison between Finland and Hong Kong is that both these countries have recently scored highly on international comparative tests of students' attainment. These are both education systems that produce high achievers in traditional tests, but teachers in one are using ICT to make more radical changes to pedagogies than teachers in the other. Nevertheless, Pelgrum and Law (2003), writing primarily to advise policy-makers, point out that education systems are currently at a turning point as a result of global trends towards "a knowledge society." They see "the most pressing concern" as related to the impact of ICT on student's learning outcomes and suggest that "new pedagogies require assessment methods that are context-sensitive such that students' abilities to solve authentic problems can be evaluated" (Pelgrum and Law, (2003, p. 24). Hence, there is an emerging consensus that pedagogical adoption of ICT invites teachers to make the kind of radical changes to pedagogy that are made possible by the affordances of ICT tools, and that new forms of assessment are needed to identify and celebrate new kinds of learning.

Providing a Context that Supports the Pedagogic Adoption of ICT

Lankshear et al. (2000) suggest that pedagogy can best be understood as "a social practice in 3D," and learning as "a process of entry into and participation in some Discourse or other: that is some social practice where people, words, beliefs, actions, tools, artefacts, values, standards, goals and purposes get integrated in meaningful ways" (p. 136). Changes in technology provide new entry points for students into the discourse of education and give teachers new tools to help students make meaningful connections with their out-of-school experience. However, all the inter-locking contextual features need to be in place, or at the very least open to change, if pedagogic adoption of ICT is to transform the nature and quality of students' learning. McCormick and Scrimshaw (2001) suggest that pedagogic adoption of ICT varies according to educational purposes. ICT is often used as an "efficiency device" or an "extension device" and it may only challenge existing pedagogic practice when the aim is to use it as a "transformative device" (McCormick and Scrimshaw, 2001, p. 51).

All writers have agreed that teachers are key to successful adoption of ICT and most agree that teacher professional development needs to focus on both technology skills and support for pedagogical change to embed ICT. Watson (2001b) drawing on interviews with "exemplary" IT users in the UK, Canada and the USA emphasises the need to cater for individual differences and take into account teachers' personality types, but also suggests that finding a "killer application" can be crucial in starting the process of pedagogic adoption. Cuban et al. (2001) show that barriers to adoption of ICT in two high schools in Northern California's Silicon Valley sprang from the historically embedded culture of high schools, the logistical difficulties of accessing technology within the structure of "the six-period day," low teacher motivation and above all "defects in the technology" (due one presumes to ineffective systems for procurement, installation and maintenance of technology). They predict that "the incremental approach" to change, which is the norm in most US high schools, will not lead to wide-spread pedagogic adoption of ICT: Policy-makers have not understood that ICT adoption requires radical re-structuring.

Those writers who focus on the level of the school provide further evidence of the need for structural change. Venezky (2004), drawing on a series of case studies, emphasises that "both infrastructure and teacher competencies were critical for success" (Venezky, 2004, p. 15). He stresses the need for good leadership and a culture encouraging experimentation and risk-taking. Karpati (2004) reports similar conclusions from work in Hungarian schools and stresses the importance teachers placed in working as a team. In Canada, Wood et al. (2005) emphasise the affective nature of teachers' responses to technology. They found that the constantly changing nature of technology makes many teachers feel that they are perpetually novices in its use. Forkosh-Baruch et al. (2005) identify two distinct patterns of ICT-based pedagogical innovations in schools in Israel – "islands of innovation" in which small groups of teachers led by an enthusiast engage in ambitious projects "aiming at depth rather than extension;" and "school-wide implementations" in which "the principal's vision and motivation is of central importance" and the innovation leads to "change in the nature of teacher–teacher relationships, based on collaboration and mutual support" (Forkosh-Baruch et al., 2005, p. 213). Although they celebrate the success of individual "islands of innovation" they show that school-wide innovation is essential for "scaling up" to the wider system.

Integrating Research with the Pedagogic Adoption of ICT

The complexities of educational innovations require a holistic strategy capable of building change in social practices informed by the practical power of theoretical knowledge. Thirty years ago, Bussis et al. (1976) showed that unless teachers engage with the theories underpinning changes in classroom practice the innovation remains merely cosmetic. To address this practical difficulty, Somekh and Davis (1997) describe the Pupil Autonomy in Learning with Microcomputers (PALM) and Initial Teacher Education and New Technology (INTENT) projects in which involvement in action research provided teachers with the opportunity for situated learning. They stress that change is a form of learning and, like students, teachers need to learn *actively* and have opportunities to try things out and evaluate the outcomes on the basis of evidence, with the support of strong leadership and a community of peers. There is now a body of evidence that this approach is effective. Krumsvik's work with the Godøy island school described earlier in this chapter is one example. Another is the collaborative project, Knowledge Producing Schools (Bigum, 2002), in which schools were reconstituted as knowledge providers, using ICTs to give students an authentic role as knowledge producers and thereby re-orientate the school's relationships with parents and the community. This led to fundamental changes in classroom pedagogy. A third is the Developing Pedagogies with E-Learning Resources project, a collaborative partnership between university-researchers and teacher- and student-researchers that used socio-cultural activity theory to research the process of innovation through monitoring the effects of intervention (Somekh and Saunders, 2007). With the connectedness provided by ICT, teachers can engage in inquiry into their own developing ICT-mediated pedagogies as part of an on-line community. Advice and resources for working in this way are available on the Mirandanet website (Preston, 2006).

The pedagogical adoption of ICT is complex and requires an integration of vision, system-wide experimentation and new roles and relationships for teachers and students. ICTs, when used in ways that make use of their affordances, are a powerful driver for change. Let us not forget that classrooms have never been ideal learning environments and teachers in public education systems have always been somewhat burdened by working with students who are there under compulsion. ICTs can help to make schools less-stressful workplaces for both teachers and students. The affordances of the Internet, digital photography and cyberspace are radically changing how knowledge is constructed, represented and accessed in the world outside school, and policy-makers need to acknowledge this and restructure the systems of curriculum, assessment and school organisation that were originally developed to suit a now out-dated social order.

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5.4

MODELS AND PRACTICES IN TEACHER EDUCATION PROGRAMS FOR TEACHING WITH AND ABOUT IT

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Introduction

Parallel with the developments in research on learning with IT and on pedagogies for teaching with IT, the last 40 years have seen important developments in teacher education and professional development in this area. These range from the earliest strategies where self-motivated teachers took home a desktop machine and a manual to study in the evenings, through skill development workshops provided by hardware and software vendors, to the wide variety of models and approaches currently in use, including train-the-trainer strategies, many different types of formal courses, technology mentoring by critical friends, in-school just-in-time support and collaborative online teacher communities, to mention just a few. This chapter will examine research informing the development and evaluation of models and strategies for teacher learning with and about IT, in both pre-service contexts and teacher continuing professional development. These developments are informed by research on tertiary education, adult education and use of IT in education, but a comprehensive treatment of all these influences is beyond the scope of this chapter; the focus here is on models, structures, practices and strategies in teacher education.

The importance of teacher education in this area is indicated by the frequently heard assertion that one of the major barriers to the effective integration of IT into teaching and learning is inadequate teacher professional development (e.g. Watson, 2001). Other criticisms have concerned the focus of much of the available professional development on the acquisition of basic IT skills (Downes et al., 2001; Pearson, 2003), advocating greater emphasis on curriculum integration and pedagogical issues.

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At the outset it must be acknowledged that there are significant changes in pedagogy associated with the use of IT. Webb and Cox (2004) examined these changes, explaining that they result from different learning opportunities or affordances provided by the developments in technology, in interaction with the whole learning environment.

> The evidence suggests that new affordances provided by IT-based learning environments require teachers to undertake more complex pedagogical reasoning than before in their planning and teaching that incorporates knowledge of specific affordances and how these relate to their subject-based teaching objectives as well as the knowledge they have always needed to plan for their students' learning. The need for teachers' professional development is clear but enabling teachers to adapt their pedagogical reasoning and practices in response to learning opportunities provided by IT is likely to be a very difficult and complex process. (Webb and Cox, 2004, p. 235, 278)

In their comprehensive review paper, Webb and Cox identify effective pedagogical practices related to IT for a range of subjects in primary and secondary schools, and consider the implications for teacher education. They emphasise that teachers need to understand the affordances provided by specific types of IT as well as those provided by physical models, experiments etc. and to decide what combination of these will be of most benefit to their particular students in achieving their objectives.

The present chapter first examines a range of goals, purposes and aims for teacher education programs described in the literature. Then various structures for such programs and strategies used within them to attain their goals are reviewed. The chapter concludes with consideration of some approaches to evaluating IT teacher education programs.

Goals, Purposes and Aims of Teacher Education Programs

There is a range of different models of teacher education and continuing professional development in current use. A major source of this diversity stems from differences in the underlying goals and purposes of the programs. In this section a representative set of goals underlying many of these models will be outlined.

Models Based on Reasons for Promoting IT Use in Classrooms

Downes et al. (2001) associate the diversity of models and strategies for teacher learning in this area with different approaches to defining what is required from IT in education. These writers delineate four "Types" of reasons for promoting IT use in classrooms, and thus a range of purposes for teacher education and professional development programs:

- Type A: encouraging the acquisition of IT skills as an end in themselves.
- Type B: using IT to enhance students' abilities within the existing curriculum.

– Type C: introducing IT as an integral component of broader curricular reforms that are changing not only how learning occurs but what is learned.
– Type D: introducing IT as an integral component of the reforms that alter the organization and structure of schooling itself (Downes et al., 2001, p. 23).

Watson (2001) advocates a "reforming outcome for the enormous IT investment educational agencies are making" and argues for a need to "rethink professional development intentions from skill provision with infrequent curriculum integration examples to a model that will enable teachers to see the reforming or transforming possibilities of IT" (Watson, 2001, p. 182). Finger et al. (2007) also take a "transforming" approach in their text for teacher pre-service education and professional development. Watson identifies the necessary stages – orientation, adoption, evaluation, innovation and institutionalisation – for professional development programs with reforming intentions. Each stage needs a different approach to professional development. Watson and others (Dowling, 2003; Haaksma-Oostijen and Puper, 2003; Law, 2003; Saito and Ohiwa, 2003) draw attention in particular to the need for programs to prepare teachers for changes of role when IT is used well in classrooms.

Meeting Standards Set by Education Departments or Other Bodies

Education Departments encourage teacher professional development and specify skills that new graduates and practicing teachers should have (Watson, 2001). These may be mandated for accreditation or employment, or they may be intended as guidelines for teacher professional development. A brief outline of the situation regarding specified IT standards or competencies for teachers in several countries is presented here to illustrate ways in which such standards are developed and used.

In England, IT-related competency statements for teachers were developed in 1998. In 2002 these were revised and the standards were replaced by non-statutory guidance for teacher training and more explicit guidance for IT, related to the National Curriculum for schools (Selinger and Austin, 2003). Tests in IT have been developed, which trainees must pass in order to be awarded Qualified Teacher Status (QTS). The IT QTS test is designed to assess skills relevant to all teachers. It assesses the ability to carry out basic IT tasks using a word processor, spreadsheet, database, presentation software, e-mail and an internet browser. A full description of the test is provided on the UK Training and Development Agency web site (http://www.tda.gov.uk).

There is no National Curriculum in the USA. A range of agencies and professional organizations set standards (Davis, 2003; Thomas and Knezek, 2008). However the US Department of Education funded project undertaken by the International Society for Technology in Education (ISTE) has developed National Educational Technology Standards for Teachers, including models for teacher preparation programs and standards-based performance assessment tools for measuring the achievement of the standards (ISTE, 2000, 2002). After an introductory section considering technology integration into teaching and general education, this substantial book has chapters on integrating technology into English language arts, mathematics, science and social studies at each level of education – early childhood, elementary, middle and secondary school. The standards and performance indicators for teachers are grouped under the following: technology operations and concepts; planning and designing learning environments; teaching, learning and the curriculum; assessment and evaluation; productivity and professional practice and social, ethical, legal and human issues (ISTE, 2002, p. 9). Extensive examples of application of the standards and model strategies are provided. This set of standards has been adopted by the US National Council for Accreditation of Teacher Education.

The National Goals for Schooling in Australia, adopted by all state, territory and commonwealth ministers of education in 1999, state that students leaving school should be confident, creative and productive users of new technologies, particularly IT, and understand the impact of those technologies on society (Pearson, 2003). Each of the state Education Departments has developed IT competency requirements or guidelines for teachers; generally these are supported by professional development materials. Development and research is being carried out by education academics and professional associations such as the Australian College of Education and the Australian Curriculum Studies Association (Downes et al., 2001).

Government policy in education in Northern Ireland has often followed initiatives taken by the Department for Education in England and Wales; however since the introduction of a devolved administration in Northern Ireland, Ministers for Education now determine education policy (Selinger and Austin, 2003). A framework for policy in initial teacher education, pinpointing teacher training in IT as a key issue, was developed in 1997 by the Department for Education for Northern Ireland. Aims for teacher development in institutions in Finland have been set by a project called OPE.fi (Niemi, 2003). The aim was for all teachers to have developed basic IT skills in the period 2000–2004; half of all personnel in educational institutions should have high-level skills. These skills and competency levels are specified by the Ministry of Education, for both pre-service and in-service teacher education.

A set of suggested IT competencies for teachers in the Netherlands has been developed by Hogenbirk and de Rijcke (2006). In contrast to the skills-focused standards seen in many other examples, these competencies begin with words such as "Becoming aware of …," "Sharing …," "Considering and using …," "Reflecting on …," "Using local and global resources to …," "Recognising responsibility to …" and "Fully exploiting ICT capabilities to. …" The competences are structured in a matrix format, each cell representing an interaction between one of self, pupils, colleagues and environment, with one of pedagogy, curriculum, professional development, organisation, policies, ethics, innovation and technical aspects (Hogenbirk and de Rijcke, 2006, pp. 58–59). These, like the requirements set by several other government and similar bodies, are published with a set of professional development materials.

Preparation for Teaching IT as a Specialist Subject

Teaching IT is an area where relatively few people can draw on extensive experience from their own school years. This is in contrast to other subject areas; a mathematics teacher, for example, will have experienced perhaps 12 or 13 years of subconscious critical observation at the receiving end of the pedagogical modelling of other mathematics teachers. Even for teachers in training, who now are likely to have had at least some IT experiences during their time at school, the rate of development of the technology has meant that IT environments in the schools in which they will work and the associated pedagogical affordances of the technology will be different from those present during their schooling. A current example at the time of writing this paper is the relatively recent introduction of interactive whiteboards in schools.

Hammond (2004) notes that while there is a huge literature on the use of IT in teaching and learning, there is much less written on the teaching of IT as a subject. Webb (2002) draws attention to a debate that has taken place over the last 20 years about whether IT capability should be developed through teaching IT as a separate subject or through using IT in an integrated way across the curriculum. Both these writers comment on widespread concern about teachers' subject knowledge in the area, and note the absence of a strong discipline-related research base to inform teaching in this area. For example, relatively little is known about the means by which learners actually acquire programming skills (McDougall and Boyle, 2004).

Schubert (2003) describes the development, content and delivery of new university courses for specialist IT teachers in Germany. The developers, in collaboration with colleagues from other European universities, prepared web-based materials to support these courses. In addition to computing topics, the students are required to consider a range of social and ethical issues with the assistance of classroom mentors. An innovative approach to certification is taken: the focus of attention is not only the product of an IT project, but its design process and effectiveness as well, which is examined in group discussions with presentations, self-reflection and assessment of social issues and the impact of IT on teaching and learning.

Preparation of Future IT Leaders in Schools

A range of leadership programs, commonly offered at system level or as postgraduate courses at universities, are available for principals and senior teachers aspiring to a principal's position, and often these include material concerning IT. Typically these use competence models of management training, similar to leadership programs in other areas of education management.

Chambers (2002) describes a novel course using problem-based learning and a cognitive apprenticeship model to assist pre-service teachers in developing leadership skills in the implementation of IT in primary schools. Teams of students undertake realistic tasks involving IT in a fictional primary school. A rich description of the school is available on the course's web site. The four problems tackled are the following: integrating IT into the curriculum at the school, developing a 3-year IT budget, developing an IT professional development plan, and developing a 3-year IT strategic plan. Students gain knowledge, experience and confidence in tackling the kinds of issues that they are likely to encounter when in a school leadership role, and they develop leadership skills in managing a student team to prepare a detailed report and present recommendations to the fictional School Council.

Structures and Strategies

Formal Courses at Tertiary Institutions

Almost all pre-service teacher education and some continuing professional development for in-service teachers are undertaken as award-bearing programs in universities or colleges. Many different models of IT education exist within these programs. They are regularly modified in response to developments in technology or to changes in teacher certification requirements. The websites of most universities present current structures and course content for these programs.

Pre-Service Courses

Courses preparing for secondary school teaching usually contain a component of curriculum studies or "method" subjects; a student preparing to teach IT as a specialist subject in schools would include IT method in his or her program. In addition to the IT core subjects in teacher preparation programs, elective subjects for IT skill development or for consideration of across-curriculum and pedagogy issues are offered in some programs. The IT leadership course described earlier is an example of this strategy.

It is clear from the literature that there is a widely held view that all teachers should graduate from their pre-service courses with good skills in IT. Where there is no agreement is whether these skills are best obtained through separate IT subjects (with titles such as "IT in the classroom") or through using IT integrated across the curriculum throughout the teacher education course (Webb, 2002). Downes et al. (2001) point out that the separate IT subjects provide a focus on skills acquisition and seem appropriate where accreditation of skills is necessary, but tend not to provide the opportunities for teacher education students to consider the use of IT across a range of subject areas, and rarely lead to integration within practical experience in schools. They note that while introductory IT subjects have become common in teacher education programmes, subjects providing skills for the integration of IT into teaching and learning are far less evident, although the bulk of the literature supports integrated approaches for student teachers to be able to make meaningful use of IT in their teaching experiences. Pearson (2003) raises the need for appropriate staffing in this area, noting that in some universities these subjects are taught by staff whose primary expertise is in computing rather than in the use of IT in education, with the result that course content that may not be directly relevant and useful to initial teacher education students.

Pre-service teacher education courses typically provide students with a mix of on-campus coursework and school-based professional experience. The relative proportions of these two components can vary widely and is itself the subject of considerable debate. It is important that student teachers have good experience of using IT during their teaching practice in schools. Downes et al. (2001) report on a study of student teachers that found that until they had worked with children their interests and concerns had only related to equipment and hardware; through the activities with the children they developed interest in pedagogy and concerns for technology use to enhance students' learning.

Some universities support partnership arrangements to facilitate placement of student teachers in schools with well-integrated IT use. Pre-service students might be paired with practising teachers in a mentoring role, or collaborations arranged with IT teacher associations or teacher groups from other curriculum areas (e.g. Davis, 2003). Where partnership arrangements with local schools exist student teachers might work on campus with children in face-to-face classroom situations (Downes et al., 2001). Virtual classrooms on CD-ROM or online can also be developed for similar purposes, and online mentoring by practising teachers can be arranged to provide assistance and advice to student teachers working on projects and campus-based tasks (Chambers, 2002). If student teachers spend sustained periods in schools, for example undertaking internships towards the end of their course, small classroom-based action research projects can be undertaken in partnership with classroom teachers (Pearson, 2003).

It is widely agreed in the literature that IT should be used extensively to support learning throughout initial teacher education programs, to model its use in teaching and to demonstrate a wide range of IT's affordances for teaching and learning in a range of curriculum areas (Davis, 2003; Drenoyianni, 2004; Pearson, 2003). Professional agencies and the institutions themselves are encouraged to develop exemplars such as multimedia case studies (see also van den Berg et al., 2008), or examples of electronic portfolios or toolkits, to guide and inform contemporary teacher education practice (Chambers and Stacey, 2005; Downes et al., 2001; Hewitt et al., 2003).

Textbooks for IT in pre-service teacher education courses have been prepared in many countries. Generally these reflect the experience, reflection and research of teacher educators working in the area. In countries or systems where school IT subjects and teacher education requirements are prescribed centrally, the textbooks are developed to support these courses. For example, pre-service teacher education textbooks have been written recently to support the teaching of IT as a curriculum subject in the National Curriculum in the UK, by Kennewell et al. (2003) for secondary level, and by Potter and Darbyshire (2005) for primary schools.

An application of IT that has been explored in some teacher education courses is electronic networking for student teachers, school-based mentors and university supervisors (Pearson, 2003). Pearson argues that this has the potential to be an important innovation in initial teacher education and reports that student teachers have been generally positive about the benefits of this form of communication. He cautions though that in some cases the potential has not been fully realised, with access to computers in schools, and "lack of time" to read and respond to messages being reported by student teachers. A full treatment of the use of electronic networking to foster teacher communities for professional development is provided in the chapter by Looi et al. (2008), in this handbook.

Postgraduate Courses for Professional Development and Research

In some education systems it is required that teachers undertake regular award-bearing courses as professional development for continued employment or for promotion. In others there is no compulsion, even no recognition of formal professional development activity, but teachers continue nevertheless to undertake postgraduate study to update or extend their qualifications, knowledge and skills. IT is an area regarded by many teachers as important in this regard, particularly because of the ongoing rapid developments in technology and its role in education, and in many cases because they want to become involved in research in the area. Some of these programs consist purely of coursework and are regarded as most valuable for teachers wishing to update knowledge and skills; some programs comprise preliminary coursework followed by small research projects, and some involve the undertaking and reporting, with academic supervision, of more major research studies.

A survey of university websites reveals that many institutions now offer research programs at Master and Doctoral levels specialising in IT in education. For example, Davis (2003) describes a PhD program involving opportunities for internships as teachers and researchers. Research projects undertaken in partnership with schools and other educational settings can lead to particularly novel ideas and approaches. An example is reported in a study undertaken in an after-school computer clubhouse, where children worked with young volunteer mentors from the IT industry; highly successful but novel pedagogical strategies were revealed, consistent with the work practices of IT professionals, and utilising students' considerable willingness to seek skills they need as they work on programming projects (McDougall and Boyle, 2004).

In addition to the formal award programs just described, many universities and IT professional associations offer professional development modules that can be taken as stand-alone programs or, if an assessment requirement is completed, can also be used as credit towards a university award course (Pearson, 2003).

Non-Award Programs, Less-Formal Models

Teacher professional development is variously referred to in the literature as staff development, in-service training, and continuing professional development (Downes et al., 2001).

Programs from Sources Outside the School

Many substantive professional development programs on IT for experienced teachers are initiated by employing authorities, though these may also be conducted by other providers. Often these are presented for two or three members of staff from each of several schools, as the centre of a train-the-trainer model in which these teachers are expected to return to their schools and teach other staff members what has been learnt. Pearson (2003) notes that in the absence of published evaluations of subsequent classroom practices, the impact of IT professional development programs of these kinds cannot be determined.

Specially resourced "navigator" or "lighthouse" schools may be developed by central authorities, to provide on-site visits, short courses or mentoring for staff from other schools. Again the impact of these exemplar schools is not known as the experiences of teachers visiting them, and the actual changes in classroom practice that may have resulted from these visits, are not typically documented (Pearson, 2003).

Downes et al. (2001) found in their research a range of models of systemic professional development programs with a focus on IT. Strategies used included sponsorship of self-directed formal professional development, school-focused programs, single event programs, serial courses, curriculum development or teaching projects, professional learning communities projects and teacher research projects. Infrastructure components involved with these initiatives included central and advisory services, teachers' centres, exemplar schools, allocation of specialist staff to schools as professional development coordinators, development and provision of resources, provision of hardware to teachers, partnerships with teacher education institutions and recognition and certification of learning.

Publications of teacher IT standards often include professional development materials – scenarios, "model" lesson outlines, and so on (ISTE, 2002; Kirschner and Wopereis, 2003; Hogenbirk and de Rijcke, 2006). Central authorities may also prepare and distribute booklets for teacher professional development, or multimedia materials such as video-based case studies of learning environments, or in-service training modules (Downes et al., 2001; Karpati, 2003). Again, authors such as Downes et al. note that there is as yet little empirical or theoretical evidence to support the extensive claims about the effectiveness of the use of such media.

Many university teacher education departments have in-service courses where IT is used as a tool for developing teaching and learning. As examples, Polyzou (2005) studied the evolution of teachers' knowledge through the design of teaching materials using an authoring tool, and Angeli and Valanides (2005) advocate the use of an instructional systems design model and activities involving design of IT-enhanced lessons to develop IT-related pedagogical content knowledge. However Watson (2001) questions the role of tertiary institutions in provision of IT professional development, arguing that university staff may be far removed from actual school classrooms. Watson further suggests that university resources are often inferior to those in schools, though the opposite view is proposed by Karpati (2003).

Vendors of hardware and software provide a range of workshops for teachers. Generally these comprise short programs focused on the development of skills needed to use the products concerned, although the Apple Classrooms of Tomorrow project (Sandholtz, 2001) is a clear counter-example.

Professional and teacher associations provide professional development through organization of conferences. These are held at local, national and international levels, and may be research-oriented, more practically focused or a mix of both. In this rapidly changing area, attendance at such events can be of considerable value for classroom teachers.

In-School Professional Development Activities

Watson (2001) argues that teachers prefer school-based short courses and workshops rather than extended courses from sources outside the school. “Curriculum days” or “school development days” (usually one or two days per term) provide opportunities for teachers to address policies and programs that are specific to their own schools (Pearson, 2003). School-based on-site teacher in-service training courses are found to be more effective than those conducted at college campuses or laboratories of training firms; one reason suggested for this is that schools do not have the level of infrastructure available at the external venues, and thus teachers cannot apply knowledge gained in the well-equipped settings (Karpati, 2003).

In-school mentoring is popular as a strategy for professional development (Downes et al., 2001). Some members of a school’s staff might be appointed or designated as technology mentors and given a time allocation for professional development tasks such as individual just-in-time consultations, small group support, team teaching or software assessment and acquisition. Jones and Vincent (2006) describe an effective mentoring scheme in a school introducing interactive whiteboards. Contrary to the more common introduction of experts as mentors, this school’s principal deliberately chose two current staff members from different discipline areas who were not experts in technology use. These teachers used their time allocation to learn and share with other staff members, who willingly accepted help from their staffroom colleagues and gradually developed a culture of sharing technical knowledge and pedagogical ideas more widely across the school.

Individual Teachers’ Activities for Personal Professional Development

A good deal of teacher professional development in IT occurs as a result of teachers’ individual activities. Some of the strategies used include self-directed learning through private reading or study, attendance at short courses, seminars or workshops, reflection on practice or action research, joining teacher online communities and participation in the activities of a teacher or professional association. Kirschner and Wopereis (2003) emphasise the need for teachers to be reflective life-long learners. They advocate teachers’ participation in communities of practice, communities of interest and communities of expertise in schools, teacher training institutions and society in general.

The provision, usually by teacher or professional associations, of a range of IT-related conferences was mentioned earlier. Large numbers of teachers attend these conferences, and many present papers or demonstrations about ways in which IT is being used in their school settings. Many of these presentations are “cutting edge” demonstrations of ways in which IT can support learning. The sharing of information and the networking among teachers that develops as a result of participation in these conferences present important opportunities for teachers to shape their own professional development (Pearson, 2003).

Evaluation of Teacher Education and Professional Development Programs

It was noted earlier in this chapter that the literature provides relatively little evidence of evaluation findings for many of the IT teacher education initiatives described. Indeed it is argued that very little encouragement is given for evaluating the strengths and weaknesses of professional development practices (Watson, 2001). This is not to say no evaluation has been undertaken; it is possible simply that the results of evaluation studies have not been published. For example, Davis (2003) reports that evaluations were a required part of all projects within the Preparing Tomorrow's Teachers to use Technology initiative in the US, with the results being shared at annual conferences.

Calls for more and better evaluation work in this area have resulted in the development of evaluation frameworks and approaches to assist in this endeavour. Downes et al. (2001) point out that the effectiveness of any teacher development model will depend to some extent on the goals which the model's designers want to achieve through IT use. These writers acknowledge that the simultaneous existence of the four types of goals – acquisition of IT skills as an end in itself, IT integration in the curriculum, IT as part of curriculum reforms and IT as a means to transform education – complicates the task of assessing models of teacher professional development (Downes et al., 2001). Watson (2001), whose transformational goals for IT in education were also outlined early in the chapter, states that the literature provides numerous examples of what are claimed as successful models of professional development, but, she argues, most of these aim at integrating IT into existing curriculum and thus will not result in any fundamental or lasting educational change.

McDougall and Squires (1997) propose a framework for reviewing teacher professional development programs in IT, which uses five commonly observed foci for teacher professional development: skills in using particular software applications, integration of IT into existing curricula, IT-related changes in curricula, changes in teacher roles and underpinning theories of education. These foci are considered in terms of a "perspectives interactions" paradigm, which looks at interactions between pairs of the three "actors" contributing to the learning situation when IT is used: the teacher, the software designer and the student. This approach is based on a situated view of cognition ensuring an authentic approach, and leads to consideration of the comprehensiveness of a teacher education or professional development program. This framework has been used to review several professional development initiatives (Davis, 1997).

The IT standards publications from the ISTE (2000, 2002) describe assessment systems designed to assist teacher preparation institutions in evaluating the success of their programs. The book (ISTE, 2002) contains suggestions for assessment of student teachers throughout, measuring progress towards attainment of the ISTE standards. It also contains recommendations for institution infrastructure to enable quality programs.

In a study using comparative case methodology, Sandholtz (2001) examines the teacher development programs of two different organizations: a private computer company and a public school district. Both programs were considered effective when judged by participants' evaluations, gains in skills and plans for use of IT in classrooms. However Sandholtz looked beyond this result, investigating the teachers' abilities to implement what they learned in their classrooms. She used the following five criteria: access to equipment, administrative support, technical support, collegial support and classroom implementation. She first found that key components of effective technology programs include the following: teacher input to the design, teacher choice, administrator involvement, situated teacher development, participant collaboration, constructivist environment, flexibility and adequate funding. Further she concluded that issues of access and support directly influence the extent to which teachers use IT in their classrooms.

Conclusion

New opportunities for valuable learning experiences afforded by the powerful technologies now available in schools mean that more than ever we need effective teacher education programs for teaching with and about IT. It is clear that a wide range of models and practices for such programs already exist, and that novel approaches and strategies are continually being developed. The existence of such a range of models seems appropriate in the light of differing goals and purposes for the use of IT in education and in a context in which the technology itself is constantly developing to enable new ways of exploiting its power to support learning and teaching. This constant technological change creates a need for ongoing learning throughout a teaching career, further contributing to the devising of different models and practices for pre-service teacher education and continuing professional development.

The constant development of the technology means that there is still need for teacher education programs containing elements of IT skill development, despite the now wide availability of and access to technology in schools in many countries. However there is a clear need for programs that address the more complex issues of curriculum integration of IT, transformation of education through using IT, and pedagogical strategies to exploit the potential of IT to support individual and social learning.

There have been relatively few published evaluations of specific approaches, and the impact of IT teacher education initiatives on classroom practices remains largely undocumented (Pearson, 2003). Much more research is needed in this area (Downes et al., 2001; Romeo, 2003; Webb, 2002), particularly evaluation studies and investigations of linkages of IT supported pedagogical strategies with student learning, so that the time and resources expended on teacher education programs for teaching with and about IT can be used most effectively.

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5.5

MULTIMEDIA CASES, TEACHER EDUCATION AND TEACHER LEARNING

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Introduction

The use of cases in teacher education is not a new phenomenon, with early records of case methods dating from the beginning of the last century. However, the rapid expansion of information and computer technologies over the past decade has influenced case construction and use in profound ways. Written cases are now being integrated with video and other textual forms to create sophisticated hypermedia case environments. Hypermedia (more commonly referred to as *multimedia*) case platforms provide the potential to incorporate various kinds of contextual, theoretical and pedagogical information into a rich and multi-layered representation of classroom teaching. In this chapter we explore the implications of these developments for teacher education and teacher learning. The chapter is arranged into four sections. In the first section we relate case methods to recent insights into teacher learning. Next, we examine the different types and uses of cases, followed by a review of the ways in which multimedia cases are being used in teacher education programs. In conclusion, we offer a short summary of the current evidence and future potential of multimedia cases for teacher learning.

Cases, Teacher Learning and Knowledge

What Are Cases and Why Are They Important in Teacher Education?

Three central notions appear to lie at the heart of the case idea. First, a case is based on a "real life" situation or event focusing on the particulars of that situation, while

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simultaneously taking a holistic view. Second, a case is assembled or constructed by careful research and study, typically involving the researcher in a series of descriptive and interpretive acts around a particular phenomenon. And finally, a case provides potential learning opportunities at various levels for those involved in the construction of the case and for those who may interact with the case.

It is this third notion – of cases as learning opportunities for teachers – that forms the focus for this chapter. Under this notion, cases are not just accounts of practice; they are created for pedagogical purposes. Hence, the design of the case – including the phenomenon selected, the issue highlighted, the contextual information included, the length of the case, the case medium and the supporting material – is directed towards providing learning opportunities for case users. Similarly, the conditions under which a case is constructed or used – such as the way the case experience is structured for the user and the interactions between case users, and users and facilitators – are considered from a pedagogical or instructional standpoint. The case and its surrounding pedagogical tools are sometimes referred to as the case method.

It is claimed that cases may serve a number of pedagogical purposes. One of the original categorisations was proposed by Shulman (1992), who building on his earlier (1986) work, suggested that cases might be used to:

- teach principles or concepts of a theoretical nature
- develop precedents for practice
- convey moral or ethical principles
- teach strategies, dispositions, reflection and habits of mind
- illustrate visions or images of the possible.

According to Merseth (1996), case purpose falls into three categories – cases as exemplars; cases as opportunities to practice analysis, the assimilation of differing perspectives, and contemplation of action; and cases as stimulants to personal reflection. These three types – exemplar, analytic and reflective – are analogous to Cochran-Smith and Lytle's (1999) notions of promoting knowledge-of-practice, knowledge-for-practice and knowledge-in-practice and Wallace's (2001) notions of primary, secondary and tertiary use of cases (see later).

From Written via Video to Multimedia

In discussions about cases and case-based learning, advantages of a video above a written format are articulated. Video cases offer non-verbal signals and immediacy not possible in narrative cases. Students may eyewitness teaching practices that approximates being actually present in the classroom. For this reason, video cases provide a more open ended, less cued representation of practice. Moreover, video cases capture the complexity of teaching and the simultaneously occurring events in the classroom far better than do written cases. Watching and discussing a video case is perceived as a more authentic and meaningful learning experience than is reading a narrative case (Clarke and Hollingsworth, 2000; Derry, et al., 2002). However, not all sources point to the significance of video above written cases. Brophy cites from Baker's (1970) meta-analyses of film and video use in teacher education: "One conclusion was that teachers in general and novices in particular usually do not gain many new insights or ideas about improving their teaching from simply watching classroom videos. If they do not have a clear purpose and agenda for viewing the video, they are likely to watch it passively, much as they might watch a television program. A further concern is that video cases do not have the contextual and background information and the reflective comments that may easily be included in the story format of a narrative case (Sherin, 2004).

This drawback may be overcome by embedding video cases in a hypermedia environment: multimedia cases. A multimedia case provides a richer and more layered picture of classroom teaching. Moreover, hypermedia programs provide teachers with the opportunity to access video in different ways. There are usually multiple starting points and multiple paths that a user can take to explore the data provided. The application of computer technology enables for cases to be learner-controlled. They may pace learning according to personal needs. A wide range of different content may supplement the video. For example, reflections from various persons (teacher in the video, teacher educators, prospective teachers) offer extra lenses to view the video. Context information about the teacher's educational philosophy, the school or student work samples provides for a framework to interpret the events on the video. Hyperlinks to all kinds of information may be added to the video such as lesson plans, teaching tips, conceptual information about the content of the lesson, underlying principles from learning psychology and so on.

With this rich array of additions multimedia cases rise above the critique on both written and video cases that they portray a too shallow representation of what classroom teaching is about. However, from a perspective of teacher learning there are still challenges. Salomon and Almog (1998) refer to the "butterflying defect" as a metaphor to characterize learning behaviour in hyperlinked environments. Learners act like a butterfly hovering from item to item without really touching them. Studies of multimedia cases in teacher education underpin this effect: many students zap to the different components of a multimedia case and the intended deep processing of the information in this learner-controlled environment does not occur (Blijleven, 2005; van den Berg, 2001; Williams, 2004). Therefore, multimedia cases need to be carefully embedded in teacher education and professional development programs.

Enhancing Teacher Learning Through Cases: How Are Cases Related to Theories about Teacher Learning?

There is a growing body of evidence that effective teacher learning is situated in the complexity of professional practice (Putnam and Borko, 2000). In making judgments in pursuit of multiple goals on behalf of learners with diverse needs, teachers simultaneously act upon several different problems in a single action. However, when prospective teachers enter teacher education programs, they have little awareness of this complexity. Years of "apprenticeship of observation" (Lortie, 1975) have an enormous effect on the preconceptions that teacher candidates bring to the task of becoming a professional. Addressing these preconceptions and helping students to "think like a teacher" is, therefore, a fundamental goal of teacher education.

However, future teachers are not only asked to *think* like a teacher, but also to put what they know in action, that is, to *act*. To enact what they know, teachers require a deep foundation of factual and theoretical knowledge organised in coherent conceptual frameworks, and the practical experience to make this knowledge productive for learners. Moreover, teachers need to develop meta-cognitive habits of mind that can guide decisions, to *reflect* on practice in support of continual improvement and to *transfer* their learning to other settings.

Think

Learning to think like a teacher means replacing the "apprenticeship of observation" (Lortie, 1975) with another form of apprenticeship learning: cognitive apprenticeship. Cognitive apprenticeship supports learning in a particular domain by enabling teacher candidates to acquire, develop and use cognitive tools in authentic domain activities (Brown et al., 1989). The word cognitive emphasises that this type of learning goes beyond learning by observing actions. It is about using the tools that enable these actions. In teaching this also implies gaining insight in the reasoning behind the actions.

Anchored instruction provides a model for creating problem contexts that allow students to see the utility of knowledge and to understand the conditions for its use. Multimedia cases are a means to anchor teacher learning in the complexity of practice (Bransford et. al., 1990). The case format represents professional practice in a way that promotes the experiential nature of learning. Picturing professional knowledge as a sequence of events or a story serves as a vehicle for remembering, learning and understanding. However, as noted earlier, learners require support to gain the full educational potential of multimedia cases. Future teachers are asked to develop the ability to notice and interpret what is happening in a classroom (van Es and Sherin, 2002). In other words, teachers need to learn to identify what is important in the teaching situation, to make connections between specific events and the broader principles of teaching and learning and use what they know about the context to reason about a specific situation. Multimedia cases provide a learning environment in which this "interpretative stance" can be learned, because it contains an authentic situation in the form of a video of classroom practice. Embedding the video in a multimedia learning environment that contains additional theoretical and contextual information, assignments or directions to a specific aspect of the lesson pictured may help future teachers to think and to reason "as a teacher."

Act

Interpreting the events depicted in multimedia cases is a precursor to adapting and enacting those ideas in the classroom. Exemplary cases represent a class of cases in which future teachers might learn from good practices of experienced teachers. Such cases are used to illustrate a principle or procedure. An expert teacher acts as a model of excellent instruction or innovative practice (Clarke and Hollingsworth, 2000).

Contrary to acting or observing in real classrooms, video technology offers the possibilities of reviewing the "model" teacher. Moreover, a multimedia environment includes the opportunity to scaffold the learning of the principle or procedure by providing insight into the cognitive processes of expert teachers and other types of advice and information. In other words, multimedia create a multi-layered representation of teaching practice that helps teachers learn from excellent practice with the intention to enact these practices in real classroom situations. This type of learning with multimedia resembles a classical transfer model that emphasises the correspondence between the conditions of learning and the conditions of the transfer situation (Mayer and Wittrock, 1996). The case representation is a means of narrowing the gap between general knowledge about principles and procedures, and enactment in real classrooms.

Reflect

Reflection is a key concept in teacher learning and professional development. Two types of reflection are often distinguished – reflection-in-action, which refers to cognitive processes controlling rapid activity in-the-moment, and reflection-on-action as a deliberative process occurring outside of action (Schön, 1983). The latter type of reflection may also be viewed as critical thinking, whereas the former refers to split-second behaviour in which it is hardly possible to distinguish between perception, interpretation and reaction. Those immediate actions embody the heart of daily teaching activities. Determining how pre-service teachers may acquire an adequate repertoire of these kinds of actions is core in teacher education.

Korthagen and Kessels (1999) address this question by proposing a "level approach" to teacher learning that is grounded in practice. Gestalt psychology, the discipline that studies how people see and understand the relation of the whole to the parts that make up that whole, is central in their approach. The first level consists of the formation of a *gestalt* – or what van den Berg (2001) calls an *image* – based on experiences with concrete examples. In a multimedia case, this image (or gestalt) is connected with the concrete situation depicted in the video in a multi-layered way, and restricted to certain characteristics of this situation. An essential characteristic of an image is its implicit or tacit character. Reflection on images leads to more "aware" levels in which mental networks are constructed by practical (level 2) and theoretical (level 3) reasoning. Contrary to *in situ* classroom teaching, video cases have unique features to facilitate this sense making process because they can be viewed over and over again by a great number of people (both face-to-face and virtual).

One of the most remarkable differences between classroom teaching and watching a video is that the latter does not ask for immediate action. In the absence of the immediacy of action, teachers have the time to intentionally make sense of the images formed out of their experience of watching the video. This sense making is facilitated by the additional "add-ons" of multimedia cases (part of what might be called the case method), which serve to further stimulate teachers' reflection through discussion and consideration of alternative perspectives. Reflecting, discussing and considering different perspectives result in mental recordings of the images of the video footage in comprehensive reasoning. This type of teacher knowledge, teacher practical theory, is rooted in practice and is no longer implicit because of its verbal articulation.

Transfer

While teacher learning is generally associated with transfer to professional practice, Cognitive Flexibility Theory (CFT) takes transfer as a key concept. CFT holds that the goals of advanced knowledge acquisition in ill-structured domains must include flexible and adaptive knowledge transfer (Derry et al., 2002). This theory is about preparing people to select, adapt and combine knowledge and experience in new ways to deal with situations that are different from those previously encountered. Transfer is particularly important in teaching because teachers typically work with many students at once and have to juggle multiple goals. Many teacher education approaches fail because they represent this complexity in an unrealistic and simplified manner. According to Derry et al. (2002), learning to teach through oversimplified representations may contribute to later flawed reasoning in practice. Multimedia case methods may address this concern by offering an environment in which teacher learning is embedded in the complexity of practice and in which learners are encouraged to build multiple understandings of cases and use concepts repeatedly in case analysis. Derry et al. (2002) claim that multimedia cases enable opportunities for future teachers to employ important foundational principles that are unlikely to be encountered during limited field placement or even in the first years of teaching.

A Typology of Multimedia Cases: Primary, Secondary and Tertiary Use

Multimedia cases operate like a *chameleon* in the way that they easily adapt to different learning purposes and theories. A powerful means of thinking about cases and pedagogical purposes, incorporating the goals of building knowledge-of-practice, for-practice and in-practice, is to consider multimedia cases in terms of three different types of uses – primary, secondary and tertiary (Wallace, 2001).

Primary Use

The first type is called *primary* use of multimedia cases. According to Wallace (2001), primary use may involve a participant in the direct construction of the case. Here the case becomes a video story, used by the participant as an adaptation to enrich her or his understanding of the events described (Sykes, 1996). A case, under this conception, is seen as “a point on an array of interconnecting and largely disjointed and indeterminate understandings of what it means to teach” (Carter, 1999, p. 174). Typically, primary use involves the participant teacher in videotaping his or her own teaching and constructing (and sometimes presenting) the accompanying case. It is argued that primary involvement in cases most closely matches Schön’s (1983) notion of problem setting or framing, whereby the practitioner names the things to attend to and frames the context in which to attend to them.

While primary case use is more easily accomplished in narrative formats, there is an increasing recognition of the importance of including teachers in the development (and use) of multimedia cases. Rather than seeing teachers as simply "video objects," primary use recognizes the teacher as a central figure (and learner) in the construction process. For example, Rosaen et al. (2004) describe the rich learning benefits obtained by a group of literacy teachers when they were involved in the (co)construction of a set of video cases of their own teaching. The participating teachers reported that the project affirmed the value of their work. They appreciated the opportunity to discuss literacy teaching with their peers and noted practical ideas to introduce in their own classroom. Louden et al. (2001) showed how a group of experienced science teachers collaboratively developed a set of multimedia cases of their own teaching to illustrate and facilitate rich discussion of teaching standards. In a similar vein, Sherin and Han (2004) described how middle school mathematics teachers developed "professional vision" by meeting in a monthly video club to watch and discuss excerpts of videos of their classrooms. In another variation on primary use, Beck et al. (2002) reported on a project where pre-service elementary teachers constructed their own multimedia case studies of their mentor teacher's classroom and incorporated analyses of the mentor teacher's strategies, student learning or understanding, teacher–student interactions, student–student interactions and professional standards.

Secondary Use

As Wallace (2001) explains, under *secondary* use of cases, the participant interprets a finished case through the lens of her or his own experience. However, under secondary use, the experience of the case user is accorded less authority than the case itself. The interpretive act is linked to evidence provided by the various media – through events emphasized, downplayed or omitted, accompanying "expert" commentaries, implicitly or explicitly stated theories, focus questions or standards of instruction. That is, the multimedia case – imbued with layers of propositional knowledge – is employed as more a method of direct instruction or exemplification than it is a profound experience for the user.

Secondary case use is perhaps most prevalent in pre-service teacher education settings. Abell et al. (1998), for example, developed a set of multimedia cases of teaching elementary science for conceptual change. The case materials were used in elementary teacher preparation programs to provide a kind of "field experience" with exemplary science teachers. Similarly, Baker (2005) reported that multimedia case-based instruction provides meaningful experiences to pre-service teachers, and may potentially enhance field experiences. Maloch and Kinzer (2006) explored the influence of multimedia cases in pre-service literacy methods courses by following a set of pre-service teachers into their first years of teaching. Bliss and Reynolds (2004) used what they call "video docucases" (a form of exemplary cases) with pre-service teachers as a means of illustrating teaching standards. They claimed that this method increased their students' comprehension of the standards, contributed to their enculturation into the world of quality teaching and helped create visions of themselves as teachers.

Tertiary Use

The final use of cases is termed *tertiary* use. As Wallace (2001) explains, during tertiary use the case provides a leitmotif for the reader's or viewer's interpretive act. Here the reader's experience and perspective takes precedence over the knowledge held in the case. The case is used as a trigger for discussion and exploration, rather than a standard against which to judge the viewer's response. Tertiary-use cases typically are more dilemma than exemplar-focused, used to open debate rather than to close it down, inviting layer-upon-layer of different users' commentaries on the case. Sykes (1996) calls this a strong use of cases, whereby interpretation of the case is a creative experience, constructed more or less independently of the case itself.

The difference between tertiary and secondary use of cases is subtle. Often both uses are evident in the same project, as users move to higher levels of interaction with the cases. The essential difference between the two, however, is that tertiary use has more to do with the user's experience and practice than with the practices illustrated in the case itself. Many case projects address this issue directly. For example, Hewitt et al. (2003) attempted to personalize video case methods by focusing pre-service teachers more directly on their own pedagogical decision-making processes. In a mathematics teacher education project, Masingila and Doerr (2002) found that multimedia cases helped student teachers to frame many of the issues that they encountered in their own practice (such as checking for student understanding and the use of questioning). In a kind of meta example, Doerr and Thompson (2004) described how four teacher educators adapted their own instructional practices by observing and trying to understand how their pre-service secondary teachers attempted to make sense of teaching by studying a multimedia case.

These three uses of multimedia cases – primary, secondary and tertiary – offer different balances among the case narrative and user experience, theory and practice, and the users and developers of cases. They are also likely to result in different balances among thinking, acting, reflecting and transferring. The key issue appears to be whether or not professional knowledge is considered to reside *in the case* or is brought bear *on the case* (Sykes, 1996). There is no hierarchy intended here – primary, secondary and tertiary uses of cases often overlap and intersect. Multimedia cases can be created by primary participants, and then interpreted by different groups of participants for secondary or tertiary purposes. Tertiary case use can also lead to primary use as participants tell their own stories or video their own classes in response to a case. The framing of the case is important – open-ended cases are more likely to produce tertiary conversations than are closed cases. But, we also know that the same case can be interpreted in lots of different ways, depending on how the conversations are framed and facilitated (Doerr and Thompson, 2004), and the experience of the users (Wallace and Louden, 2000).

Anchoring Multimedia Cases in Teacher Education Programs

While multimedia cases clearly carry great promise for teacher education, they do not, as Shulman (1992) reminds us, teach themselves. As Brophy (2004) suggests, simply watching classroom videos is unlikely to improve pedagogy, or stimulate new ideas and insights about teaching and learning. Whether they are used in the primary, secondary or tertiary sense, multimedia cases and associated case methods need to be carefully constructed in order to reach their full potential. We argue that effectively anchoring multimedia cases in teacher education programs involves several considerations – intentionality, creating context and scaffolding, quality conversations and praxis.

Intentionality

Multimedia cases are intended to provide learning opportunities for users. They need to be carefully designed and created for pedagogical purposes highlighting particular phenomena or issues. Therefore by setting clear intentions and agendas a number of purposes can be served. First, they allow users to situate teaching cases within a broader discourse about teaching and learning while simultaneously focusing on the particulars of a case. For example, Lampert and Ball (1998) used video to illustrate the development of students' mathematical knowledge and lesson participation over time. The theoretical framework that underpins the work of Bencze et al. (2001, 2003, in press) includes teaching and learning about the nature of science; science, technology, society and environment education; technological design; and scientific inquiry. Second, a clear purpose for the case presents a focal point for case users, and stimulates opportunities for rich discussion, analyses and reflection, that might otherwise be missed. Third, multimedia cases can provide openings to expose pre-service students to alternative practices and frameworks in education (Marx et al., 1998). For example, Wong et al. (2006) used multimedia cases to demonstrate a range of non-traditional teaching practices such as hands-on practical work, encouragement of pupil talk and the infusion of nature of science, while Pedretti et al. (2008) developed a case to teach explicitly about science, social justice and socio-political action.

Creating Context and Scaffolding

One of the great strengths of multimedia cases is the rich context they depict – visual cues, subtle classroom nuances and the complexity of the classroom. They present teaching episodes in rich, authentic real-life settings and provide teacher candidates with the opportunity to examine in detail the planning of a lesson, its delivery and the reactions of both teacher and students as the lesson unfolds. However, as stand-alone experiences, multimedia cases can be ineffective. Brophy (2004, p. xii) writes about the "disappointing results" when student teachers were allowed to use the videos in whatever way they wished. Similarly, self-guided inquiry into student teachers' own questions without much guidance or direction proved to be unsatisfactory. It is clear that the pedagogical apparatus that accompanies the case – the case method – is a significant part of the user's experience with the multimedia case. Just as the case itself is contextualized, so must be the use of the case.

A number of strategies to scaffold students' progress towards intended goals have been cited in the literature. Examples include developing focused viewing guides or activities for pre-service students to use while viewing the case (Bencze et al., 2003; Brophy, 2004), or suggesting how the case might be viewed multiple times for multiple purposes (Friel and Carboni, 2000). Most effective is the use of multimedia case methods in tandem with other supporting materials and activities such as readings related to the featured aspects of teaching, pre- and post-instructional strategies, written responses to readings and to the case, in-class discussions, examination of appropriate curriculum documents and post-case discussions (Pedretti et al., 2008; Tippins et al., 1999). Finally, the video case itself can be supplemented, through hyperlinks, with resources such as lesson plans, assessment and evaluation tools, examples of students' work, student interviews and teacher interviews.

Quality Conversations

The notion of "quality conversations" (Wallace, 2003) is central to the effective use multimedia cases. Embedded in a rich landscape of teachers' stories and practices, cases carry the potential to generate quality dialogue between educators and teacher candidates. In other words, multimedia cases provide "a leitmotif for the [viewer's] interpretive act" (Wallace, 2001, p. 186), a place from which conversations spring.

Constructing contexts for quality conversations is central to effectively anchoring multimedia cases in teacher education. Providing guiding questions, tasks and activities to be completed while viewing the case, and conducting post-viewing group discussions assist in promoting quality conversations. Pre-service students are also encouraged to work in pairs or small groups (see Abell and Cennamo, 2004; Brophy, 2004) as a way of stimulating discussion. In in-service situations, teachers are provided with opportunities to talk about their own teaching, but usually within a context of some framework or theme. In an innovative use of multimedia cases, Pedretti et al. in press invited the onscreen teacher, Anna, to participate in a class discussion as teacher candidates viewed the case. Anna's presence in the class allowed student teachers opportunities to ask her questions, comment and reflect on what they had seen in the case.

Praxis

Multimedia cases give teachers powerful insight into what it is like to "be there." However, "videos can never fully replicate the complexity of working in a real classroom because the student teacher herself/himself is only present as a distant observer" (Wong et al., 2006, p. 6). How then might multimedia cases be used to narrow the gap between general knowledge about principles and enactment in classrooms, between theory and practice? Possible strategies include providing teacher candidates with opportunities for personal reflection and practice within a teacher education program (Abell and Cennamo, 2004; Wong et al., 2006).

For example, the use of cases by Hewitt et al. (2003) included opportunities to practice analysis. The video was stopped at various points in the lesson where the teacher was faced with an unexpected decision or challenge, and pre-service candidates were asked to describe to their partner how they would respond in that situation. Other strategies cited in the literature include providing small-scale opportunities for teacher candidates to design and implement curriculum with their peers or with children in schools through micro-teaching, workshops and class activities (see for example, Bencze et al., 2008; van den Berg et al., 2004). In summary, experiences for teacher candidates can be enhanced through close association with highly personalized and contextualized teaching and learning situations, and by providing opportunities to personalize knowledge, theoretical orientations and practices.

Conclusions

In summary, it is clear that the multimedia case movement is in a high and healthy state of experimentation, invention and eclecticism. Primary, secondary and tertiary case use is in evidence internationally, in a range education settings (pre and in-service), foci (content and pedagogical content knowledge, classroom and school relationships, ethical issues), media (video, accompanied by commentaries and other artefacts) and uses (teacher preparation, professional development, teacher certification and evaluation, exemplification of curriculum and teaching standards).

As we have seen, there is a growing literature on the learning processes that are evoked by multimedia cases and on the use of these cases as learning opportunities in teacher education. This work is likely to proceed apace as information and computer technology capability and use continues to expand. While there is clearly much excitement and some promising lines of research, we should also sound a note of caution. For the most part, the multimedia case literature is still largely advocacy-based. With a few notable exceptions, some of which have been discussed in this chapter, the evidence for learning is frequently in the form of interesting experiences and conversations around case construction and interpretation rather than classroom praxis. There are also questions about whether multimedia case methods are substituting representations for context immersion, and whether users can learn from cases without having contributed to the selection and framing of the case. In other words, what is the link between doing cases and doing teaching, between thinking, acting, reflecting and transfer? Further questions are also emerging about the myriad of ethical issues surrounding multimedia case construction and use, and whether the underlying pedagogical purposes of case use are being lost in the "technology hype" surrounding the development of new media. While video and multimedia offer increasing possibilities for representing and accessing images of teaching in new ways, it is important to stay focused on the core issue of how these new media forms can be embedded in effective case methods, that is, how can they be used to promote teacher learning.

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COMMUNITIES OF PRACTICE FOR CONTINUING PROFESSIONAL DEVELOPMENT IN THE TWENTY-FIRST CENTURY

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Challenges that Teacher Professional Development Face

With rapid technological advancements in the past two decades, children today are characterized as the technologically savvy "generation Y" (http://en.wikipedia.org/wiki/Generation_Y), who are comfortable with multitasking, working simultaneously with multiple sources of information communication technologies such as wireless devices, portable digital assistants (PDAs), search engines, blogging, instant messaging, network games, video conferencing, and others. From such experiences, they unconsciously but inevitably develop sophisticated ways of managing and using information in their decision-making, often involving a rich interplay of heuristics appropriated from everyday life and formal education.

It becomes apparent that teachers can no longer engage their sophisticated students with simplistic strategies and pedagogy. Spurred by the rapid advancement of technologies in the new knowledge economy, teachers are pressured to prepare their students for a future that is quite different from the present, one that "involves teams and collaboration, based on the idea that in a fast-changing environment, where knowledge goes out of date rapidly and technological innovation is common, a team can behave smarter that any individual in it by pooling and distributing knowledge" (Gee, 2004, p. 284). Faced with these arduous yet inevitable pressure and challenges, there

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is a strong impetus for teacher professional development to help teachers remain current and relevant in their practice to address the dynamic and emergent needs in educating the generation of tomorrow.

Despite decades of research about education reform, there is yet to be significant changes in teachers' practice in the classroom. Classroom talk and practices are still predominantly characterized by a transmission–acquisition efficiency-driven type of pedagogy. Such a phenomenon could in part be attributed to the perennial waves of educational reform that aim to improve various aspects of education and learning such that teachers who have been in the service long enough realize that the only enduring aspect of the educational system is to rely on the pedagogy (often of a transmission nature) they know best so that that their students will perform in flying colors in the standardized examinations.

The ways in which teacher professional development is traditionally being conducted are problematic. Traditional teacher professional development programs have been criticized for being ineffective because they are often organized as fragmented and intellectually superficial workshops or seminars (Borko, 2004). These are typically in the form of prepackaged training courses conducted by an external agency outside school curriculum time. Such training is usually initiated by external agencies that presuppose the needs of teachers, and thus, may lack relevancy. We do not even mention the alternative: Huge one-off reform efforts that never reach most teachers and never take root in the prevailing culture.

In some cases, even when training has been successful and teachers are willing to experiment with innovative practices, they are repeatedly dampened by the lack of localized support during implementation. As such, novel curricula or pedagogies are not often sustained and teachers are left to fall back on what they know best, the transmission–acquisition mode of teaching (Cuban et al., 2001). On the whole, traditional professional development in the form of external training is yet to prove its effectiveness and teachers' feedback and inputs to the kinds of development they require are often muted and consequently their needs are not met.

Since Lave and Wenger's (1991) exposition of the construct of communities of practice (CoPs), one strategy that is deemed promising is professional development through the fostering of CoPs, which provides a valuable platform for teachers to connect and interact among themselves, to share and support each other on their specific problems, experiences, and lessons learned, and to do so at their own time and pace. Problem-solving in this context is not an academic exercise but a means toward finding a practical and informed resolution in matters that have implications to society and others. CoPs thus reflect a constructivist, in-situ social approach to learning that is rather different from the current practices adopted in traditional professional development and consistent with professional learning in other professions (Brown and Duguid, 2000).

Community of Practice as an Effective Professional Development Strategy

Our thesis is that the connections between the vision of CoPs and the vision of reform-minded professional development for teachers are in concordance. Explicating the importance of CoPs, Schlager, Fusco, and Schank (2002) states that "research is converging on a common set of effective professional development characteristics and strategies that stem largely from concepts about communities of practice" (e.g., Darling-Hammond and Ball, 1997; Lieberman, 1996).

Why is constructing CoPs a suitable professional development strategy? According to Whitehouse et al. (2006), CoP has been widely used as a pedagogical touchstone for a number of teacher professional development intervention models. In fact, of all the online teacher professional development studies they reviewed, more than 60% are described as being consistent with a *community of practice* stance in their research.

The term *Community of practice* was first coined by Lave and Wenger (1991) to mean a set of relations among persons, activity, and world, over time and in relation with other tangential and overlapping CoPs. Communities are "groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis" (Wenger et al., 2002, p. 4). Schlager and Fusco (2004) suggested that the central distinguishing characteristic of education CoPs from other types of communities and work groups is the mutual engagement by members of various stakeholder groups in the collective enterprise or practice of educating children. Barab et al. (2004) define CoP as "a persistent, sustained social network of individuals who share and develop an overlapping knowledge base, set of beliefs, values, history and experiences focused on a common practice and/or mutual enterprise… CoPs possess histories, cultural identities, interdependence among members, and mechanisms for reproduction" (p. 55).

In this chapter, we add to the corpus of definitions that CoP is distinctive in terms of *practice*. It is the practice that binds the individuals into a collective whole, rendering a community its character, activities and even its idiosyncrasies. The power of the practice abstracts down to the individuals within the community such that each member is a representative of the whole, rendering the individual a sense of belonging and identity. What is seldom mentioned in the literature is that it is also the *practice* that forms the curriculum for the community. The goals, objectives, design of the activity structures, and social organization are typically not based on how to transmit or acquire skills and knowledge but rather on how the practice is conducted. They do so by sharing stories, problematizing work-related issues, and actively constructing their knowing processes. In Schwen and Hara's (2004) words, it is an "epistemology of practice" (p. 165).

Learning in the mode of practice is not merely the transfer of knowledge from the group to the individual, and reciprocal; the individual is both transformed by the group and in return transforms the group (Rogoff, 1994). It is such a whole-person developmental approach that CoP advocates, making it appealing as a locus of and catalyst for professional development. The mutual (individual–collective) benefiting mantra is attractive to organizational leaders who have to provide opportunities for individual advancement and yet progress the collective. In partnership with colleagues, teachers can struggle with the uncertainties of their profession and receive support, mentoring, and coaching (Darling-Hammond and McLaughlin, 1995).

Also central to CoPs is the notion of learning in-situ or situated learning. Knowledge is dynamically constructed as we conceive of what is happening to us, talk, and move (Clancey, 1995). Following this view, learning is performative – how well a teacher performs in the practice as he or she participates within the community.

Knowledge is contextualized and "resides" within the practice. Novice teachers learn from the experienced; school problems are solved collectively; and there is less need for external consultants to conduct de-contextualized training programs – all of which are conditions appealing to teacher professional development. Both "inside and outside" knowledge (Lytle and Cochran-Smith, 1993; Cochran-Smith and Lytle, 1999) are necessary and must be in proper balance. Too much emphasis on either can militate against improvement.

Despite the optimism surrounding the design of CoPs, Schwen and Hara (2004) highlighted the potential misapplication of the construct, in which "a healthy CoP is one in which practitioners find personal and profound meaning in their work. Learning is often not a formal agenda, but it is a secondary outcome of becoming knowledgeable while working in the field…" (p. 161). In other words, one cannot design a CoP for learning, and community building is obviously not a panacea for all teacher professional development problems. Its power and efficacy can only be manifest when there is a fit with the socio-cultural context. The Activity Theory Framework could be one method of assessment because this framework "enables us to zoom in on individual groups and their activities and then dolly back to view those activities in the context of the larger community of practice" (Schlager and Fusco, 2004).

CoPs for Continuing Professional Development in the Twenty-First Century

Professionals in the twenty-first century need to have characteristics of adaptability, flexibility, and of being mobile innovative knowledge workers (http://www.21learn.org/arch/articles/perkins.html). Unlike the midwives and tailors in Lave and Wenger's writings, people in the twenty-first century see themselves as "free agents" (Gee, 2004, p. 292), unwilling to commit themselves on an extended basis. They continuously update their skills and knowledge from time to time, depending on their projection on the needs and drivers of the economy. Much work in the twenty-first century involves collaboration, and a professional is likely to spend about 40% of his or her time working in teams, and success is likely to be directly related to the ability to work as a team player and leader. (http://www.socsci.flinders.edu.au/flexed/innovations/). Furthermore, teams are assembled on a project basis, of which the manpower makeup largely hinges on the needs of the project. It is therefore common and typical for an individual to be in several teams and projects concurrently.

Given the above landscape, is the CoP construct too old for the twenty-first century? After all, ethnography of the kind of work described in Lave and Wenger's (1991) writings are those from the premodern era such as butchers and tailors. Members in these communities often grow to expert status after an extended enculturation. In this new world, enabled by advanced technologies, the enculturation process is not only shortened but that to remain marketable, people aspire to be enculturated and subsequently become expert in several arenas and communities concurrently. Additionally, these "shape-shifting portfolio people" believe they must manage their achievements, skills, and experiences like a portfolio, "ready to rearrange these skills, experiences and achievements creatively (that is to shape-shift into different identities) in order to define themselves anew (as competent and worthy) for changed circumstances" (Gee, 2004, p. 292).

CoP will certainly continue to have its role in the twenty-first century because the epistemology of practice is congruent with the beliefs of how work is done in the twenty-first century, that is, where work knowledge is distributed yet tacit. As Gee (2004) states, "in a community of practice also knowledge is distributed across people, tools, and technologies, not held in any one person or thing, and dispersed, that is, people in the practice, using modern information and communication technologies, can draw on knowledge in sites outside the community of practice itself" (p. 285). In fact, just as our students handle multiple sources of information effortlessly in their decision-making, we posit that they will mature to become people who will be able to negotiate the multiple identities from participation in several communities in a coherent gestalt. Depending on situations, they will be able to put up the appropriate behavior, and to adapt dynamically to changing circumstances. Problem-solving is therefore not a rule-based exercise but a sense of what is best for the situation.

Online Community of Practice for Teachers' Professional Development

Although CoP has positive impact on teacher professional development, traditional challenges such as teacher isolation, lack of time for collaboration or reflection, and varied interest among teachers remain as obstacles in implementing and sustaining such CoPs. With computer-mediated communication (CMC) technologies, some of the challenges have been addressed. The virtues and promise of CMC technology to assist teachers' professional development have been identified. CMC technologies help to overcome traditional challenges of face-to-face CoP for teacher professional development. They can provide continuity and optimize communication in the process of distributing information, knowledge, and best practices among wide audiences. As pointed out by Zhao and Rop (2001), CMC technologies transcend time and space to bring together teachers who otherwise may not be able to communicate with each other in face-to-face situations, and "the nature of CMC technologies may enhance reflections and community building among teachers" (p. 90).

There are two ways for CMC technologies to support CoP. One is the complete online CoP, where participants do not meet face to face. The other is a blended mode CoP, where participants meet both face-to-face and online. These online CoPs differ from traditional pure face-to-face CoPs in their intensity of participation, representation of members, and accessibility to resources, information, and expertise (Hung and Chen, 2001). Online CoPs are viewed as consistent with new models for teachers' professional development and are able to provide teachers with opportunities to learn collaboratively, build a common understanding of instructional approaches, and reflect on practice in conjunction with other teachers (Riel and Polin, 2004). This is the "ideal" but not the norm for online CoPs.

For a successful online CoP, having the appropriate tools is important otherwise it will be impossible to mediate the virtual world and take advantage of its potential.

Wenger et al. (2002) encourage consideration of the following when choosing tools to set up a CoP: a home page to assert their existence and describe their domain and activities; a conversation space for online discussions; a repository for their documents, including research reports, best practices, and standards; a good search engine to find things in their knowledge base; a directory of membership with some information about members' areas of expertise in the domain; in some cases, a shared workspace for synchronous electronic collaboration, or to enhance teleconferences with visuals; community management tools, mostly for the coordinator, but sometimes also for the community at large. Few teacher online CoPs have all these. Those in Tapped In come close, but most lack the budget, technical support and infrastructure to support high bandwidth options.

Nowadays the notion of using CMC technologies to support CoP is gaining prominence and more and more online teacher groups considered themselves as CoPs. However, many online teacher groups are used primarily for peer emotional and moral support rather than for reflection on practice. Some online teacher groups lack teachers' participation and are devoid of any sense of group identity. In developing an online CoP, Schlager et al. (2002) warns against the "build it and they will come" attitude. The technology for setting up CoPs is not sufficient. Extensive scaffolding (Johnson, 2001) and support for sociability (Barab et al., 2001; Preece, 2000) are also required.

In their review of literature on electronic networks as reflective discourse communities, Zhao and Rop (2001) found five common factors (described as necessary but not sufficient) for successful networks. First, teachers must be able to access and use the technology easily. Second, teachers need a reason to participate. Zhao and Rop found that many of the existing networks were university-based projects, which leads to a design that is more representative of the researcher's priorities rather than the teachers'. The third factor was the time-frame of the project. Because many of them were grant-based projects, they tended to have a short life span and thus did not have time to respond to mistakes and still evaluate effectiveness. Fourth, the lack of teacher time was a reason for nonuse of electronic networks. Fifth, the need for quick and visible products often works against the time, money, and energy needed to create true reflective discourse communities. As can be seen, it is indeed a challenge to start and sustain an online community to support a CoP. In the next section, we will identify the key design tenets from the relatively few online CoPs, which are sustaining and scalable.

Design Tenets for Building CoPs in the Twenty-First Century

There is a huge volume of rich accounts and reports in literature on the work done using CoPs for online teacher professional development (see Dede (2006) and Vrasidas and Glass (2004) for collections of recent empirical studies). Relatively few CoPs have sustained and scaled yet some while most CoPs have ended up with fragile and even fractured groups communicating intermittently (Barab et al., 2004). Given the thrust to prepare our students and correspondingly our teachers for the twenty-first century, we scan through the literature with an eye for the future. From the numerous cases, we attempt to highlight the key tenets we felt pertinent in the twenty-first century for successful community building, and we do so from a design perspective. We concur with Gee (2000/2001) that "if commodities are not central to the new capitalism, what is? The answer, I believe is *design*." These design tenets are not meant to be prescriptive but rather, in our opinion, broad strokes to be customized according to context.

Foreground Practice

From a CoP perspective, the opportunity to engage in participatory practices anchored in social interactions is critical to the learning process (Barab and Duffy, 2000). Observations of traditional CoPs such as tailors, midwives, quartermasters, butchers, and alcoholics reveal that activities, social relations, goals, etc., are fundamentally grounded in practice (Lave and Wenger, 1991). Similarly, the design of online CoPs should foreground practice, such that teachers can individually and collaboratively reflect on and learn from their rich implementation experiences.

The Inquiry Learning Forum (ILF; http://ilf.crlt.indiana.edu/) is one such model that seeks to be authentic and situated as part of daily practice (Barab et al., 2002, 2004), and was successful when it supported a teacher education model. It is a course simulating online CoP, in which grade 5–12 maths and science teachers create, reflect, share, and improve inquiry-based pedagogical practices. It is designed around a "visiting the classroom" metaphor consisting of components related to the practice, including video segments of the lesson, reflective commentaries, descriptions of lesson plans, activities, resources, and student examples. As teachers build cases of their own lesson implementations, they are asked to reflect on individual segments, a process requiring them to question and explain pedagogical decisions. These reflections are then shared with other teachers through discussion groups for collaborative dialogue and critique. What is novel in such an approach is that when the activity is conducted together with a novice teacher, the master teacher explicates the thinking underlying the actions, thereby modeling in the form of apprenticeship. In this case, the professional development is embedded in the practice as the master teacher works with the novice to explore effective pedagogical methods to support students in the learning process. Teacher learning thus becomes situated and authentic.

Another CoP that was created by Rogers and Babinski (2002) for new teachers focused on solving problems of practice. At each meeting, a teacher presents a problem he or she is encountering, followed by an update on previously discussed issues. Then the new problems are discussed more fully by the group and the meeting ends with the teachers writing an evaluation of the meeting. This CoP focuses on real and immediate problems, and it allows teachers to construct knowledge through situated and authentic problem solving. Barab et al. (2006) referred to such an approach as reflection-*in*-practice. It involves transacting with our experiences, connecting with our feelings, and attending to our theories in use, which is different from the more common professional development model of reflection-*on*-practice, which involves taking a step back and examining a particular experience after the fact (Schön, 1983). Such an approach entails building new understandings to inform our actions *within* the situation that is unfolding. In her intensive case studies of teacher knowledge, practice, and learning among teachers in two high schools, Little (2003) also describes this type of "study group" CoP for professional development.

Understand and Capitalize on Existing Social Networks

The explicit exposition of practice through online professional development, which can connect teachers from different schools, districts, and states, is favored in a hectic and bustling new economy. If online technology is used as a mechanism for CoP, it should be deployed to help and support local communities of teacher practice (Schlager and Fusco, 2004), rather than be created in isolation from existing communities.

One way to analyze if constructing CoP is a suitable strategy for online teacher development is to understand and thereby capitalize on the existing social networks for design. The point is to understand the social structures that are currently serving teacher groups and to engage the groups in determining its social learning needs and possible intentions in a new community function. Teachers' professional development needs to vary from group to group and such needs cannot be determined by "outsiders." Many existing CoPs do not attempt to create communities from scratch, as such attempts have brought problems of identification, establishment, and maintenance (Schuck, 2003). Instead, these CoPs build on existing communities. For example, the Beginning and Establishing Successful Teachers (BEST) (http://www.uow.edu.au/educ/students/best.html) site in Australia, mainly developed for primary and early childhood teachers, built the CoP on the basis of communities established at the university among preservice teachers (Herrington et al., 2006). Likewise, research on ILF also suggested that the forum was most successful in supporting existing groups of inquiry rather than growing new ones (Barab et al., 2004).

Membership Makeup – Dynamism in Diversity

Tapped In (http://tappedin.org/tappedin/) is a web-based learning environment created to transform teacher professional development for professional development providers and educators (Schlager et al., 2002). One of the many CoPs that use Tapped In is the Milwaukee Public Schools Professional Support Network for new teachers. Each cadre consists of a group of new teachers with two leaders who are experienced teachers (Schlager et al., 2004; Koch and Fusco, 2008). Cadre sizes range from 11 to 26 teachers and the groups are composed of a mix of members from the novice to the expert, from the inexperienced to the seasoned, from the lurker to the active participant. In these sessions, they "expose misconceptions, find people who play similar roles, admit ignorance, share experience, offer resources, and build knowledge" (Holland et al., 2006, p. 222). There are some rich interactions and exchanges, which are possible only when members within the community come from diverse backgrounds, knowledge, and expertise. The ILF intends that the membership crosses boundaries by linking preservice, in-service, and university faculty together in sharing and reflecting on the practice and art of teaching (Moore and Barab, 2002).

An Australian CoP called "STAR Tech Program" (http://www.startechprogram.org/) helps teachers integrate technology tools into the curriculum to benefit students with and without disabilities. This CoP brings general education, special education, technology, and curriculum teachers and specialists together to share expertise about a topic, interact on an ongoing basis to further their learning, and over time build a shared body of knowledge (Zorfass and Rivero, 2005).

The notion that work and knowledge is distributed within a CoP aligns itself with the way work is done in the new economy (project basis), where it is the aggregation of varied expertise in a team for problem solving that matters. This alignment renders this design tenet appropriate for the twenty-first century.

Task or Activities that Require Collaboration and Peer Mentoring

Terms such as *task analysis* or *nature of tasks* sound typical of the instructional design paradigm where analysis is conducted to ensure that the learning tasks are well chunked and organized. However, we seek to highlight the importance of the complexity and convolution in the tasks that members of CoPs engage in. It is through engagement with complex, non–straight-forward activities (which is typical in life) that members appreciate the notion of distributed expertise, that there is no direct solution to problems, and that negotiation with other members in the community is necessary to get things done.

Evidenced in a study that attempts to foster CoPs among a group of heads of departments in some Singaporean schools, it was found that the nature of the tasks became a determinant for collaboration (Lim et al., 2005). Tasks that are not too specific and that allow members to relate and contextualize into their own culture are those that afford a greater degree of success. Tasks that contain higher risks in terms of uncertainty and complexity in the processes and outcomes create a greater need for collaboration and sharing among the participants, rendering them more inclined to rely on one another for support and division of labor.

Lead and Mentor Practice

A CoP needs leaders who can provide social support services, such as organization, governance, networking, and brokering, for the community (Lieberman, 1996; Schlager et al., 2002). New members need to observe models of participation in the community as legitimate peripheral participants (Lave and Wenger, 1991). Leaders model and reinforce community rules and norms of practice; they encourage and support the growth of others toward leadership (Schlager and Fusco, 2004). Leaders may bring in external catalysts into the communities, for example, experts in certain areas who can share their perspectives with teachers (Wearmouth et al., 2004);

experienced in-service teachers for teacher education students (Barnett et al., 2002), or fellow teachers in peer-to-peer collaborative settings (Yang and Liu, 2004). Take the BEST programme as an example: there is a mentor for each major issue and these mentors are exemplary teachers recognized by the Australian College of Educators. These expert teachers have volunteered their time to assist, by providing advice and support on a regular basis (Herrington et al., 2006). In the WIDE program (http://wideworld.pz.harvard.edu/) coaches are deployed to help participants in large enrolment courses feel connected. When the atmosphere of discussion is not friendly, the leader or mentor can intervene before the debate is transformed into out of control, hostile flame wars.

Mentoring and coaching may be loosely structured or implemented in such a way that the mentors play specific roles in setting up activities or task structures. In online CoPs, it is likely that leaders emerge from their contributions to the community, rather than being imposed onto the community. Long-sustaining CoPs maintain an ecology of leaders, contributors, and participants from its membership whose roles may change with time (Schlager and Fusco, 2004).

Balance and Leverage on Designers and Users

Many CoPs are designed by "outsiders" such as researchers instead of "insiders" such as teachers themselves. Therefore, when designing a CoP, the focus should be placed on the needs of the "insiders." Schlager et al. (2002) have warned against the attitude of "build it and they will come." Trying to design an artificial structure to create someone else's community is a challenge. Only when teachers see relevance in their participation of the CoP and think that the CoP would bring them benefit and satisfaction, will they participate in it (Wenger and Snyder, 2000). Therefore, fostering, sustaining, and scaling a CoP is a complex, dynamic process that involves not only technical preparation, but also a socio-cultural understanding of teachers' needs. As pointed out by Barab et al. (2004), the design of CoPs involves balancing and leveraging complex dualities from the "inside" rather than applying some sets of design principles from the "outside." The balance may also have dramatically shifted toward the insiders designing their own CoP infrastructures due to the availability of Web 2.0 tools and services. Indeed, some nascent CoPs have emerged recently in places such as Ning, Facebook, and Elgg.

Technology Architecture Supporting Establishment of CoPs

From the design tenets discussed in the preceding sections, we move on to discussing technology architectural considerations required for the development of an online learning environment that supports the continual professional development of teachers. These architectural considerations are intended to elicit the potential of the design tenets, and therefore, should not be taken separately as principles for achieving pedagogical outcomes for online learning.

Making Use of Existing Tools and Artifacts

An online learning environment for teachers needs to provide a range of tools and artifacts that members of the community can use in their professional development. They include curricula, assessment, case studies, software packages, technological tools, and others. Communication, coordination, knowledge generation, and knowledge building depend on the broad use of a common suite of tools and the generation, reuse, and refinement of community artifacts, not only within projects but also across projects over time (Schlager and Fusco, 2004). Thus, designers of online environments for CoPs should think hard about whether to introduce new tools and artifacts in the online environments instead of making use of those that already have a culture of use by the community.

Situating Needs by Way of Organization of Issues

An online learning environment may encounter the problem of lack of well-defined context within which progressive inquiry can take place. As CoPs are driven by the relevant practice and its corresponding practice-related issues, navigation within online environments should not be remote from the practice. The ILF is designed around a "visiting the classroom" metaphor to situate the needs of a teacher (Barab et al., 2004). Immersive environments are typically designed round a spatial metaphor of real-world spaces. Such designs of online environments should foreground the participating teachers' needs and issues.

Conference features in online learning environments can be organized by issues. Some issues can be very broad and one can navigate through an enormous amount of forums or discourse without meeting one's needs. Conference features could perhaps be organized by issues as well as context, e.g., mathematical ICT resource integration for public high schools.

Meaningful Tagging for Sharing of Authentic Artifacts

The metaphor of learning by participation, reflection, and knowledge discovery in an online environment may be hampered by inefficiencies due to lack of focus and centralized control (Penuel and Roschelle, 1999). Through knowledge organization, the online environment can have a core set of resources organized to provide the context for generating conversations. To ensure authentic artifacts or case samples uploaded or downloaded by teachers for discussion are searchable and traceable by other like-minded practitioners, tagging of these resources should be done in a manner meaningful to the teachers. Abstract textbook terms should be avoided and appropriate contextual terms should be used where possible. Community tagging should be a key feature of online CoP infrastructure to build "folksonomies."

Scalable Technology and Repository Features to Facilitate Artifact Sharing

CoPs, whether online or offline, are preferred to last on an extended basis. Online environments should be designed to plan to last for a long while to sustain the lifelines of communities, which may get into cyclical stages of evolution, growth, or decline over time. There is a danger of depending on technology stability, which may make an online environment obsolete or no longer supported technically. The repository features in an online environment that supports CoPs should thus cater for volume both in terms of server space as well as the number of online participants without compromising on productivity and efficiency performance.

Provision of Individual Construction Spaces and Public Sharing Spaces

Managed flow of information and control is essential to the structure of many successful educational activities (Guribye et al., 2003). The provision of individual spaces makes workspaces for teachers to create their own artifacts and refine them before they are comfortable in releasing them to public spaces in the online environments. This makes visible an individual's practice as well as cognition to others (akin to blogging). Such spaces not only foreground the practice by showing the series of tasks and subtasks a teacher takes in his or her teaching but also manifest how a teacher connects the learning from the public community discourse to his or her private practice.

Persistence, Adaptation, and Personalization of the Environment

An online environment for CoP supports social interaction, knowledge sharing, and collaboration. The teachers can create, share, rate, tag, and repurpose artifacts and content, which should stay persistent. When online CoPs reach a certain level of complexity, new members may not be aware of what is available or doable in the space, what she is supposed to do and contribute, sure of what help and resources she can get, etc, ultimately reducing the effectiveness of the CoP to create, share, evaluate, and evolve knowledge. Adaptation and personalization then becomes important to facilitating effective navigation, knowledge sharing, and knowledge construction, and creating a trusting atmosphere for teachers to share and work together seamlessly (Gaudioso et al., 2006). To develop a strong sense of ownership and belonging to an online community, it pays to have the environment personalized and adapted for the teacher. The environment remembers the interests, profile, behaviors, and online trajectories of the teacher, the groups, and the community, and makes use of such information to adapt itself to serve their respective needs.

Reciprocity with Technology Development

Designers of CoP would be more usefully served by thinking about "technology-supported group development" rather than by thinking about "technology-led group development." Emphasis should be placed on how the technologies are used to sustain a CoP (Barab et al., 2004; Farooq et al., 2007). One way to achieve this is to use the portal of the CoP as it was being developed to provide feedback for needs assessments and formative evaluations to inform further development of the project.

These communities contribute to the portal's growth and development while at the same time tap into its rich assets and networks.

Teacher Professional Identity Formation in CoPs

The study of teachers' professional identity has emerged as a research area (e.g., Bullough, 1997; Connelly and Clandinin, 1999). Based on the concept of "professional identity," Beijaard et al. (2004) argued that there is a constant tension between what teachers personally value and pursue (agency) and what is collectively seen as relevant to teaching (structure). In their professional practice, teachers learn to integrate both perspectives, and identity can perhaps help us understand how teachers do so.

In recognition of the social nature of identity, Jenkins (1996) further explained that identity has an active component, "identity is not just there," and it must always be established (p. 4). Identity formation is an active process and is located within the ebb and flow of practice and process. This view of social identity differs from the more traditional, individually-based approach to identity in arguing for an ongoing dialectic between internal and external forces. Thus, identity is not a unilateral construct but rather an ongoing process of synthesis as external and internal contexts change, "… where the internal and external meet" (p. 23–24).

The dialectic between engaging in the practice, the community, and the self for a teacher is well explicated by Danielewicz (2001):

> Teaching is a complex and delicate act. It demands that teachers analyze the situations, consider the variables of students, texts, knowledge, ability, and goals to formulate an approach to teaching and then to carry it out… These abilities suggest that teaching demands nothing less than identity to accomplish these tasks; this is more than just playing a role… identities require the commitment of the self to the enterprise in a way that acting out does not. A teacher must rise to the occasion time after time, the self goes on the line every day. (p. 9–10)

The practice influences and is being influenced by the individuals who participate in it. Identities besides being an outcome of CoP can also serve as a tool for analyzing the functioning of the CoP. Gee (2000/2001) argues that a focus on the contextually specific ways in which people act out and recognize identities allows for a more dynamic approach than the sometimes overly general and static trio of "race, class and gender" (p. 99). A teacher may be a member of different CoPs, for example, a math teacher belongs to the ICT community in her school, and she is also a member of the math teacher community in the district or zone, as well as a member of math teacher in a national association. By analyzing how her different identities are played out as she switches between different roles and practices in each CoP, we can probably better understand how identities get augmented, discarded, or changed over time.

Conclusion

We started this chapter by positing a case for continuing professional development of teachers that prepares them for twenty-first century skills, competencies, and identities as teachers. The construct of CoP in the twenty-first century is still relevant as a construct for thinking about successful teacher learning, but new technologies and new ways of working and learning require new interpretations and augmentations to the original framework. Based on the literature, we proposed design tenets for supporting and sustaining communities in the twenty-first century: foreground the practice, rely on existing social networks, build on strengths of membership diversity, construct task practices that require collaboration, and peer and leadership mentoring. In light of rapidly emerging Web 2.0 technologies, we further proposed technology architectural considerations for the development of an online learning environment that supports the continual professional development of teachers.

We argued that such CoPs provide the contexts for professional identity formation, which in turn dialectically influence the communities themselves. The members influence the processes and the outcomes of the community by the identities and roles they play. Their sense of identities as individuals and as a group is shaped by the dialectical processes happening in the community. More research in the area of identity formation in CoPs can help us to better understand how CoPs facilitate teachers' doing and knowing, working toward the practices of the twenty-first century teacher.

There are still a number of challenges to the establishment and sustaining of CoPs for teachers' professional development. A CoP needs to accumulate a critical mass of participants to constitute the community. Favorable conditions for CoPs as socio-technical environments include symmetry of ignorance, conceptual collisions, and epistemological pluralism (Fischer, 2007). However, we do not yet understand fully how these play out in the generation of powerful ideas for teachers. Another challenge pertains to imbuing the teachers with the culture of adoption and usage of the online environment, which makes it a sustainable and growing CoP. The challenges ahead of us pertain to issues on how to design for sustainable CoPs, and how online environments can support these communities, and we continue to examine these questions from new perspectives. We seek to understand how such communities grow, tease out design tenets, and apply them to design online CoP supports, including the organization and culture of work, practice, or learning.

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5.7

HOW MAY TEACHER LEARNING BE PROMOTED FOR EDUCATIONAL RENEWAL WITH IT?

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Introduction

The process of teachers learning to use IT effectively to support learning and teaching is linked to the adaptation of education to the context of the twenty-first century. Although the application of information technology in education can take very different forms, it is the use of IT to support educational transformation that constitute the core concern in policies and strategies to support teacher learning to incorporate IT in pedagogical practices. That is, the process of diffusing information and communication technologies into educational organizations to promote personal and system-wide improvements in learning and teaching is more challenging than promoting its use to support traditional forms of education or adding IT as a curricular discipline in its own right (Law, 2008). Therefore, the major aim of this chapter is to inform educational change and renewal with IT for the twenty-first century societies in which technology is prevalent. An instrumentalist approach is taken to empower teachers and other leaders, although it should be noted that much of the literature takes a deterministic perspective, with many authors adopting a market-oriented approach (Surry and Farquhar, 1997).

This chapter emphasizes the importance of teachers as leaders of renewal of educational systems with IT interpreted through multiple ecological layers starting with an overview of the global biosphere of education. The chapter then zooms through layers of educational ecosystems framed by the region, school and classroom before considering characteristics of IT innovations that may be marketed to teachers. Revolutionary change in education is identified in virtual educational organizations that apply IT to extend access to education. Having taken a relatively simple view centered on a classroom nested within a school and its region, the chapter discusses

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interacting educational systems, including simultaneous renewal of teacher education and K-12 schools that has been catalyzed by IT.

The beginning of the twenty-first century is a time of unpredictable change for education and for most other sectors of society because of rapid socio-economic changes. Dutton's (2004) briefing for the *World Summit on the Information Society* of the United Nations Educational Scientific and Cultural Organization (UNESCO) explained the role of technology in social transformation and identified IT as "a double-edged sword." He emphasized that every individual and society has a choice in reconfiguring access, including access to education, and noted that technology is "changing the dynamics of the classroom" and "redrawing of the borders of educational institutions." Education is changing and everyone has a role to play because "the crucial factor is not information *per se*, but the ability to control access to information, people, services and technologies" (p. 47). This includes the problem of significant inequitable access to resources in education, which is doubly important because education is a key factor in the ability of individuals and communities to access and use information suited to their needs.

A Global Perspective

One way of visualizing educational renewal is to adopt an ecosystem perspective developed by ecologists to analyze the living world. An ecological perspective of education recognizes that a variety of ecosystems interact in the global biosphere and that a micro ecosystem, such as a classroom, is nested within another ecosystem, the school, which is part of the nation's macro educational ecosystem. Figure 1 depicts this layered ecological perspective of the global educational biosphere. It was inspired by Zhao and Frank's (2003) study, which saw that "a classroom is nested within a multilevel ecological hierarchy including government agencies, societal institutions, local community organizations and the school bureaucracy" (p. 815). In addition, I have applied systemic perspectives developed over my career and influenced by researchers such as Fullan (2001), Hargreaves (2003), and Somekh (2008). The picture may be somewhat different across countries, but the multilevel ecological hierarchy still applies.

Let us consider the outermost global level of Figure 1, which provides a perspective on mechanisms that spread IT in education in the twenty-first century. At this level, ecozones or regions of education may follow continental borders or, given the importance of culture and national identity, national boundaries may be preferred. From this perspective, although the educational ecozones of the UK and North America are similar to one another and very different from those of Asia and Sub Saharan Africa, changes with IT in education in one zone would have a tendency to stimulate change in another.

The organizations given in Figure 1 are arranged in the same order around each level using four categories that stimulate or retard change with IT across the levels. The lines that link each corner with the central frame of the classroom denote flow across the educational ecozones and between the levels. Starting at the top left corner, the

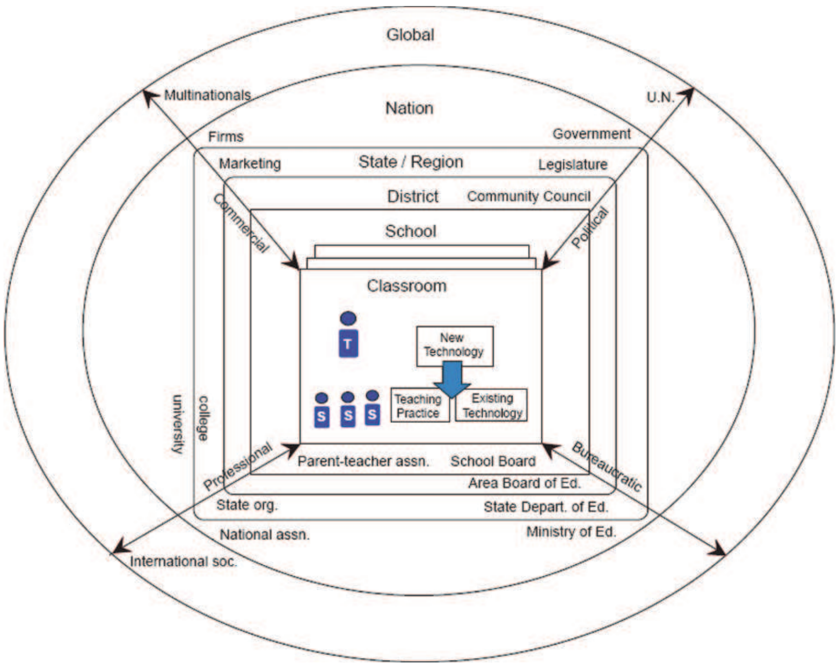

Fig. 1 Influences of IT in the global biosphere of education, including nested ecologies

categories I have identified are *commercial, political, bureaucratic,* and *professional*. These are illustrated in the outmost frame of Figure 1.

Many multinational IT vendors have developed global educational initiatives to enhance education and build capacity for their services. While most of the influence of these *commercial* organizations is mediated in levels closer to the teacher, a few global organizations have directly impacted classroom practices. For example, Cisco Network Academies provide IT hardware, software, accreditation, and teacher training directly into secondary schools and colleges with more than 11,000 academies in 160 countries (http://www.cisco.com/edu/emea/index.shtml). Such educational innovation with IT can serve the company and country's need for skilled IT workers to maintain the regional IT infrastructure while also changing education with IT (Selinger, 2006). UNESCO is a global *political* organization that promotes equity in change with IT. For example, in 2002 UNESCO published its first planning guide "ICT and Teacher Training" to inform policy makers and institutional leaders. UNESCO republished this handbook in five languages over time and improved dissemination with three workshops on different continents in economically less-developed regions of the world (UNESCO, 2002; copies in all languages are available in full in this book's online appendices). The international group of authors of this planning guide (including the author of this chapter) brought together knowledge from their respective educational systems and helped improve the flow of information across the globe.

Although collaboration of *bureaucratic* institutions is weak across political borders, regional communities have developed significant IT innovations to improve cohesion within regions. For example European School Net (http://www.eun.org) shares information on IT in education and promotes collaborative work across Europe, and recently, the New Educational Partnership for Africa's Development (NEPAD) has emerged with a similar goal for Africa. The development of mutual support also applies to *professional* nonprofit organizations. For example, the International Education and Resource Network (iEARN http://www.iearn.org) provides services and teacher training to support teachers to connect their classrooms world wide as well as to come together for conferences. For teacher educators, the Society of IT and Teacher Education (SITE, http://www.aace.site.org) publishes journals and attracts participants from over 50 countries for its conference annually.

Selwyn's (2002) research of system-wide changes in IT in education encompassed national and international organizations to provide evidence of the socio-economic forces that have pushed technology diffusion in the UK. Selwyn's discursive construction of educational computing in the UK analyzes documentary evidence from many sources, including marketing literature of the government sponsored "BBC computer" and policies of the government of France, Japan, and the US that influenced the British government. His interviews of government officials, advisors, and multinational corporations that sell hardware, software, and telecommunications to schools traces the origin of the UK "National Grid For Learning" as a strategic vision for the nation. Although, according to the executive of a multinational IT corporation, "the actual adage in the entire IT industry is that education is 'a high maintenance/low margin' business" (p. 65), Selwyn provides evidence that these companies see multiple benefits from the educational sector: profit, educational branding for sales to the much larger home market, employable people for their IT sector to support sales in other sectors, and building a future consumer base. This also applies to other countries, for example, CCC Kei Wa Primary School (2007) in Hong Kong noted that an initiative that used the web to improve pupil's learning of English had resulted in an increase in the home ownership of computers with Internet access from 30% to 100%. While these economic motivations may be obscure to educators, they clearly fit with an ecological perspective of socio-economic change with IT in education.

Schools' Local Area as an Ecology

The three central layers of Figure 1 show each teacher's classroom nested within their school and its district, including collaborating districts. Zhao et al. (2002) provided evidence for their ecological framework, which conceptualized teachers as the "keystone species" with the "IT-using teacher" as an "invasive exotic species" who interacts with and displaces traditional teachers as the keystone species. Zhao and Frank (2003) used ecological modeling analysis to study uses of IT over time in a "contained educational system" of 19 schools in 4 districts in the US and found evidence of co-evolution of both IT and teachers' pedagogies. Change was more likely when there was an "empty niche" (for instance, telecommunications was exploited to communicate with parents where there had been little communication before), but IT was rarely exploited for curriculum purposes where it competed with existing curriculum activities.

Zhao and Frank (2003) identified four basic mechanisms that support teachers' adoption of IT in the school system: recruitment or selection of new teachers with IT as a selection criterion; training or socialization supportive of IT use; provision of opportunities to explore and learn with IT; and leveraging change through the social context, including opinion leaders. Additional recommendations included learning about IT in the curriculum, management of the influence of peers, and stress caused by competing innovations. At the program level, Zhao and Frank explained why professional development for individual teachers outside the school context often provided little support for innovation, whereas group or whole-school initiatives coherent with the school's strategic plan and supported by its leadership were more effective in promoting renewal with IT in education.

My criticism of Zhao and Frank's ecological framework is their misleading use of the term *extinct*. A teacher who adapts his or her practice to incorporate IT does not become extinct, after all the teacher remains. What has occurred is that teachers (as well as their collaborating administrators and support staff) have adapted pedagogical and organizational practices with IT in education. The term adaptation is more accurate because IT is rarely adopted without adaptation into its new context, and what may appear at first sight to be one IT application is in fact a cluster of innovations informed by development of the teacher's technological and pedagogic content knowledge (AACTE, 2008). Alternatively, one may suggest that what becomes extinct is the prevailing practice rather than the people themselves. If one were to view practices as "genes" of an "organism," then it may be expected that evolving organisms would develop different gene compositions in response to environment changes. This adaptation of educational practice with use of IT will now be discussed in more detail by considering the ecology of a school. The importance of such "eco-friendly" professional development has been confirmed in a study of the UK national initiative to train all teachers to use IT (Davis et al., 2008). This adaptation of educational practice with the use of IT will now be discussed in more detail by considering the ecology of a school.

A School Perspective

The ongoing adaptation of school practice with adoption of IT may be interpreted with maturity modeling, which identifies characteristics that distinguish stages of change in school ecology with increasing penetration of IT. Organizational change with IT starts with *localized* exploitation, when one or more school teachers adopt one or more IT innovations. As the number of teachers and students using IT increases and activity proliferates, the increasing demand for resources stimulates management to appoint an IT coordinator to manage demand, resulting in *internal integration*. The range of innovations continue to mature within the organization and when users work together to *transform* their pedagogy and educational practice the third stage is reached. The next stage involves IT in a redesign of the school's external networks, such as adding partner schools into the school's course offerings, leading to further *embedding* of IT. Although few traditional schools reach the *revolutionary* stage where the organization redefines its scope of work, virtual organizations start at this stage. The establishments of open universities and virtual schools that depend on IT to increase access to education have revolutionized the scope of schooling, with catchments and student diversity well beyond that of traditional institutions. For example, the UK Open University and the first U.S. Virtual High School (Zucker and Kozma, 2003) both recruit students worldwide. They also deliver courses in collaboration with a network of traditional schools and colleges close to students and the innovative educational processes include an unbundling of the teaching role (Harms et al., 2006; Natriello, 2005).

An ecological perspective provides a means to appreciate that the increasing maturity of IT use may be followed by a decline, and that differing school ecologies cannot be assumed to follow the same path with IT applications. For example, Tearle (2003) provides a detailed case study of an exemplary UK secondary school that remains unlikely to move from the second stage of *internal integration* of IT due to restraints from regional and national authorities, including "high stakes" standardized tests. In addition there are cases where a school has moved back a level. Hargreaves (2003) provides an illustration of a knowledge-society school, Blue Mountain in Canada, which was set up at the third or *transformative* stage, with an IT coordinator and state of the art technology used effectively in learning, teaching and administration. However, following external shocks of budget cuts and a change in principal, the Blue Mountain School reverted to a more traditional approach with coordinated integration and localized innovation with IT. In addition, Hargreaves (2003) observed that Blue Mountain School was not successful in transferring its practice to other schools within the district. Yuen et al. (2003) also recognized that international case studies of "innovative schools" analyzed by the SITES module 2 project were unlikely to provide a blueprint for other schools to follow.

The IT Coordinator

Widespread adoption of IT in a school normally results in the creation of a new role, the IT coordinator (Bradley, 1992; Owen, 1992; Lai, 2001; Davis, 1991), as noted in the previous section at the second stage of *internal integration*. Lai (2001) researched the role of IT coordinators in New Zealand secondary schools and found that it was rarely a full-time position, but usually coupled with the responsibilities of a deputy or assistant principal (28%) or a head of the department for IT, technology, or mathematics (61%). According to Lai, the IT coordinators served the leadership roles of planner, manager, envisioner, trainer, and technician and tended to have responsibility for the purchase, maintenance, and support of IT equipment as well as for teaching others how to use it. A significant workload issue was identified, with technical management of a computer network being identified as one of the most frustrating.

Owen's research into IT coordinator roles and responsibilities in the UK in the 1990s identified considerable stress because such coordination included change management that impacted the work of the senior management team. It was rare (at that time) for an IT coordinator to be a member of the school's executive team that probably occurs at move to the third or *transformation* stage of organizational maturity. Evidence for the need to share leadership at multiple levels within a school was presented by Tong and Trinidad (2005) in Hong Kong using a model that was developed in Australia. This model is split into strategic, department, and teacher levels and identifies influences and feedback loops that drive educational IT change processes. Leadership was shared within and across the school and involved the chief executive, the IT coordinator, curriculum coordinators, and individual teachers. IT coordination involved work across the departments of the school as well as within discipline and age-specific groupings. Kirkman (2000, p. 46) also provided confirming evidence of the importance of multilevel IT leadership across a UK high school, with the caution that "a network of subject ICT coordinators who could offer application-specific support … can block curriculum change through inaction, passive resistance or a political response" (p. 46). This evidence confirms research related to conditions for successful adoption of IT by Ely (1990).

IT coordination has been less formal in primary or elementary schools, and the literature suggests that an IT coordinator was perceived as a temporary phase until teachers become proficient with IT (Strudler and Gall, 1988). However, in a follow-up study Strudler (1995–1996) found that there was a continuing need for an IT coordinator to support provision of resources and professional development within each school and, when IT coordination was not retained, the school's progress in IT use tended to stagnate.

While individual teachers mainly operate in their classrooms (center of Figure 1), IT coordinators have access to and support many classrooms. In ecological terms, IT coordinators are a special member of the "keystone species" of teachers with an extraordinary ability as change agents to spread or retard innovation. Their ability to continue to innovate is enhanced through IT-mediated networks. An extreme example of this is the international MirandaNet Fellowship (http://www.mirandanet.ac.uk/home.php) that promotes ongoing professional development across countries with support from commercial partners and government agencies. Preston et al. (2000) describe the two-way benefits of this collegial network between the UK and Czech Republic. However, before these more complex ecologies involving overlapping communities of practice are discussed, the classroom that is the central ecology depicted in Figure 1 is considered.

A Teacher Innovating with IT

The process of innovation takes time and the stages of adoption and rejection can be characterized for the individual and the community(s) in which they work. Hall and Hord (1987) provided a Concerns Based Adoption Model (CBAM) of innovation that emphasized that IT adoption is more likely to occur when the innovation is perceived to address the teacher's personal concerns. Teacher's concerns may best be interpreted through the recently elaborated framework of Technological Pedagogical Content Knowledge – TPCK. At the heart of the TPCK framework is the complex interplay of three primary forms of knowledge: content, pedagogy, and technology. Building on Shulman's (1987) idea of Pedagogical Content Knowledge, the TPCK framework attempts to capture some of the essential qualities of knowledge required by teachers for IT integration in their teaching, while addressing the complex, multifaceted, and situated nature of teacher knowledge and AACTE (2008) provides content focused chapters on its application within teacher education. In addition, evidence of student achievement gathered through IT during curriculum activities is likely to require additional teacher learning before value can be added for assessment and accountability purposes (Underwood and Dillon, 2004).

A seminal longitudinal study of the innovative Apple Classroom of Tomorrow (ACOT) identified five stages of "instructional evolution" for a teacher using IT in well-resourced classrooms accompanied by ongoing professional development. The stages were entry, adoption, adaptation, appropriation, and invention (Sandholtz et al., 1997). Students of innovative ACOT teachers demonstrate high levels of skill with IT, an ability to learn on their own, problem-solving, and movement toward more collaborative work patterns. The CBAM and ACOT stages of teachers' pedagogical innovation with IT have been developed further by Sherry et al. (2000) into the "Learning/adoption trajectory" model with the following stages: Teacher as Learner, Teacher as Adopter, Teacher as Co-adopter, Teacher as Reaffirmer or Rejecter and, finally, Teacher as Leader. The later stages promote further adoption, particularly the final stage because a Teacher as Leader advocates for IT and provides support to others (Sherry et al., 2000). Taking an ecological perspective, it may be seen that the Teacher as Leader has co-evolved with IT and such teachers will provide a strong influence on further adoption or evolution with IT.

These models of individual change with IT emphasize that the individual teacher's concerns and context impact the adoption of IT in education. Part of the context involves the attributes of the IT innovation itself. New technology innovation in the classroom depicted in the center of Figure 1 is also part of the ecology. Rogers' (2003) seminal research in the diffusion of innovations identified that "The characteristics of an innovation, as perceived by a social system, determine its rate of adoption. Five attributes of innovations are (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability, (5) observability" (p. 36). Ferster (2006), through a sophisticated analysis of the adoption or rejection of 43 IT-related innovations in education, confirmed that the attributes selected by Rogers (2003) were indeed the most influential ones.

Ely (1990) identified eight conditions that facilitate IT innovation complementing Rogers' attributes and confirmed that they apply in contexts that are technically, linguistically, and culturally foreign to the original developers. The International Society for Technology in Education (ISTE, www.iste.org) holds the following conditions as essential for effective IT integration: dissatisfaction with the status quo, knowledge of existing skills, commitment by those involved, availability of resources, availability of time, encouragement and expectations for participation, and evident leadership. Research confirms that effective leadership is necessary to promote educational renewal because such leaders appear to manipulate their school ecology to enhance the conditions (Yee, 2000, 2001; Jenson et al., 2002).

This chapter, having started with a global ecological perspective on change with IT in education, has now zoomed into the perspective of the teacher as a leader of innovation with IT and research discussed provide many clues as to how the ecology of education can be manipulated to promote educational renewal. Given our focus on teachers' learning, it is also important to consider the more complex overlapping ecologies involved in the professional development of teachers, including preservice teacher education.

Simultaneous Renewal of Preservice Teacher Education and K-12 Schools

Teacher education institutions also appear to progress through similar maturation stages with IT, but change is more complex because changes in learning and teaching also involve partnering with K-12 schools where students practice teaching. Goodlad (1994) called this "simultaneous renewal" of teacher education and K-12 education.

The first national project to integrate IT in preservice teacher education, Project INTENT (Initial Teacher Education and New Technology) in England, provides insight into the change process in five different organizational structures and the micro politics of institutional change that moved all five institutions one stage in organizational maturation from the localized stage to coordinated integration of IT with potential for internal process redesign (Somekh and Davis, 1997). Somekh et al. (1997) empirically derived key concepts and strategies and then compared and contrasted them with well-known theories of innovation of that time. They confirmed Fullan's view that change is a messy mixture of problems, excitement, and the power of individuals to bring about change (2001). Davis (1997) has identified and described the complementary institutional, group, individual, and indirect staff development support strategies that evolved in the University of Exeter's teacher education programme and involved all stake holders on the campus during project INTENT. It is not difficult to recognize many factors discussed earlier, especially in the author's detailed account of the professional development of an individual social studies teacher educator (Davis, 1991).

The challenge of simultaneous renewal involves changing two ecologies – the teacher education classroom and the practice of future teachers in K-12 schools. Davis (2003) presented five cases of best practice for technology in U.S. teacher education, all of which include strategies for ongoing simultaneous renewal. The complexity of change with IT is illustrated by Garofalo (2006), who successfully improved high-school pupils' learning by changing his own practice in preservice teacher education while also ensuring that K-12 partner schools had compatible IT resources. While student teachers rarely experience such compatible classroom ecologies, it is exciting to envisage the speed of educational renewal if modeling of appropriate transferable pedagogy coupled with access to compatible field experience and classroom resources were to become common place.

Finally it is vital to note that lack of equitable access to IT and related socio-technical change conditions differentially impact teachers and their schools. For example, minority teachers typically have less access to IT in school and at home. The same applies to teacher education programs for minority teachers (Bowser-Brown, 2004) and for teachers in much of the third world (Leach et al., 2004). In addition, access to high-speed Internet is more problematic for minorities and for rural areas. One strategy that has been adopted to reduce such inequity is to start the introduction of IT with a disadvantaged group. A system-wide example is the Enlaces project in Chile, which successfully introduced IT into education nationwide. The innovation began by working with indigenous people who did not have a written language. The project first developed a graphical interface for these people and a culturally appropriate curriculum that fit their ecology (UNESCO, 2002) and then spread those innovations across the nation through partnerships that involved all schools of teacher education. The success of the Enlaces approach influenced other national professional development initiatives.

Teacher education requires simultaneous renewal across a number of educational organizations, and thus IT in teacher education stimulates further change. All the individuals and organizations involved move through stages of adoption and maturing use of IT in messy multilevel processes that may be facilitated or retarded by leaders and change agents at many levels in different ecologies. In addition, strategies to address inequitable access to IT are essential, including access to IT in teacher education.

Summary and Conclusions

This chapter has described and developed an ecological perspective to understand how teacher learning may be promoted for educational renewal with IT. Starting with a global perspective, diverse socio-technical forces were mapped with illustrations and evidence of their impact. The chapter then zoomed through organizational perspectives, in which traditional institutions seem to mature midway through five stages, whereas virtual organizations start at the fifth revolutionary stage with a redefinition of the scope of education achieved through a network of organizations. The individual perspective of the teacher adopting IT in the context of a classroom emphasized each teacher's ownership of the innovation process that addresses individual concerns, which change with time and context. The IT coordinator's role and professional development were discussed. Theoretical models were used to explain the multistaged processes and illustrated with case studies and evidence. The final section explained the challenges of simultaneous renewal of teacher education, which encompasses overlapping ecologies. Although the promise of teacher learning with IT for educational renewal is particularly exciting in teacher education, ensuring the essential conditions for transfer across multiple classrooms appears most challenging.

To present an ecological perspective on educational renewal with IT, the author found it necessary to clarify the complex and chaotic processes of continuing multiple innovations, many of which oppose one another. In addition, Rogers (2003) warns that his axioms may be overturned by innovations with communication technologies. For example, teachers' online communities of practice such as those described by Sherry et al. (2000) and Preston, et al. (2000) do change the ways in which innovations are communicated and they can impact multiple ecologies in different locations.

This chapter indicates that many studies of the diffusion of IT in education have taken too simple an approach and that much research remains to be done. Much published research has focused on one ecology, ignoring impact on interacting ecologies and feedback between ecologies. Therefore, important variables and changes with time have been ignored and the conclusions may be seriously flawed. It will also be important to develop research methodologies that support more complex investigations adapted to the ecological perspectives outlined in this chapter. Teachers are the *keystone species* in the educational ecologies of the twenty-first century world, which is permeated with IT and the struggle for equity. This is because educators share the moral goal of supporting all the students to achieve their potential while working within our societies that are changing rapidly with technological and economic forces. In these circumstances, teacher learning with IT for educational renewal has an increasingly significant influence on society as already identified by Dutton (2004).

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Section 6

IT IN SCHOOLS

6

IT IN SCHOOLS

Sara Dexter
Section Editor

Around the world, considerable money has been invested in IT for primary and secondary schools and as a result policymakers expect improvements in teaching and learning. An increasing school accountability trend has underscored these expectations and added to them that gains be measured through scientifically rigorous research and keyed to national interests, particularly global competitiveness. Teachers working alone in their classrooms cannot produce the sort of large-scale results and significant outcomes that are expected, and so it raises the question of how IT might be harnessed at a school-wide level in order to bring about the desired ends.

Key questions that are raised are how can leaders best coordinate teachers' efforts across a school?; how can leaders best position school organization resources to support teachers' efforts?; how can focusing on the perspective of the school organization to study the barriers to and opportunities for IT effectiveness provide insights into aligning it with efforts at the teacher, curriculum, and policy levels of the system?; and how can outcomes from IT be best defined and measured? The chapters of the *IT in Schools* section of the book teases apart the salient issues behind these questions and presents the key research that addresses them.

The premise of this section is that maximizing the effectiveness of IT use at the school-wide level requires leadership and decision making about IT integration goals for classrooms and the IT implementation environment across a school. This includes how IT leaders can use the nature and scope of a school's IT vision to unify and guide teachers' uses of technology in support of teaching and learning. A related issue is creating an effective learning and support environment (i.e., technical, instructional, and social support) for the teachers to achieve the IT vision at the school. Since it is likely that a group of people will distribute the leadership responsibilities for the successful integration and implementation of IT throughout a school, the processes these team members use to guide and coordinate their decisions and work is also an issue of interest when considering IT at the school-wide level.

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The first chapter of Section 6 will provide an overview of these leadership issues for IT in schools and discuss the conceptual framework of this section. Each of the following chapters in this section then elaborates upon the key ideas from the framework.

- Chapter 6.1, *Leadership for IT in Schools*, lays out an overview of issues for IT leaders. By elaborating upon the key functions of leadership, desired outcomes for leading school-wide IT use, the team-based nature of IT leadership, and key decision processes, it serves as an overview to the section and an introduction to topics discussed in subsequent chapters.
- Chapter 6.2, *Framing IT use to Enhance Educational Impact on a School-Wide Basis*, presents several frameworks that could be used to develop a school's IT vision, with advantages and limitations of each noted.
- Chapter 6.3, *Quality Support for ICT in Schools*, examines the high-quality support programs that are needed at a school in order to foster teachers' learning about IT integration and ease its implementation in classrooms.
- Chapter 6.4, *Distributed Leadership and IT*, selects from the research on leadership, particularly distributed leadership, and its key elements in order to illustrate how expert knowledge can serve as a key source of power for IT specialists who may not hold formal leadership positions.
- Chapter 6.5, *Total Cost of Ownership and Total Value of Ownership*, describes the process of data-driven decision-making as well as the considerations for implementing it, with particular attention to two possible models of data-driven decision making about IT in schools: total cost of ownership and total value of ownership.
- Chapter 6.6, *The Logic and Logic Model of Technology Evaluation*, first raises the question of what outcomes of technology integration are reasonable to expect and then discusses how to approach evaluating whether or not those outcomes have been reached.

6.1

LEADERSHIP FOR IT IN SCHOOLS

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Introduction

Effective leadership for information technology (IT) in a school is a significant predictor of its use by teachers and students (Anderson and Dexter, 2005). The outcomes of strong IT leadership include the coordinated use of IT to support teaching and learning among a school's teachers and the implementation environment they share. Planning and operationalizing effective school-wide IT use is a complex leadership task, which usually results in distributing the responsibilities for the successful integration and implementation of technology across a team of multiple staff members. To design an effective leadership team, the school or school system's chief leader must understand the full scope and nature of concerns that arise when IT is adopted school-wide to support instruction and operations.

To provide a conceptual framework for the IT in schools section of this handbook, this chapter examines leadership functions and decision making as they pertain to IT integration goals for classrooms and to IT implementation across a school. Each subsequent chapter in this section will then elaborate on key concepts raised here.

Dimensions and Aims of IT Leadership

Functions of Leadership

Recommendations for what leaders should know and be able to do can be organized into three basic functions of leadership: setting direction, developing people, and making the organization work (Leithwood and Riehl, 2003; Leithwood et al., 2004). As it has evolved, leadership research has come to frame leadership more

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as a function rather than as a role (Spillane et al., 2004). Therefore, the study of IT leadership has expanded its focus beyond the role of head leaders (e.g., principals, headmasters) to include the roles of specialists (e.g., IT coordinators, staff developers) and teacher leaders (e.g., department chairs). This chapter examines IT leadership as practiced by a team that includes members of these various groups (i.e., head leader, specialists, and teacher leaders).

In terms of setting direction, researchers have found that leaders should set high expectations and raise the academic bar to form a culture of continuous improvement, emphasize instructional practices found to be most productive, focus teachers on curriculum design that increases student engagement and motivation, and involve teachers in decision making (Hoachlander et al., 2001; Waters et al., 2003). According to this research, to develop the IT capabilities of teachers, leaders should foster intellectual stimulation among them, provide them with well-designed professional development, and facilitate such focused activities as integrating IT to meet the learning needs of each child. Finally, to make the organization work effectively, organizational and management practices should be aligned with the school's direction. These goals can be accomplished by establishing order and discipline, understanding and facilitating the change process, using time and other resources wisely so as to allow people to be successful, and then continually monitoring and evaluating their progress and needs.

These research studies also emphasize the importance of leaders' knowing *when* and *how* to apply this knowledge. Context matters and strategies must be adjusted appropriately to the situation (Hoachlander et al., 2001), including leading in a distributed fashion (i.e., weaving other leaders into a workable governance structure) (Portin et al., 2003).

Goals for IT Leadership

Ideally, a school's IT improves the teaching and learning processes that take place there. To do so, leaders should consider such instructional design issues as selecting IT according to desired learning outcomes and to how it might add value to teaching and learning and support assessment practices (Dexter, 2002). Any IT integrated into a school's learning and teaching activities must be chosen carefully for its appropriateness for the subject matter and the cognitive activity demanded by the learning outcome to enhance the accessing, processing, and communicating of data, information, and knowledge by making these processes more feasible, interactive, or collaborative. Technology can also aid the assessment of learning outcomes by making students' thinking visible and allowing teachers to capture versions of students' work as it progresses.

For a school to achieve the best uses of IT in support of learning, most of its teachers will need opportunities and support for professional development. Research shows that providing these learning opportunities is a significant challenge for most schools. In an US study, less than 15% of the nation's K-12 schools provided high-quality technology support contexts that offered one-on-one support, facilitated teacher discussion, and focused on integration topics (Ronnkvist et al., 2000). But such high-quality support has been found to support teachers' learning together about instructional uses of technology (Dexter et al., 2002, 2003). Thus, the basic leadership functions of setting direction, developing people, and making the organization work can be reconceptualized as attending to the purpose of the technology, to teacher development and professional community building, and to technology access and support.

The literature on learning organizations suggests that when IT leaders expect instructional innovation and flexibility among the school staff, they should work to instill team learning, build a shared vision, and employ systems thinking. School contexts that support such collective learning among the staff members increase the likelihood that all staff members' learning needs will be met (Marks and Louis, 1997, 1999). To accomplish this complex goal requires a team of individuals working together to focus technology use in support of student learning and to establish support contexts for teachers.

If the goal of technology leadership is to support the individual and collective learning of a school's teachers, what should that learning environment look like? A recent synthesis of the last 30 years of research on learning, *How People Learn: Brain, Mind, Experience and School* (Bransford et al., 1999), identifies four essential elements of a learning environment. First, it should be learner-centered, taking individual learners' needs into account. Second, it should be knowledge-centered, directed toward developing deep understanding. Third, it should be assessment-centered, using feedback and other assessment mechanisms to guide the learner. Lastly, it should be community-centered, encouraging the social processing of information. Although *How People Learn* focuses mainly on learning environments for students, its four-part framework can be applied to teachers' learning environments as well (i.e., to the school as a workplace). Its recommendations for effective teachers' learning environments are congruent with professional criteria for professional development for teachers (National Staff Development Council [NSDC], 2001). They also echo research findings on professional community among teachers and its correlation with student achievement (Louis et al., 1996). Further, they are consistent with findings about high-quality technology support – specifically, that it includes one-on-one support, facilitates teacher discussion, and focuses on integration topics (Dexter et al., 2002).

IT Leadership to Set Direction

Although individual teachers may select the technology-integration goals for their own classrooms, often an entire school staff may adopt school-wide goals for how technology is used to support teaching and learning and perhaps to promote changes in teaching or assessment practices. In such cases, the outcome of IT leaders' work to set direction is quite likely to be shaped by larger initiatives or policies at the district, state/province, or ministry levels and perhaps to also address issues related to student achievement and/or school improvement efforts. At such times, IT integration goals span multiple grade levels and content areas, which often results in these goals being expressed more in terms of cognitive rather than content goals or in terms of desirable pedagogical practices or instructional planning guidelines. Later in this section, Twining (2008) presents a number of frameworks that can be utilized to categorize and compare types of goals when planning for the school-wide integration of IT.

Among other resources, IT leaders can use to better understand and execute this function and goal of IT leadership is the research about how and when IT supports learning and other key goals of schools. A recent and rigorous 4-year study by BECTA in the United Kingdom (2007) and earlier metaanalyses and wide-scale studies in the United States (Mann et al., 1999; Fadel and Lemke, 2006; Kulick, 1994; Sandholtz et al., 1997; Scardamalia and Bereiter, 1996; Sivin-Kachala, 1998; Waxman et al., 2002; Wenglinsky, 1998) provide evidence that IT contributes to student learning, as measured by standardized tests, researcher-created measures, and national tests. This research also reports IT's benefits to students' attitudes and self-concepts.

Beyond its use in individual classrooms, IT integration in schools also contributes to reducing digital inequity and forging connections between critical groups in the education process, such as with the community to improve students' cultural connections and for business-education partnerships (International Society for technology in Education [ISTE], 1997). Information technology can also strengthen connections between the school and the home to improve parental involvement and communication about assessment information (BECTA, 2007).

The research on the impact of IT on student learning can guide leaders in establishing a direction that is evidence-based and within reasonable expectations. Such research provides greater insight into the conditions under which such outcomes could be met and into other leadership functions such as developing people and making the organization work.

Other resources are available to help IT leaders plan their vision for IT and operationalize it into measures by which they can track progress. The North Central Regional Education Lab (NCREL), an educational technology resource center in the United States, promotes the development of an effective vision rooted in learner outcomes and outlines what the organization must do to support the changes necessary to achieve those outcomes (NCREL, 2000). Across the world, most countries have developed a vision for ICT integration as part of their national policies or laws (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2007), and many of those have been operationalized into expected benchmarks and outcomes. The majority of outcomes identified by such resources focus on student learning, but others also emphasize school management and changes in curriculum.

IT Leadership to Develop People

The intended outcome of what this chapter refers to IT leaders' implementation efforts is to put into place the necessary support and learning environment to develop teachers' integration skills and IT-supported pedagogy. Applying the research on effective learning environments (Bransford et al., 1999) to their efforts to develop teachers' technical and instructional knowledge – i.e., how to operate and integrate IT – can provide leaders with a number of recommended targets for such work.

A learner-centered design for IT support that is targeted at developing teachers' integration knowledge will assume that there are differences in the levels of prior knowledge and learning preferences among teachers. Thus, IT leaders should create a system where their IT support staff will collect data about teachers' learning needs and help design materials appropriate for different skill levels, perhaps even on an one-to-one basis. IT leaders also need to consider whether their support staff's knowledge of the types of instruction required by various content areas is broad enough to include all the teaching staff who are trying to learn to integrate technology.

A knowledge-centered IT learning environment will be focused on developing teachers' deep understanding of how to integrate IT into curriculum and assessment, and how IT can support students' learning. Therefore, IT support staff needs to have an instructional background or at least a solid understanding of the learning process to provide the necessary guidance and to communicate clearly about learning goals and purposes. One longitudinal study of a 1:1 student-to-computer installation in the United States found that ongoing professional development support and interactions with peers over an extended period of time were necessary for the teachers to develop understandings of the capabilities of the IT tools and their flexible application (Sandholtz et al., 1997).

An assessment-centered IT learning environment for teachers will provide teachers with formative feedback and input to support learning (Bransford et al., 1999). Such feedback might occur through classroom observations, sharing of lesson plans or student-produced work, or collaborative instructional design sessions where teachers brainstorm together. Leaders who assign IT support staff to observe teachers' classes need to make explicit the differences between evaluation and coaching and the power relationships between teachers and support staff. IT leaders can look to the scholarship on supervision and evaluation (Nolan and Hoover, 2003) as well as on mentoring and coaching (Healy and Welchert, 1990; Joyce and Showers, 1996) for clarification of these differences and how to proceed.

Creating such a rich learning environment for teachers is a complex task that requires considerable expertise in the topics to be taught as well as in how to work with adult learners in a clinical/practice environment. IT leaders must think about how to acquire such expertise in their system or school, perhaps by establishing staff roles with assigned specific IT duties. In this section, Strudler and Hearrington (2008) address the issues of IT support staffing and the research on differences in their roles and use of time.

The research on teacher leadership and professional learning communities also provides IT leaders with guidance on how to cultivate expertise among the school's staff members and to spread such expertise across the school. This research's attention to the necessity of norms and social practices that foster trust and collaboration and a culture of continuous improvement (Louis et al., 1996; Marks and Louis, 1997, 1999) is in accordance with the finding of *How People Learn* that effective learning environments are community-centered.

Teacher leaders are defined in different ways, but usually are characterized as teachers who share their expertise with peers and influence and engage them about their practice (Forster, 1997; Moller and Katzenmeyer, 1996; Riel and Becker, 2008; Rosenholtz, 1989; Wasley, 1992). In the literature about teacher leadership, IT leaders can find several organizational components that can encourage identifying teachers as experts and promoting them to a role of leader. These include less-hierarchical administrative structures, reconceptualized views of leadership, and framing instructional improvement initiatives to look for and honor teacher expertise rather than simply to find and address deficits in their knowledge (Murphy, 2005).

Professional learning communities are also defined in a variety of ways, but typically as school-based learning organizations (Roberts and Pruitt, 2003). In such a community, the goal is to improve student learning by fostering individual and collective learning by teachers, students, staff, principals, and parents. Professional learning communities help establish norms of practice (Roberts and Pruitt, 2003), and in so doing can both communicate expectations for IT integration and support collective learning in the organization. This collective learning can generate a dialogue through which to develop consensus among teachers about the direction of IT implementation, opportunities for learning about how to implement IT themselves, and school support for these efforts. The research on professional learning communities identifies several vehicles that IT leaders can consider using to spread expertise, which include reflective dialogue, interaction, collaboration, and shared values and norms (Kruse et al., 1995).

In summary, IT leaders' efforts to develop a supportive environment for teachers to learn about IT integration must take on an instructional focus and approach that is fruitful for each individual. Such an individualized approach focused on deep understanding about IT-supported teaching and learning can be further supported through the collective effort and collaboration of teachers as they work together to provide one another with input and feedback.

IT Leadership to Make the Organization Work

IT leaders' work to structure the organization to support teachers' IT-supported pedagogy is another aspect of IT implementation. Case studies consistently show that teachers' integration of IT into their classrooms is impeded by a shortage of IT resources or by resources that cannot be depended upon (Garner and Gillingham, 1996; Ginsberg and McCormick, 1998; Kirby, 1998; Means and Olson, 1995; Sandholtz et al., 1997; Schofield, 1995). Thus, IT leadership outcomes must include providing ready access to supported and managed IT hardware, software, and network resources.

What is considered ready access to IT is dependent upon the context of the school's larger vision and its goals for IT. Various studies describe the advantages and limitations of different IT distribution models, such as computer laboratories, rolling carts, small groups per classroom, and so forth (c.f. Means et al., 1995). Yet if the integration goals are focused on students in a particular grade or content area, the distribution of the IT must be designed so that the goals for the frequency of use can be achieved.

The distribution of the IT is important not only to meeting a level of ready access but also to establishing the structure of teacher development programs. Each distribution model implies which teachers in a school will require technical, instructional, and social support for the effective use of the IT. In a case study of a district implementing a 1:1 distribution model, Dexter (2006) found that because schools could select only one teacher per subject and per grade level to participate in the training, the potential for teacher sharing and collaborating about innovation for new pedagogy within each school was reduced. Another district implementing a 2:1 computer to student access program selected pairs of teachers in particular subject areas per grade level to participate to embed peer support for new pedagogy within the school and focus the target for instructional support from the district (Dexter and Anderson, 2003).

Although ready access that considers the technical, instructional, and social support implications of IT integration is important, another key concern for IT leaders is how to help teachers establish effective logistical and classroom management of IT. For example, in a case study of a 1:1 computing project in a US middle school, the several hundred participating students needed to recharge their laptops' batteries each day, which created a logistical challenge (Dexter et al., 2005). The IT leaders and teachers at the school worked together to determine an orderly routine that took into consideration the technical limits of the laptops' batteries and the behavior management of students as they all converged upon the carts that provided the recharging capability.

Roles and Responsibilities in IT Leadership Teams

IT Expertise and Team Membership

To date, most discussion of and research on IT leadership does not consider the range of leadership outcomes discussed earlier, but rather has been more narrowly focused on such technical aspects as planning, purchases, and staffing. An exception is the recent set of recommendations regarding levels of IT knowledge and skill expertise for school leaders (NETS-A) published by the International Society for Technology in Education (ISTE, 2002; Thomas and Knezek, 2008) as educational technology standards for administrators. These standards include a broad range of IT knowledge and skills, ranging from IT leadership and vision to using IT to support and manage operations to creating systems for the assessment and evaluation of IT. The majority of states in US have adopted these standards as a part of the licensing regulations for school principals (ISTE, 2004).

The range of the different yet equally important technical and instructional decisions required for IT integration, the rapid rate of technological change, and a general lack of IT leadership training among formal school leaders increases the likelihood that the functions of IT leadership in schools will need to be shared, or distributed, across a group of staff members to collectively harness an adequate level of expertise. *Distributed leadership* is a term used to convey not only that leadership is shared, but that it is distributed across the situation, the leaders, and the followers (Spillane et al., 2004). In this model, leadership is viewed as an “emergent property of a group or network of interacting individuals” that suggests an “openness of the boundaries of leadership” and in which “varieties of expertise are distributed across the many, not the few” (Bennett et al., 2003, p. 7). For example, in most US schools, technology leadership consists of a shared set of responsibilities distributed among the principal, a technology coordinator, and teacher leaders (Anderson and Dexter, 2005). Case studies can provide a finer level of detail on how the IT that is present in the school, such as whether the site is a laptop school or one with a limited number of computers, also shapes how, where, and when IT leadership needs to be distributed (Dexter, 2006). Bennett’s (2008) discussion of distributed leadership that appears later in this section gives special attention to the role that power from expert knowledge plays in distributed IT leadership.

IT leadership Practices

Spillane and others argue that school leadership is best understood in terms of the tasks that make up leadership practices. Therefore, their approach to studying leadership extends beyond those in a formal authority role in a school (e.g., principal or headmaster) to include an array of individuals who interact and engage together in using the various tools, structures, times, and space needed to carry out those leadership tasks (Spillane et al., 2001, 2004). IT leaders adopting a distributed leadership perspective should attend to how those routines, tools, structures, and time and space structure the IT leadership team members’ communication and information sharing, affect the coordination of their work together, and constitute IT leadership practices. Such a focus on leadership practices draws attention to how IT leadership occurs not only through an IT vision and plan and the hiring of IT staff, but also through smaller, more routine structures and tools, such as a technology committee that provides opportunities for teacher input and a vehicle for making decisions at the school or a ticket system that logs and tracks support requests. Recognizing all of these IT-related leadership practices can help leaders evaluate if there is a sufficient number of tools, routines, and structures to carry out the IT vision for the school.

Two patterns of practices that can help IT leaders plan for effective leadership are data-driven decision making and program evaluation. *Data-driven decision making* is a term meant to connote the importance both of acquiring and analyzing relevant information and of carrying out an effective set of steps for making a decision. One data-focused model for collecting and analyzing relevant information about IT is called the total cost of ownership (TCO). Originally developed by business and industry to determine the cost and effectiveness of levels of access to technology in relation to the levels of support for its use, in the last decade, the TCO model has begun to be applied to schools (COSN, 2001). The TCO model is also evolving to incorporate the idea of value as a key metric, which is referred to by some as the total value of ownership (TVO) model (Rust, 2005). The TVO model focuses on the gains in key items of value to the organization, such as its efficiency or its capacity to communicate or collaborate within or beyond the organization. Later in this section, Moyle (2008) discusses the contributions that the TCO and TVO models can make to IT leaders' efforts to carry out data-driven decision making for planning and setting priorities for their schools.

A trend toward data-driven decision making offers some promise for increasing the capacity of school leaders to determine what data might inform the effectiveness of a school's IT efforts and programs, and how and where to collect those data. Program evaluation creates an even more comprehensive data-focused decision-making approach and feedback loop that could be used by IT leaders to guide their leadership practices. Investing the time and effort necessary to conduct an evaluation of the inputs and efforts being made to reach school-wide technology integration goals and the resulting outcomes can provide administrators with a powerful tool in guiding a large variety of types of efforts central to their schools. In this handbook, Zhao et al. (2008) critique typical approaches and models used to evaluate IT in schools, discuss formative and summative measures for determining the impact of IT on learning, and suggest a logic model that could be used to guide IT evaluation in schools.

Conclusion

When IT leaders set a vision for the use of technology as an effective support to instruction, they must also take responsibility for providing the effective workplace learning environment needed for teachers to achieve it. If leaders are focused on teacher learning as the key goal for instituting systemic supports for new instructional practices, they can use the *How People Learn* framework to develop a more complete consideration of the workplace environment necessary for teachers to learn about and implement technology-supported pedagogy. We know from research and practical experience that learning is more powerful when colleagues engage in professional development together, and that such gains are further leveraged when this collective learning also addresses key organizational factors that aid new pedagogical practices supported by technology.

Considering technology leadership as a school-wide characteristic rather than associating it with a particular leadership role shifts attention away from the charisma or expertise of any one individual and suggests that leadership preparation of all team members should include, as well as technical expertise, the development of communication, coordination, and teamwork skills. The leadership of technology integration and implementation requires that IT leaders possess a range of knowledge and skills; ISTE's NETS-A standards for leaders provide a comprehensive list of these. An effective team-based approach to IT leadership includes the key decision makers in the school who have the authority to direct resources, staffing, and policies; at least one person with expertise on technology integration who can lead the learning for teachers; and ideally, teachers who can provide input on the progress of technology integration and implementation progress and ground technology decision-making and evaluation efforts in the key goals of the curriculum.

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6.2

FRAMING IT USE TO ENHANCE EDUCATIONAL IMPACT ON A SCHOOL-WIDE BASIS

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Introduction – Importance of Consistent Understandings

There has been a substantial level of investment in "educational" ICT, which started in the late 1970s and has continued and grown up to the present time (Twining, 2002a; Haydn and Barton, 2007). Despite this the impact of IT on teaching and learning has been patchy at best (Twining et al., 2006). At the beginning of the twenty-first century there was a growing call for a moratorium on IT expenditure in schools (e.g. Cuban, 2001), which was largely driven by this lack of return on the investment that has been made in "educational" IT.

This lack of return on investment was evident in the difference between the claims made for IT and its actual impact on education, which Trend et al. (1999) described as a "reality-rhetoric gap." There is substantial support in the literature for the view that such a gap exists (e.g., Condie and Munro, 2007). Despite this there is still a widely held belief that IT has the potential to enhance education (e.g., Wood, 2006).

In early 2003 the dICTatEd project was set up to investigate ways of enhancing the impact of investments in educational IT. The dICTatEd project (dICTatEd, 2007) argues that one of the reasons for this "reality-rhetoric gap" is to do with lack of shared understandings within the education community (including among policy makers, researchers and practitioners). This lack of shared understandings is evident in:

– a lack of precision in the research literature (Schrag, 1999; Twining, 1995, 2002b; Alvarez and Kilbourn, 2002), including a shortage of clear definitions (Galton et al., 1998; Harris, 1999),
– confusion about key terms among practitioners (Twining et al., 2006)
– lack of shared educational visions about the role that IT should play in education, based on over 9,000 responses to the dICTatEd online questionnaire from respondents in 94 countries (Twining, 2007).

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The importance of having shared visions is widely recognised in the literature, both in relation to commercial organisations (Peters and Waterman, 1995; Kotter, 1996; Senge et al., 1999) and in education (Fullan, 1992; National College of School Leadership [NCSL], 2003; DfES, 2004), particularly where this involves significant change (Gilbert, 1996). The UK's NCSL, in its training materials for aspiring headteachers, points out:

> The 'vision' is a rather grand way of describing what a school sees as its purpose. It represents the aspirations of the school and summarises what it would like to achieve.… The vision is a 'preferred future' – the school as we would wish it to be. … At an everyday level, vision is found to work. Repeatedly, inspections of schools and educational research have shown that the school's vision is important in determining its success, This is not surprising: where a group shares a common purpose it achieves more than if its members go in different directions using sundry methods to achieve ends to which only a fraction of them aspire. The essence of leadership and team building is to serve a common purpose. To work in harmony with similar methods, shared approaches and common goals increases the effectiveness of the group. (NCSL, 2004, p. 7)

Thus a critical issue for schools is how to ensure that they have a shared vision of the role that IT should be playing, that is translated into a consistent strategy for IT implementation.

> … before any school or school system can have effective policies and practices to incorporate IT to support learning and teaching, the school must have a clear vision of the learning it is aiming to foster and the organisation it is aiming to be.
>
> (Moyle, 2006, p. 5)

This chapter explores a number of frameworks for thinking about IT in education, which have the potential to support vision building and the strategic implementation of IT in schools.

Frameworks for Thinking About IT in Education

A framework is a tool to help structure and organise one's thinking, in this case about the use of IT in education. Squires and McDougall (1994) make a clear distinction between two types of theoretical IT frameworks, which might be called:

- Software frameworks
- Pedagogical frameworks

Twining (2002b) suggested three further categories:

- Achievement frameworks
- Cognitive frameworks
- Evolutionary frameworks

	These are characterised by a focus on ...
Achievement frameworks	learning outcomes achieved by individual learners
Cognitive frameworks	explanations of the 'cognitive' impact of computer use
Software frameworks	software per se
Pedagogical frameworks	educational practices surrounding computer use
Evolutionary frameworks	the way in which computer use changes over time

Fig. 1 Summary of foci of different categories of educational IT frameworks

These frameworks differ in terms of their foci, as summarised in Figure 1. They differ from guidelines in that they provide ways of thinking about and analysing practice rather than providing advice on how to achieve effective educational IT use.

Each of the five types of framework identified above are explored in a little more detail below and their relevance to the development of educational visions and the strategic implementation of IT in schools is considered.

Achievement Frameworks

Achievement frameworks provide a means of "measuring" the quality of learning with ICT. They thus include curricula such as the National Curriculum within England and National Educational Technology Standards (NETS) for students in the USA (ISTE, 1998), both of which provides descriptions of what children at different levels of competence will be able to do. Achievement frameworks are characterised by a focus on the learning outcomes achieved by individual learners.

The Measurement of the Impact of IT on Children's Education (MIICE, van der Kuyl, 2001) is arguably the best example of this type of framework. As its name suggests, MIICE explicitly sets out to provide measures of quality in learning with ICT. Figure 2 provides an example of a dimension and its sub-components from the MIICE framework.

Unlike most other frameworks relating to computer use in education the MIICE framework has undergone extensive developmental testing with hundreds of teachers, and an attempt was made to validate all the dimensions within it. Ignoring possible methodological flaws with that validation process, the MIICE framework still suffers from some major problems. For example, the MIICE framework consists of 13 dimensions, each of which corresponds to a potential learning outcome related to IT use (e.g., learner reflection: the learners' ability to think about what they are doing, and their ability to put it into a number of contexts). For each dimension there are between 2 and 4 sub-dimensions, giving a total of 41 sub-dimensions (e.g., taking personal responsibility). For each of these sub-dimensions there are sets of questions (e.g., Can learners use self-assessment reliably and use the results to decide on their

<table>
<tr><td colspan="2">Outcome 1: Learner reflection</td><td>Level: 2</td></tr>
<tr><td colspan="3">This relates to learners' ability to think about what they are doing, and their ability to put it into a number of contexts</td></tr>
<tr><td colspan="3">1 Taking personal responsibility for learning
1 Can learners use self-assessment reliably and use the results to decide on their next steps?
2 Are learners able to resume work from previous activity on their own initiative?
3 Is learners' use of ICT usually closely related to the purpose of the exercise?
4 Are learners able to contribute to a project from their own interests?

2 Realistic but improving culture

1 Do learners show an interest in going beyond the minimum standards for the task in hand?
2 Do learners show an interest in comparing different ways in which ICT can be applied?
3 …..
4 …….
…….</td></tr>
<tr><td>Evidence at ages 5 to 14: Learners
1.1 can check their program against simple criteria before deciding what to do next
1.2 get on with their work from a previous session without fuss
1.3 stick to the point most of the time
1.4 …..
….
4.3 …</td><td></td><td>Evidence at ages 12 to 18: Learners
1.1 are able to use a log to assess their progress through a scheme of work using the computer
1.2 get on with their work from a previous session without fuss
1.3 stick to the point most of the time
1.4 …..…..</td></tr>
</table>

Fig. 2 An example of a dimension from the MIICE framework (based on van der Kuyl, 2001, p. 27)

next steps?), which are categorised as being at different levels. There are over 200 individual questions in total. For each of the sub-dimensions there are also statements about what would constitute evidence for children in two different age ranges at each level (e.g., At ages 5–14 learners can check their program against simple criteria before deciding what to do next; At ages 12–18 learners are able to use a log to assess their progress through a scheme of work using the computer). This results in over 400 statements of evidence. The complexity of the structure and the lack of clarity about the relationships between the sub-dimensions and evidence statements, combined with the number of separate elements, makes MIICE overly complex.

Achievement frameworks are useful in thinking about specific learning outcomes and how these might be recognised. In a context where one is under pressure to achieve "good" test results they can be helpful in providing metrics against which achievement can be measured. However, because of their narrow focus on specific learning outcomes they tend to be of less assistance in thinking about a whole-school vision about the role of IT or a strategy for how to implement such a vision.

Cognitive Frameworks

These are characterised by a focus on the "cognitive" impact of computer use. They attempt to provide a vehicle for analysing interactions, behaviours or activities in relation to the learner, and more specifically, to the mental functioning of the learner.

Laurillard's (1993) "conversational framework" is an example of a cognitive framework, which considers the interactions:

– between a teacher and a student that is mediated in some way (e.g. through speech or actions)
– within each actor, between their actions and conceptions (through reflection and adaptation).

Such frameworks are valuable when thinking about the nature of interactions at the level of the individual. As such they can help one analyse interactions in terms of the underlying processes taking place. For example, in Figure 3 there is an illustrative analysis of the use of two different IT applications, in terms of interaction at the level of actions within Laurillard's conversational framework.

This analysis shows a simplified analysis of how each of these different IT applications can be understood in terms of Laurillard's framework. This hints at a significant difference between the two approaches; in one case control of what happens next is in the hands of the software while in the other it is in the hands of the user. However, what this analysis does not help one to do is think about which approach is most appropriate. As was the case with achievement frameworks, cognitive frameworks are focussed on the wrong level of analysis to be of great help in developing a whole-school vision or strategy relating to the overall role that IT should be playing in schools.

Software Frameworks

Software frameworks are characterised by an explicit focus on the software per se; the software itself is used to define the dimensions of the framework. Squires and McDougall (1994) distinguished between four sub-categories of software frameworks.

The first group of software frameworks, which were based on application type, were particularly prevalent in the early days of educational computing. The core dimension that they used was the "type" of software, as illustrated by Wellington's (1985) framework in Figure 4.

The second group of software frameworks focussed on the role that the software was intended to play as the key dimension. The classic example of this group of software frameworks is Taylor's (1980) classification, which is illustrated in Figure 5.

'Activity' within Laurillard's Framework	**Integrated Learning System**	**Climate Simulation**
Teacher sets up 'the world' within which the student can act (which defines Step A)	Teacher decides student will use ILS	Teacher decides student will use a climate simulation
Step A Teacher's world sets the task goal	ILS provides student with a question to answer.	Simulation provides variables that can be altered.
Step B Student acts to achieve task goal	Student answers question	Student alters one or more variables
Step C Teacher's world gives feedback on action	If answer correct ILS confirms this and moves to next question (Go to Step A). If answer incorrect ILS provides tutorial and re-asks the question (Go to Step D).	The simulation shows the impact of the alteration to the variable
Step D Students modifies actions in light of feedback	Student re-answers the question. (Go to Step C)	Student alters one or more variables

Fig. 3 Illustrative analysis of the use of an integrated learning system and a climate simulation against a subset of Laurillard's (1993) conversational framework

Category	**Types of software**
Teaching programs	Drill and practice; tutorial; electronic teaching aid
Learning programs	Educational games; adventure games; simulations
Tools	Information retrieval; word processing
Open-ended software	Logo

Fig. 4 Wellington's (1985) "Application Type" framework

The third group of software frameworks used the educational rationale underpinning the software as the key dimension. Kemmis et al.'s (1977) instructional, revelatory, conjectural and emancipatory "paradigms" is the classic example of this group of frameworks (see Figure 6). Within this framework the emancipatory "paradigm" is seen as secondary to the other three "paradigms" and exists in relation to them. Thus

Category	Definition
Tutor	"The computer presents some subject material, the student responds, the computer evaluates the response, and, from the results of the evaluation, determines what to present next." (Taylor, 1980 p.3)
Tool	The computer has some functionality that saves the learner time and allows her to focus her intellectual energy on higher order tasks.
Tutee	The computer is 'taught' something by being programmed by the learner.

Fig. 5 Taylor's (1980) "Educational Role" framework

when using the framework you first identify which of the three primary paradigms applies and then establish where you are located on the dimensions of the emancipatory "paradigm."

The fourth group of software frameworks builds upon the previous three. Thus, they use two or more dimensions relating to software type, educational role and educational rationale. Chandler's (1984) locus of control framework is a good example of this, which uses the software type and the role that the user is expected to fulfil (see Figure 7).

Jonassen et al. (1998) discusses how because of their inherent characteristics certain computer applications can actually serve as cognitive tools because the learners' use of them requires that they engage in critical, creative or complex thought. His framework (which is summarised in Figure 8) is very similar to Taylor's (1980) tutor tool tutee (Figure 5) framework, in that it is based on the role of the software (Instructional vs. Constructional/Mindtools), though it also brings in aspects of Chandler's Locus of Control.

All the software frameworks described here have an intuitive feel to them – their categories seem to make sense and help distinguish between differences associated with using different applications. For this reason they are often used as a way of analysing and categorising the software that is available within a school. However, software frameworks all suffer from a number of problems, and in particular, from the issue of technological determinism – they seem to assume that the software determines the way in which it will be used. This is clearly not the case – and indeed some of the authors of what would normally be classified as software frameworks explicitly acknowledge this (e.g., Kemmis et al., 1977). When Jonassen et al. make the point that "Mindtools are computer applications that, when used by learners to represent what they know, necessarily engage them in critical thinking about the content they are studying" (Jonassen et al., 1998, p. 24), they are at least implicitly acknowledging that it is how the software is used that is the critical factor. This limitation of software frameworks severely undermines their value as tools for thinking about a school's educational vision or how best to implement it.

	Instructional	Revelatory	Conjectural
Key concept	Mastery of content	Discovery, intuition, getting a 'feel' for ideas in the field, etc.	Articulation and manipulation of ideas and hypothesis-testing
Relevant theory / theorists	Skinnerian theory	Bruner (the spiral curriculum) and perhaps Ausubel (subsumption theory)	Piaget, Popper, Papert
Curriculum emphasis	Subject matter as the object of learning	The student as the subject of education	Understanding, 'active' knowledge
Educational means	Rationalisation of instruction, especially in terms of sequencing, presentation and feedback reinforcement	Provision of opportunities for discovery and vicarious experience	Manipulation of student inputs, finding metaphors and model building
Role of the computer	Presentation of content, task prescription, student motivation through fast feedback	Simulation or information-handling	Manipulable space/ field/'scratch pad'/ language, for creating or articulating models, programs, plans or conceptual structures
Assumptions	Conventional body of subject matter with articulated structure; articulated hierarchy of tasks, behaviouristic learning theory	(Hidden) model of significant concepts and knowledge structure; theory of learning by discovery	Problem-oriented theory of knowledge, general cognitive theory
Idealisation / Caricature	At best, the computer is seen as a patient tutor; at worst it is seen as a page turner	At best, the computer is seen as creating a rich learning environment at worst it makes a 'black box' of the significant learnings	At best, the computer is seen as a tool or educational medium (in the sense of milieu, not 'communications medium'); at worst, as an expensive toy
Software 'types'	Drill-and-practice	Simulation and some kinds of data-handling programs	Modelling, Artificial Intelligence packages and computer science applications
Emancipatory 'paradigm'	Key concept: the notion of reducing the inauthenticity of student labour. Curriculum emphasis and Educational means: derived from the primary paradigm with which it is associated - for it never appears in isolation except as 'an impulse to curriculum reform'. Role of the computer: calculation, graph-plotting, tabulation or other information handling		

Fig. 6 Summary of the "Educational Paradigms for CAL" (based on Kemmis et al., 1977, pp. 25–29)

Locus of Control

'Program' ———————————————— 'User"

Tutorial	Games	Simulation games	Experimental simulation	Content-free tools	Programming languages
Programmes, instruction, drill and practice	Computer as player or referee	Computer as game-world e.g. Empire style game and adventure genre	Mathematically based models of processes such as scientific experiments	Word processors, sound and graphics manipulators, databases, scientific instruments, control technology	Logo Basic Smalltalk
Hospital model: user as patient	Funfair model: user as emulator	Drama model: user as roleplayer	Laboratory model: user as tester	Resource centre model: user as artist or researcher	Workshop model: user as inventor

Fig. 7 Categories within Chandler's (1984) Locus of Control framework

Instructional	**Constructional (Mindtools)**
Information stored in computer and presented to student (computer as conveyor of information – tutor)	Computer supports learner's knowledge construction
Interaction often limited to selecting options/navigation	Genuine interaction
Computer judges responses and gives feedback	Computer as metacognitive tool – reflecting back to the student
Developed by instructional designer to be 'valid' and 'teacher proof'	Learner as designer
Computer in control	Learner in control

Fig. 8 Summary of Jonassen's mindtools framework (Jonassen et al., 1998)

Pedagogical Frameworks

Pedagogical frameworks are characterised by a focus on the educational practices surrounding computer use. Thus, unlike software frameworks, they focus on the ways in which computers are actually used in context. Arguably two of the most important frameworks in this category are Squires and McDougall's perspectives interactions paradigm (PIP) (Squires and McDougall, 1994) and the computer practice framework (CPF) (Twining, 2002b).

The Perspectives Interactions Paradigm

Squires and McDougall's (1994) PIP is a classic example of a pedagogical framework. It places the emphasis on the interactions between three sets of key actors: student(s), teacher and designer (of software), as illustrated in Figure 9.

Using the PIP involves thinking about the interactions between each of the three pairs of actors. When dealing with what Squires and McDougall refer to as the "Teacher and Student Perspective Interaction" the focus is on interactions between teachers and students and between student and student. Squires and McDougall highlight that this needs to include both those interactions that take place at the computer as well as those related interactions that take place elsewhere but are "generated by" the computer. They suggest a range of questions that one might ask about these interactions, which relate to different dimensions of practice. Their suggested questions relate to the kinds of classroom activities; the kinds of interactions; the way in which the computer use is organized (e.g., groupings, on and off computer work, etc); the degree to which students take control of their own learning; the degree of teacher intervention; the kind of teacher interventions; the teacher's role; the students' roles and the style of classroom management.

In their original description of the PIP, Squires and McDougall (1994) assume that it will be used as a conceptual tool for evaluating the suitability of specific software for use in specific contexts. Thus, they talk about students and teachers as being

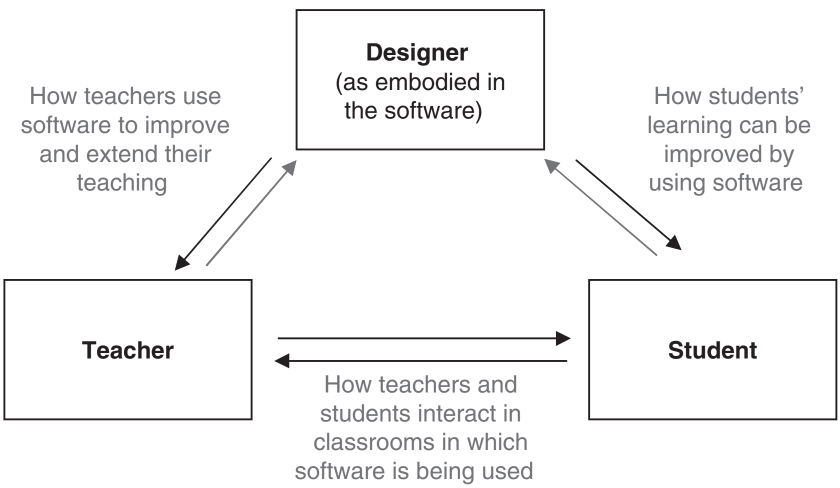

Fig. 9 A diagrammatic representation of the perspectives interactions paradigm (PIP) (Squires and McDougall, 1994)

generalised students (learners) and generalised teachers (people who support learners), while the designer encapsulates all the functions that go into developing some software. However, Squires and McDougall identify that "the use of this paradigm is not limited to software selection. It provides some basis for software evaluation, and it can be applied even more broadly" (Squires and McDougall, 1994, p. 117). The PIP "can provide a more general framework for thinking about the use of IT in educational settings" (McDougall and Squires, 1997, p. 118).

The Computer Practice Framework

The CPF (Twining, 2004) was developed to overcome some of the difficulties with applying other existing "Educational IT frameworks" such as PIPs, including their complexity and the ambiguity of the way in which they were defined.

The CPF consists of three nested dimensions (as illustrated in Figure 10). Each of these dimensions was defined in a way that was intended to be unambiguous and orthogonal (i.e., the three dimensions were discrete from each other).

The Quantity of computer use is based on the percentage of the school day during which one or more computers are used by one or more children. In doing this calculation

– the school day refers to the time when children are in school but excludes play times, lunch times, after school clubs, etc.
– if a computer is being used with children (even if they are not controlling the keys or mouse) that counts as it being used by the children.

The Focus dimension has three categories, which relate to the objectives underlying the computer use, as shown in Figure 11.

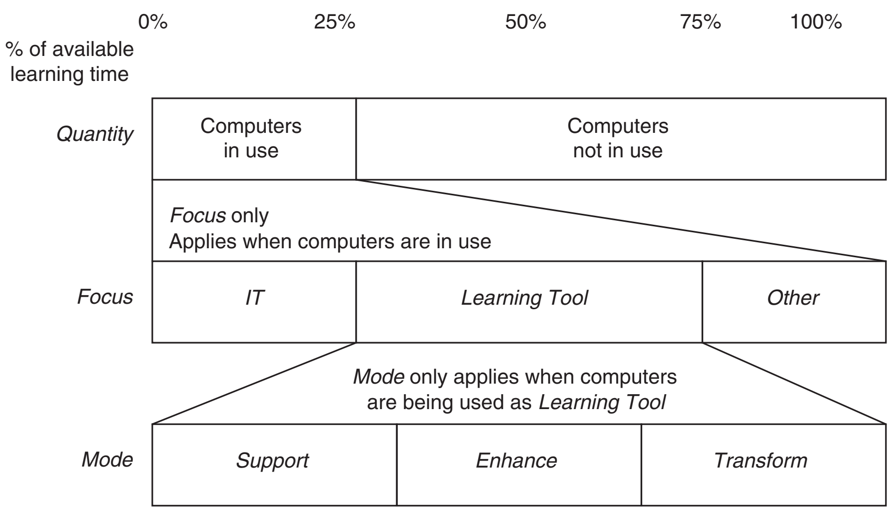

Fig. 10 Overview of the computer practice framework (Twining, 2004)

Category	Definition
IT	**Using computers in a way that helps children to develop their IT skills, knowledge and understanding.** The emphasis here is on using a computer to extend the children's knowledge, understanding or skill in computer use itself. E.g. Learning how to operate the mouse. Learning how to use the word processing software.
Learning Tool	**Using computers in a way that supports any aspect of children's learning other than *IT* itself.** This would include the following three areas: *Curriculum Tool* - Using computers as tools in a way that helps children to develop skills, knowledge and understanding in another curriculum area (i.e., other than IT). The emphasis here is on using the computer as a tool to enhance their learning in another curriculum area rather than in the area of IT itself. E.g. To develop the language skills involved in drafting and re-drafting. To extend their ability to interpret data (e.g., using a graphing package that they already know how to operate to help them answer a scientific question). To provide access to the curriculum (e.g., for children with 'Special Needs'). *Mathetic Tool* - Using computers as tools to develop children's ability to learn and enhance their approaches to learning. E.g. To encourage collaboration. To help children reflect on their own learning processes. To teach children to teach each other how to use particular programs. *Affective Tool* - Using computers as tools to support and enhance the affective aspects of children's learning. E.g. To develop their confidence and/or self-esteem (for example by allowing a child who may be perceived as 'less able' to teach other children how to use a new program). Using computers to help motivate children.
Other	**Using the computer in a way that is not covered by *IT or Learning Tool.*** Other thus includes objectives that do not relate directly to learning outcomes and/or where no learning is apparent. Objectives for using computers that fall within this category may be focussed on practical aspects of the learning situation or the larger context in which the computer use is taking place. E.g. Using computers in order to respond to pressure to do so from children, their parents, colleagues and/or external agencies. Allowing children to use the computer as a reward or holding activity whilst the teacher is working elsewhere. An example of this would be allowing children who have finished other work to 'go on the computer'. Using a computer in order to make the teacher's workload or classroom management easier or more enjoyable. Using computers as a mechanism for presenting the school in a good light or in order to be seen to be using them. *Other* would apply where no learning is evident.

Fig. 11 Definition of the focus dimension of the CPF

Category	Definition
Support	Learning objectives (excluding those relating specifically to IT) remain the same but the process is automated in some way. Support is thus about improving efficiency and effectiveness without changing curriculum content.
Extend	Curriculum content and/or process are different, but these changes could take place in a classroom context without a computer.
Transform	Curriculum content and/or process are different, and these changes could not have taken place in a classroom context without a computer.

Fig. 12 Definition of the mode dimension of the CPF

The Mode dimension has three categories that relate to the impact of computer use on the curriculum, as shown in Figure 12. The Mode only applies where the Focus is *Learning Tool*. The curriculum is taken to cover all aspects of practice surrounding computer use, including

– content (which incorporates and goes beyond the explicit curriculum as set down in guidelines or curriculum documents but omits the *IT* curriculum – i.e., excluding aspects dealing with how to operate the computer or software);
– processes.

The CPF was developed originally as a tool for enabling comparisons to be made between the IT use being made in different "educational" contexts. Thus it was originally intended as a descriptive framework for allowing differences and changes in practice to be described. However, it became clear that it provided a powerful tool for curriculum development and vision building (Twining, 2001, 2002b, 2004). For example, the Focus dimension highlights the importance of being clear about the emphasis one wants to place on learning about IT and using IT to enhance learning in other areas. Similarly, it is clear from the Mode dimension that there is a tension between "efficiency gains" (Support) and more radical impacts on practice and curriculum content, which it is critical to address in a context where IT is a limited resource. The Quantity of computer use sets limits on what is achievable in terms of the Focus and Mode dimensions.

Because of their focus on pedagogy rather than the technology per se, pedagogical frameworks may well offer the most powerful vehicles for vision building of all the frameworks so far. This fits well with the view that while having a vision is important when thinking about how to use IT in education, the key is that this should be an educational vision rather than a technological one (Barton, 2001; Conlon, 2000, 2002; Twining et al., 2006). However, pedagogical frameworks are perhaps lacking in terms of supporting thinking about the process of change that may be involved in moving from a school's current situation to the one outlined in their vision.

Evolutionary Frameworks

Evolutionary frameworks are characterised by a focus on the way(s) in which computer use changes over time. Thus, they focus on "phases" or "stages" in the embedding of IT. There are three different, though related groups of frameworks within this category, which deal with different aspects of computer use. The first is structured around the evolution of computer use in education (e.g., Heppell's (1993b) four-stage model of the evolution of educational computing). The second concentrates on the phases that a teacher's beliefs and practices about computer use in education go through (e.g., Dwyer et al.'s (1990) five-phase model of teacher development). The third group of evolutionary frameworks addresses the stages that a teacher's classroom management follows (e.g., Sandholtz et al.'s (1990) teachers' concerns framework).

The key difference between the first group of evolutionary frameworks and the other two is that it is not looking at the level of the individual classroom. However, it could be argued that all three of these sets of frameworks could be equally helpful in describing computer use at a range of levels, including at the level of an individual school or classroom. The distinction between the second and the third group of evolutionary frameworks was made by Sandholtz et al.(1990). It is based on the difference between teacher's *beliefs and practices* and their *classroom management*, which Sandholtz et al.(1990) describe as *instruction* and *management*, respectively. They acknowledge that *instruction* and *management* are intimately linked, but insist that the distinction is an important one.

Heppell's Four-Stage Model of the Evolution of Educational Computing

Heppell (1993b) presented a model that shows stages through which he argues the use of computers in educational institutions (schools) progresses. The model, which is shown in Figure 13, has four stages, which Heppell linked with the three stages of progression within his "developmental taxonomy of modes of interaction that integrated media should support" (Heppell, 1993a, p. 242).

Heppell (1993b) stated that topicality was the first stage that computer use went through and that "the learner was seen as deficient, unfamiliar, and indeed relatively few children typically had any experience of using a computer" (p. 230). It then progressed to surrogacy, which was characterized by the computer being used "as a surrogate teacher, containing a discrete and relatively small body of expertise which could be trickle fed to the 'empty vessel' learner" (p. 231). Initial movement into the progression stage involved the use of "useful little programs" and then content-free applications, which had been developed initially for business (e.g., word processors). Heppell (1993b) argued that moving to the final stage would involve radical change that took into account the new skills and opportunities that IT made available and that children were taking advantage of in their out of school lives (particularly in the context of playing computer games). He went on to say that generally this stage had not been reached, and that

Heppell's 4 stage Model			Heppell's taxonomy of modes of interaction	
Stage 1: Topicality	Focus is on learning about the technology.	↓		
Stage 2: Surrogacy	The computer is used as a 'surrogate teacher'.	↓	**Narrative**	Initiate, watch and listen.
			Interactive	Browse, explore, navigate and choose.
Stage 3: Progression	Focus on use of generic tools.			
Stage 4: Pedagogic Evolution	Computers alter the learning environment and the learners.This stage involves radical change.		**Participative**	As 'interactive', plus originate and present.

Fig. 13 Heppell's four-stage model of the evolution of computer use mapping onto his taxonomy of modes of interaction for integrated media (Heppell, 1993b)

> Stage Four will occur only when the new information capabilities of the 'information generation' are implicitly recognised and pedagogy begins to reflect the radical changes in traditional methods and assumptions that are on offer from rapid hardware and software evolution. (Heppell, 1993b, p. 235)

Heppell presented his four stages as a progression through which computer use in education moves, each new stage building upon, rather than replacing, the stage before. However, Heppell (1993b) did not see this progression as being sequential, in the sense that he noted that new technologies often start back at Stage 1. He illustrated this with reference to the introduction of CD-ROM technology, where initially much of the focus was on the technology itself (i.e., topicality). He argued that this then progressed on to looking at how CD-ROM (alias multimedia) could be used in a surrogacy role to generate financial savings (for example in the first phase of the Teaching and Learning Technology Programme (TLTP) in UK higher education). This suggested that one might end up in the anomalous position of computer use within one class falling into more than one category at the same time.

One other problem became apparent with this four-stage model, related to the notion that the stages build upon one another in a progressive sequence. Progression through cumulative stages would seem to imply that all the stages operate along the same dimension(s) of practice. However, it is clear that the different stages within this model are based around different and apparently unrelated dimensions (see Figure 14). This seemed to suggest that the notion of progression could not apply.

Dwyer et al.'s (1990) Five-Phase Model of Teacher Development

Dwyer et al.'s (1990) five-phase model of teacher development in high-tech classrooms was based on the ACOT (Apple Classrooms of Tomorrow) research. It focussed on the "stages of development" that ACOT teachers went through during the first four years of that project. In devising the framework a wide range of data were analysed, including personal reports from teachers, weekly site reports, classroom observations, interviews with students, parents, and teachers and cross-site assessment data supplemented by additional measures. These data were organised into around 13,000 learning or teaching episodes, which were analysed to look for changing patterns of teachers' practices and beliefs. It was from this that the five-phase model of teacher development emerged (see Figure 15).

Stage		**Underlying dimension(s)**
1: Topicality	**Progression** ↓	Extent to which focus is on 'learning about computers' or 'learning how to use computers'
2: Surrogacy		Software type (very similar to Taylor's model)
3: Progression		
4: Pedagogic Evolution		Degree of change or impact that computer use has on the content and processes of learning

Fig. 14 Comparison of the different dimensions that seem to underpin Heppell's four-stage model

Phase	Summarized as	More detailed description
Entry	Traditional schooling, based on didactic models of teaching and 'knowledge transmission' firmly in place.	Includes the use of a range of 'text-based' technologies (e.g., textbooks, blackboards) to support 'lecture, recitation, and seat-work' (Dwyer et al., 1990, p.4).
Adoption	Use of new technology to support traditional model of didactic teaching.	Teachers' moved away from worrying about how to connect up and operate the technology and towards thinking about how to use it in their teaching. The technology was used "to support text-based drill-and-practice instruction. Students continued to receive steady diets of whole-group lectures and recitation and individualized seatwork." (Dwyer et al., 1990, p.5). Students' attendance levels increased, and their self-esteem and motivation were 'strong'. The levels of discipline problems reported were low. Students' performance on traditional measures of achievement did not alter on average, although teachers reported that individual pupils performed better.
Adaptation	Increasing student productivity allowing more time for teachers to engage students in 'higher-order learning objectives' (Dwyer et al., 1990, p.6).	Students worked faster - productivity went up. For example, it was reported that children completed the entire maths syllabus in 60% of the time, while their scores remained similar with previous years. The quantity and quality of their writing also increased significantly. There were two impacts of this increased productivity on the teachers: "The extra time led to increased opportunities for teachers to engage students in higher-order learning objectives and problem solving in math." "outpouring of text overwhelmed ACOT's teachers and led to the need for new strategies for instruction, feedback, and evaluation." (Dwyer et al., 1990, p.6) Student engagement with schoolwork increased.
Appropriation	Roles shifted noticeably and new instructional patterns emerge – from teacher to facilitator – from didactic to constructivist.	The transition to this phase was dependent upon the level of teachers' personal 'mastery' of the technology. "Appropriation is the point at which an individual comes to understand technology and use it effortlessly as a tool to accomplish real work." (Dwyer et al., 1990, p.6). Key changes in this phase included major shifts in roles within the classrooms, accompanied by moves towards team teaching, interdisciplinary project-based work and individually paced instruction. The teachers began to recognize and value the students' expertise and noticed that the students themselves started to move towards more collaborative ways of working. The teachers started to make greater use of students to teach each other, and at the same time the teachers' role changed moved towards "becoming facilitators rather than dispensers of knowledge." (Dwyer et al., 1990, p.7). Another key characteristic of this phase "was an increasing tendency of ACOT's teachers to reflect on teaching, to question old patterns, to speculate about the causes behind changes they were seeing in their students." (Dwyer et al., 1990, p.8).
Invention	Purposeful radical change in classroom practices.	This phase was not reached within the ACOT work that is reported by Dwyer et al. (1990), but they identify that their teachers were beginning to be ready to think about purposeful educational change. The invention phase is thus "a placeholder for further development" (Dwyer et al., 1990, p.8).

Fig. 15 Description of the five-phase model of teacher development (Dwyer et al., 1990)

The language used in the framework reflected its origins in the USA. For example, the descriptions of the entry and adoption phases both refer to "lecture, recitation, and seat-work." These are not terms that are commonly used in the context of primary education in many other countries, and might reflect differences in the cultural context.

Similarly, there were differences in the prevalent forms of computer use between primary schools in the USA and other countries such as Australia and the UK during the time that the ACOT research was taking place. These differences were epitomised by the predominance of computer labs in US primary schools, which were almost totally absent from primary schools in some other countries where the norm was for computers to be distributed evenly throughout the classrooms. Part of the reason for this difference related to an underpinning assumption that was evident within Dwyer et al.'s model, namely, that the traditional model of education in USA primary schools was highly didactic and based on behaviourist principles.

The ACOT research from which this framework emerged had as one of its primary targets the desire to "fundamentally change teaching and learning" (Dwyer et al., 1990, p. 1) with "a decided bias towards a constructivist view of learning" (Dwyer et al., 1990, p. 2). Dwyer et al.'s model reflected the notion that using computers would lead to a change in pedagogy towards a more flexible, child-centered approach based on constructivist principles. Implicit within this seems to be an assumption that IT acts as a catalyst for change – a kind of Trojan Mouse. However, available evidence seems to indicate that technology is more often assimilated into current practice (Cuban, 1993, 2001) rather than leading to pedagogical change. Within the ACOT research, where pedagogical change was evident, this may have been more to do with the fact that the ACOT researchers "began actively educating and encouraging teachers to implement knowledge construction in their classrooms" (Dwyer et al., 1990, p. 2) than because of the high levels of IT resources.

As we have seen, the five-phase model is underpinned by clear views of "good practice," with movements from entry to invention being seen as progress or improvement. Thus the framework is value laden in the sense that certain forms of classroom practice are seen as being of higher quality than are others. This might be encapsulated in a notion of moving away from didactic or behaviorist models to student-centered or constructivist ones, and clearly means that the framework favours certain ways of using computers. This leaves it open to criticism by those who hold alternative views of effective educational practice.

Sandholtz et al.'s (1990) Teachers' Concerns Framework

Sandholtz et al. (1990) were concerned with "the evolution of classroom management in ACOT's high-tech classrooms" (p. 2). Their framework, which is summarised in Figure 16, identified three stages through which teachers progress in their use of computers. Sandholtz et al. made it clear that in applying this model, it was important to bear in mind that the stages are not clear cut or strictly sequential; teachers may "regress" temporarily when new equipment or students are introduced.

Given that both this framework and Dwyer et al.'s five-phase model emerged from the ACOT research, it is not surprising that there are many similarities between them.

Stage	Description
1.	**Main feature: Teachers' inability to anticipate problems**
Survival	Four main types of problem: **Student misbehavior and attitudes**, which include: new types of misbehaviors relating to hardware and software (e.g., copying software, sabotage); new ways to 'cheat' (e.g., plagiarism and hacking into CMA systems); new excuses for not doing work (e.g., homework not completed because the computer crashed at home); students resisting the teacher's directions (e.g., wanting to use the computers when the teacher wanted them to do something else). **Physical environment issues,** which can be related to: facets of 'traditional' classroom design (e.g., classrooms becoming more crowded and more cluttered; problems relating to lighting and glare); and 'external' environmental issues (e.g., overheating, 'floods'). **Technical problems, which included:** equipment not arriving on time; breakdowns; bottlenecks (e.g., at printers); as well as issues of software 'maintenance' and management. Technical problems were the most commonly reported type of difficulty and "upset both their daily and long-range plans." (Sandholtz et al., 1990 p.5). **Classroom dynamics,** which related to changes in aspects of classroom practice such as: an increase in noise level; increased pupil movement around the classrooms; children knowing more than teachers about how to operate the technology (and hence changes in roles).
2.	**Main feature: Teachers anticipate and develop strategies to solve problems**
Mastery	A key feature of this was the way in which teachers, as they increased their technical competence, started to share their skills with other teachers to a greater degree. Their increasing technical knowledge also: "had a noticeable impact on student engagement," and "strengthened their instruction as well as their classroom management. Teachers began to envision long-term instructional goals that focused on successful problem solving and conceptual understanding rather than specific content." (Sandholtz et al., 1990 p.6). It would appear that teachers within this stage of the model were changing their views about their role. They seemed to move towards a more problem based/learner centred model with the teacher as facilitator and the educational goals being to do with process more than product (developing skills rather than remembering facts). As part of this re-orientation teachers became less concerned about issues relating to things such as the free movement of children around the class and the noise level.
3. Impact	**Main feature: Teachers use technology "to their advantage in managing the classroom" (Sandholtz et al., 1990 p.7)**
	"teachers discovered the technology could save time rather than create additional demands." (Sandholtz et al., 1990 p.7) Initially this seemed to develop in terms of efficiency gains in the teachers' preparation, marking and administration (e.g., record keeping, preparation of materials, automating marking). It then moved into instructional areas. For example, some maths teachers reported that they "could reduce class time spent on practicing arithmetic skills by relying on computer homework; this freed class time for developing problem solving skills." (Sandholtz et al., 1990 p.7). Within this stage teachers clearly rethought their role, and in so doing started to make use of the children's expertise, both as peer tutors and to do work that the teacher would otherwise have needed to do (e.g., solving technical problems the teacher couldn't solve). By drawing on the children's expertise the teachers freed up their own time which "made it possible to provide more individual help to those who were experiencing difficulties." (Sandholtz et al., 1990 p.7). The management strategies moved towards a learner centered model. These changes in the teachers were accompanied by increasing levels of pupil interest and attention. One of the indicators of teachers having reached this stage was that they stopped worrying about having the technology and started to worry about how they would cope if they did not have the technology, as illustrated by this quote from the research data: "It would be hard to live without a computer ... It has become a way of life." (Sandholtz et al., 1990 p.7)

Fig. 16 Description of Sandholtz et al.'s (1990) teacher's concerns framework

For example, they share the same underpinned set of values about the most effective ways to teach. Thus, the teacher's concerns framework indicated that in moving from Stage 1 to Stage 2 there will be a shift from focusing on end products of learning and towards learning processes. Given that the model claimed to represent progression in the use of computers this suggests that this shift in pedagogical focus is necessarily associated with advances in computer use (from Survival to Mastery). Thus both models also seem to share the assumption that IT necessarily acts as a catalyst for pedagogical change. Many would argue that this is a false assumption (e.g., Cuban, 1993, 2001; Gibson, 2001) and the existence of the "reality-rhetoric gap" would seem to support that view.

The problem of cultural difference between the USA and other countries appeared to be less significant for the Teachers' concerns framework than to the Five Phase Model. This was probably due to the fact that it made fewer explicit demands on the underpinning view of education than Dwyer et al.'s Five Phase Model. The latter used notions of shifts from didactic to constructivist teaching as one of the main dimensions, while the Sandholtz et al.'s framework only included this as a small part of the definition of each of its stages.

Despite their limitations, evolutionary frameworks are helpful in highlighting that there is a process that a school has to go through in moving towards its vision for how IT should be being used. While some of these frameworks might seem to suggest that the process is linear, others make it clear that the implementation of IT is a messy, non-linear process. All of them give an indication of the differences in focus that might exist for individuals at different points in the change process and thus the differences in support that are necessary. However, one needs to be cautious in making use of these frameworks to ensure that the vision of change implicit within the framework corresponds with your school's pedagogical vision for how IT should be being used.

Conclusions

Figure 17 provides a brief summary of the different types of frameworks explored in this chapter and the suggested benefits and limitations of each.

As we have seen, each category of framework has a different focus, and often they are intended to be used at different levels (e.g., individual – classroom – school). They each provide a different lens for looking at the role of IT within your school. Each lens can provide a different perspective or way of thinking, which may be useful at different times or for different purposes. Within this chapter we have focussed on vision building, which is just one aspect of school or curriculum development. Many of these frameworks have the potential to support other aspects of the development process (e.g., see Twining, 2004, for a discussion of the use of the CPF to support curriculum development).

At the beginning of the chapter we argued that there had been a lack of return on the investment that has been made in IT in schools. We went on to argue that one of the key reasons for this was that schools lacked shared visions for why they were using ICT. On the basis of the analysis of different types of IT frameworks, it seems

Framework type	Useful for vision building	Other uses
Achievement frameworks	No	Provide metrics against which achievement can be measured
Cognitive frameworks	No	Thinking about interactions at the level of the individual
Software frameworks	Limited	To categorise software
Pedagogical frameworks	Yes	To compare practice in different contexts and/or over time
Evolutionary frameworks	No	To think about the change process once you have established your vision

Fig. 17 Summary of IT frameworks

likely that pedagogical frameworks, such as PIPs and The CPF, provide the most powerful tools for developing shared visions and hence enhancing the impact of IT in education.

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6.3

QUALITY SUPPORT FOR ICT IN SCHOOLS

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Introduction

As microcomputers found their way into classrooms in the 1980s, teachers began to see and experience the transformative potential of this new technology to engage students in learning. Schools increasingly allocated funds to acquire hardware and software, and more teachers began experimenting with integrating information and communication technology (ICT) in their teaching. Some early approaches to computer implementation involved setting up laboratories and offering computer literacy and programming classes, while the others focused on integrating computers throughout the curriculum. The goal of integration on a school-wide basis, of course, involves a major change in what teacher needs to know and be able to do.

As computers expanded in schools, implementation issues of coordination, staff development, and support began to emerge. One approach to address these growing concerns was through a newly created role – the computer coordinator (Moursund, 1985; Strudler and Gall, 1988). The computer coordinator, later called technology coordinator or ICT coordinator, in addition to coordinating acquisition and maintenance of computer resources, worked with the teachers to provide staff development and follow-up support.

Today, of course, ICT has proliferated in schools to the point where it is becoming ubiquitous and to varying degrees, a seamless component of the learning environment. As the technology and its applications have evolved, so too have the demands on those assigned to coordinate such efforts. The technology has become increasingly sophisticated, and users are becoming more dependent on having reliable access to it. In addition, expectations for school-wide use of ICT in the curriculum have increased the need for teachers to get help in planning for and teaching with technology.

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In this chapter, we will review issues pertaining to providing quality support for teachers to use ICT in schools. This work is based on an international review of literature, including articles from the Second International Technology in Education Study, Module 2 (SITES M2), which featured 174 case studies of schools using technology in innovative ways from 28 participating countries (Voogt, 2008; Nachmias, Mioduser, and Forkosh-Baruch in this handbook). The SITES-M2 literature specifically examined schools using ICT in innovative ways to support teaching and learning; therefore, it is difficult to discern how representative they are of other schools and ICT usage in their respective countries. On the basis of the literature, this chapter includes a discussion of ICT integration issues that serve as a foundation for the chapter, a framework for professional development for teachers, some issues pertaining to providing technology support including the role of ICT coordinators, and some conclusions about the current state of ICT support in schools.

It should be noted that we use the term ICT coordinator as the generic title of a member of a school's community most responsible for and familiar with issues relating to the use of ICT in a given school. The position may be a full-time formal position in some schools, a part-time position, or an additional duty in other schools. Some schools may not have an ICT coordinator at all. It is not known which countries have someone serving in this capacity in schools; however, we have found the position to exist in the United States, the United Kingdom (Harris, 2002), Australia (Ainley et al., 2002), Germany (Schulz-Zander et al., 2002), and Holland (Bryderup and Kowalski, 2002).

Need for and Aspects of ICT Support

Over the past quarter century, schools have adopted the goal of ICT integration for various reasons. The most pervasive rationale was tied to a sense that technology is the "way of the future," and schools need to prepare students for a technology-rich world. That general argument included the need for students to be skilled in the technical aspects of using ICT required in the work world as well as be literate in their ability to search for, gather, and critically evaluate information (Donnelly et al., 2002). Moreover, many educators looked to technology for its potential to address higher academic standards for student learning. Although the goals of ICT literacy could be addressed in contained, specialized classes, many believed that the most effective way to prepare students for our high-tech world was by integrating its use across the curriculum for authentic purposes. Furthermore, a large body of evidence suggests that ICT has the greatest potential for student learning when part of innovative, reform-minded teaching implemented across a school program (Becker, 2000; Condie and Munro, 2007; Kozma, 2003; Means et al., 1995; Sandholtz et al., 1997; Venezky and Davis, 2002; Wenglinsky, 1998, 2005).

One early, high profile project was the Apple Classroom of Tomorrow (ACOT), which was conducted at multiple sites for a decade beginning in 1985. ACOT researchers found that technology-rich learning environments tended to evolve from traditional practices toward fundamentally different forms of interactions among students, involved higher-level cognitive tasks, and led to constructivist-compatible beliefs and practices among participating teachers (Sandholtz et al., 1997). Case studies of other efforts with ICT provide ample evidence of these trends and suggest a range of positive student outcomes when the technology is thoughtfully implemented as part of school-wide reform efforts (Condie and Munro, 2007; Kozma, 2003; Means et al., 1995).

Although many studies have shown "no significant difference" in terms of the impact of technology-based methods, such studies often do not discern between effective vs. ineffective implementation of ICT. As Harris (2002) noted, to evaluate the effectiveness of current and emerging technologies and maximize their use, conditions for successful ICT implementation must first be met.

What conditions, then, help foster positive outcomes with ICT integration? On the basis of extensive survey data from the Teaching, Learning, and Computing study, Becker (2000) concluded:

> …under the right conditions—where teachers are perfectly comfortable and at least moderately skilled in using computers themselves, where the school's daily class schedule permits allocating time for students to use computers as part of class assignments, where enough equipment is available and convenient to permit computer activities to flow seamlessly alongside other learning tasks, and where teachers' personal philosophies support a student-centered constructivist pedagogy that incorporates collaborative projects defined partly by student interest—computers are clearly becoming a valuable and well-functioning instructional tool (2000, p. 29).

In an analysis of data from the National Assessment of Educational Progress (NAEP) in the USA, Wenglinsky (1998) added that teacher's professional development in technology and the use of computers to teach higher-order thinking skills were both positively related to student academic achievement. Although these findings, combined with those of Becker (2000), do not create a comprehensive list of essential conditions, they do contribute to our understanding of factors associated with successful implementation and suggest issues to address when formulating a long-term plan for ICT integration.

Theoretical Perspectives: Supporting Teacher Learning

Research has shown that efforts to integrate ICT in technology-rich classrooms involve significant changes in teachers' beliefs and practices over time. Such changes have important implications for the support necessary to help them successfully navigate through the technical and instructional challenges that they may face and ultimately construct new knowledge about their pedagogy. In studying teachers at multiple sites, ACOT researchers (Dwyer et al., 1991) identified five phases that characterize such changes – entry, adoption, adaptation, appropriation, and invention. In this model, they observed "text-based curriculum delivered in a lecture-recitation-seatwork mode is first strengthened through the use of technology and then gradually replaced by far more dynamic learning experiences for students" (p. 47). Furthermore, they found that collegial interaction and support is helpful in all of the phases and technical support is required in all after *entry*, while instructional sharing and collaboration characterize the latter three phases in the process. The researchers concluded, therefore, that a combination of technical, instructional, and collegial support is critical for teachers to make significant changes integrating ICT into their teaching practice.

Fullan (2001) noted that the implementation of an innovation is none other than a process of resocialization that requires on-going interaction. This notion is nicely illustrated by the framework for *How People Learn,* developed by Bransford et al. (1999) and adopted by Dexter and Anderson (2002) for analyzing their multicase study of teacher learning and support for ICT implementation. Dexter and Anderson (2002) explained that according to this framework, there are four essential elements for the design of learning environments:

> It should be *learner-centered*, and take individual learner knowledge and prior experience into account. It should be *knowledge-centered*, or directed toward developing deep understanding. It should be *assessment-centered*, and use feedback and other assessment mechanisms to guide the learner. And it should be *community-centered*, allowing for common sharing of information (p. 3).

This fits well with the current notion of learning communities to support teacher change (Eaker et al., 2002; Fullan, 2001; Senge et al., 2000). Fullan (2001) explains, "Professional learning communities and collaborative cultures incorporate both support and pressure through lateral accountability as teachers together monitor what they are doing" (p. 92). Although he notes that pressure is usually not thought of as a good thing, it plays a positive role in the change process. "Pressure without support leads to resistance and alienation; support without pressure leads to drift of waste of resources" (Fullan, 2001; p. 92). And that is why, he adds, professional learning communities are so effective – "they provide pressure and support in a seamless way" (p. 91).

Providing Access: Hardware Distribution

For ICT to effectively support learning in schools, students need to have adequate access. Toward that end, one strategy for distributing machines has been placing them together in a laboratory to amass a sufficient number for students to use in classes. That approach, as previously noted, works well for specialized computer classes or for basic skills work with integrated learning systems. Also, as noted by Herman (cited in Means et al., 1995), this approach was especially attractive as schools were starting up with technology, as an ICT coordinator or small group of teachers could enable many students to use the computers. However, disadvantages of such an approach have been often cited. It has been argued that if students do not use the technology tools to address their classroom work, then the power of the technology will not be maximized to enhance core academic learning (Means et al., 1995).

Although there are many examples of using general-purpose labs that are available on a sign-up basis, teachers may find that this arrangement may not fit well with the flow of their instruction.

However, ICT integration, especially project-based approaches, requires a high degree of access to networked technology tools. In studying nine sites in their case studies, SRI researchers analyzed the pros and cons of various strategies for distributing computers and providing students access (Means et al., 1995). They found that placing the computers in classrooms is only likely to be effective if each classroom receives a critical mass of machines – something in the order of six to eight. They concluded that putting one or two computers in each room for student use appears to be ineffective. These findings are supported by Becker et al., (1999), who found that teachers who have five to six computers in their classrooms are much more likely to use them on a regular basis when compared with teachers who might use a lab on a sign-up basis.

An alternative to putting multiple computers in each room has been to place computers on rolling carts, or more recently, to create carts of laptops. Proponents of these approaches maintain that the carts allow flexibility for providing access to ICT when needed. As with general-purpose labs, effective coordination is required for the system to work.

The latest development in distribution of ICT in schools is for each student to have a computer or handheld device. This approach is receiving a great deal of attention of late and has great promise for addressing the goals of seamless ICT integration in core academic subjects.

In summary, ICT has been adopted in schools for a variety of purposes, and its implementation has involved a wide range hardware configurations and pedagogical approaches. For ICT implementation to be effective, leaders must take into account the goals of the program and the needs of the teachers seeking to accomplish those goals. Where the goals involve school-wide uses of ICT, effective leadership involves helping teachers to learn and providing them with ready access to supported, managed technology. This, of course, requires a great deal of coordination in terms of the professional development needs of the teachers and the various aspects and staffing for ICT support. Each of these topics will be addressed in subsequent sections.

Teacher Professional Development

The research literature is clear that professional development is one of the critical components for effective ICT integration, and the amount of professional development teachers undertake is positively correlated with ICT use in the classroom (Becker et al., 1999; Wenglinsky, 1998). Although evidence supporting the quality and effectiveness of professional development is often anecdotal, a large-scale study of US federally funded Eisenhower projects identified six factors associated with successful professional development (Garet et al., 2001). The first three are structural features that set the context; the next three are core features that characterize the processes that occur. Each is summarized below:

a. The *form* of the activity. Reform type of activities (e.g., teacher network or study group) were found to be more effective than traditional workshops, primarily because they are longer and incorporate more the characteristics described below.
b. The *duration* of the activity (both time per session and number of sessions). Findings indicate that longer is better.
c. *Collective participation* of groups of teachers from the same school, department, or grade was found to be more effective than individual participation.
d. *Active learning* opportunities were associated with effective professional development.
e. *Content focus* was deemed more effective than generic teaching strategies not tied to particular content areas.
f. *Coherence* is the degree to which the activity is tied to school goals, policies, standards, etc. The greater the coherence for teachers, the more effective is the professional development.

Of particular relevance is the degree that the characteristics mentioned above fit with models for providing ICT-based teacher support at the school level. In a report prepared for the US Department of Education, Donnelly et al. (2002) described a range of approaches to technology-related professional development including: (a) teachers as technology trainers or *train the trainers*, (b) students as technology trainers, (c) site technology coordinators and technology resource teachers, (d) professional development workshops and summer institutes, (e) district-level support from coordinators and centers, (f) professional development from the technology itself (e.g., CD-ROMs, Web-based resources, online courses), (g) vendor-supplied training, (h) university courses on technology integration, and (i) informal approaches to technology-related professional development.

Which of these approaches appear to have the greatest promise to meet the learning needs of teachers? Of course, comprehensive plans for ICT professional development will include multiple opportunities for teachers to learn via a combination of approaches. However, all approaches on the list are not equal in their potential to impact whole-school reform. In general, on the basis of the characteristics of effective professional development described earlier, we know that approaches are preferable if they are school-based, grounded within content and grade-level groups, consistent with school goals and policies, offered over an extended period of time, and based on active learning that relates directly to teachers' curricular goals. Although approaches that support individual teachers can be extremely helpful for those involved, the full power of professional development will more likely be unleashed when it supports group goals and contributes to the professional learning communities within the school.

Numerous descriptive studies illustrate aspects of these approaches and the outcomes that can be attained. For example, Hennessy and Deaney (2005) conducted a follow-up study of 16 teacher-researchers in five English secondary schools, who had participated three years before in a professional development program designed to develop a range of pedagogical strategies for ICT integration. The follow-up study investigated how project teachers had developed and disseminated these practices over time and identified factors that influenced project outcomes. Findings included that all participants sustained and further developed the particular practices that they had developed three years prior. Mechanisms through which the evolution of their practice had taken place over time included *trialing* pedagogic strategies and gradually refining them, and receiving feedback from colleagues and collaboratively developing and sharing resources. The researchers noted that "a strong degree of departmental collaboration emerged in which the teachers appeared to treat the development of technology use as a joint learning enterprise" (p. 4).

Dexter et al. (2002), as part of the Second International Technology in Education Study, Module 2 (SITES M2), identified highly effective technology-using schools and investigated the relationship between the presence of a well-supported ICT program and the professional community among teachers. The researchers found that the teachers' shared need to learn technology contributed to the development of professional community and likewise, the professional community at the school contributed to more innovative and thoughtful use of the technology. As the participating schools were identified as exemplary in their use of technology toward reform-minded practice, it is difficult to assess the impact of the technology in the schools' culture and dynamics. However, the authors did conclude that the effective use of technology and positive professional community appear mutually supportive, and that the synergy created by this reciprocal interaction can move schools toward becoming effective learning organizations.

Staffing for ICT Support

Effective leadership and support is clearly needed to realize the potential of ICT to impact teaching and learning. The leadership role of the school principal, or head teacher, has been shown to be important to the implementation of various reforms and innovations in schools, including ICT (Harrison, 1998; Ronnkvist et al., 2000). Although such leadership is a necessary condition to effective implementation of ICT in schools, it is not sufficient by itself.

In addition to leadership, support for ICT that is readily available to all members of a school community is critical for success. Such support may be provided by a variety of people, but over the years the position of ICT coordinator has developed into the primary and leading support provider in many schools. An understanding of quality ICT support requires an appreciation of the needs of the people who work, teach, and learn in schools. These needs, some local to particular schools but many common to schools everywhere, have shaped the cast of characters providing support for ICT in schools in general and the role of the ICT coordinator in particular.

Because of the increasing complexity of teachers' jobs, technology proliferation, and increased reliance on ICT in schools, teachers and other school personnel simply cannot keep up to date with developments in ICT (Harrison, 1998; Ronnkvist et al., 2000; Strudler et al., 2005; Hearrington, 2006; Zhao et al., 2002; Davidson, 2003; Davidson and Olson, 2003). A simple measure of this complexity is the number of computers per student. In the United States, there were 125 students for every one computer in the 1982–1983 school year (Moursund, 1992). The Organization for

Economic Co-operation and Development (OECD) reports that this ratio is less than 1:5 in some European OECD countries in 2006 (OECD, 2006). The Japanese Ministry of Education (2006) reports that the number of students per computer in Japan ranged from 1:9.6 in elementary schools to 1:4.6 in secondary schools in 2005. In the United States, the ratio of students per computer was 1:3 in 2003 (OECD, 2006). The increasing complexity of the duties of all members of a school's community, in conjunction with this increase in ICT over the years, makes it difficult for individuals to fully utilize and understand the technologies, resulting in increased importance of the ICT coordinator and a team approach to dealing with the issues of ICT in schools.

Support Needs

Schools have come to rely on ICT for an increasing number of purposes. They use ICT for administrative tasks, personal productivity of faculty and staff members, instruction, as well as intra and extra school communications. The expanding use of ICT and the increasing variety of hardware, software, and technologies in schools has been described as a form of proliferation requiring ever-increasing support (Hearrington, 2006). In addition, schools need technical support to keep the equipment functioning, instructional support to help teachers plan for and use ICT as a teaching and learning tool, professional development, ICT planning and coordination, and a liaison with district personnel and outside resource providers (Strudler and Gall, 1988; Strudler et al., 2005; Ronnkvist et al., 2000; Davidson and Olson, 2003).

An example school in the USA with 1,000 students may contain over 300 computers, plus associated peripheral devices, and a network infrastructure in addition to other ICT. Standards for computer support in business and industry typically call for one technician for every 50–75 computers, which is also the goal in schools (Consortium for School Networking, 2001; International Society for Technology in Education, 2007). Using these numbers as a benchmark, this example school should have between four and six people providing ICT support. Clearly, this level of support is not available in schools. Indeed, where the support of a coordinator is available it may be diminished because in one study, 45% of ICT coordinators in the United States reportedly had teaching duties in addition to their coordinator duties (Ronnkvist et al., 2000).

This support for ICT in schools is important because it has been empirically shown that the availability of quality ICT support impacts the frequency, variety, and increased use of technology in the classroom. Dexter et al. (2002) operationalized *quality technology support* as the combination of (a) access to one-on-one personal guidance and help, (b) frequent teacher participation in technology-oriented professional support among peers, (c) professional development content focused on instruction and integration, and (d) access to resources. These results suggest that educational leaders and administrators who hope for greater integration and more powerful uses of ICT in classrooms should take steps to provide such quality ICT support (Dexter et al., 2002).

Frameworks for ICT Support

Recognizing the need for quality support, the British Educational Communications and Technology Agency (BECTA) and the International Society for Technology in Education (ISTE) have created frameworks by which school districts can measure their support. Another useful framework for thinking about implementing technology in schools, including support issues, is the Educational Technology Integration and Implementation Principles (eTIPS) (Dexter, 2002). Each of these frameworks is discussed later.

BECTA has created the Framework for ICT Technical Support (FITS), which is a process of establishing a service desk, managing incidents, managing problems, managing change, managing hardware and software configurations, strategically releasing these configurations for use, creating, and managing service levels, planning for continuity in the event of a disaster, and managing finances (BECTA, 2004). FITS is a comprehensive, systems approach that attempts to implement proactive processes for support by using a change management strategy to modify organizational ICT behaviors. BECTA has also created the ICT Competencies, which specifies the technical, support, development, and personal competencies of school ICT coordinators (called teaching assistants in the framework), ICT technicians, senior ICT technicians, and ICT senior systems managers (BECTA, 2007). The ICT Competencies Framework lists skills for the school ICT coordinator such as to connect up and check hardware for normal operation, install simple software applications, verify that computer drives are working, arrange desktop icons and create class work areas, be able to provide basic user account management, connect a preconfigured computer to a network, and maintain records of hardware and software.

ISTE has created the Technology Support Index (TSI), which does not specify the technical skills of a school ICT coordinator, but instead specifies the kinds and qualities of support a school needs (ISTE, 2007). The TSI covers equipment standards, staffing and processes, professional development, and enterprise management. Perhaps most important to the role of the school coordinator are the TSI recommendations that the computer-to-technician ratio be 75:1 and that schools have a comprehensive staff development program, including online and just-in-time training. Finally, the TSI recommends that school staff have technical performance proficiency expectations and that they learn how to troubleshoot simple problems (ISTE, 2007).

The Educational Technology Integration and Implementation Principles in Schools (eTIPS) is a six-point framework divided into classroom and school level principles. Classroom principles include: (1) learning outcomes should drive the selection of technology, (2) technology use provides added value to teaching and learning, and (3) technology assists in assessment of learning. School level principles are: (4) ready access to supported technology is provided, (5) professional development is targeted at successful technology integration, and (6) professional community enhances technology integration and implementation (Dexter, 2002). The fourth eTIPS principle requires that technology be functional, accessible in terms of physical location and time available, and that technical and instructional support should be available on an ongoing basis, especially when needed (Dexter, 2002). This framework provides a useful, holistic, way at looking at ICT support in context with other school and classroom level conditions needed for successful implementation of ICT.

Support Staff

This section describes what is known about who provides support for ICT in schools, details about the ICT coordinator position, and the relationships between professional learning communities and ICT. Although we sought to provide an international perspective on the prevalence and duties of ICT coordinators and others providing ICT support in schools, much of the data found were primarily from the USA. The role of learning communities in the implementation of ICT in schools, which is also addressed, reflects a broader international perspective.

Who Provides ICT Support in Schools?

In, perhaps, the most comprehensive examination of school technology support available in the United States, Ronnkvist et al. (2000) reported the results of their survey of a national sample of 488 principals, 467 school ICT coordinators, and 2,251 teachers in 1,215 schools. They found that 87% of schools had someone assigned to fill the role of ICT coordinator, but that only 19% of schools had someone serving in that capacity on a full-time basis. Many of the coordinators in this study also held additional jobs. Coordinators reported additionally serving as classroom instructors (45%), network coordinators (26%), media specialists (16%), and miscellaneous other roles (13%).

In addition to school ICT coordinators, surveys of school library media specialists (traditionally called librarians) in the United States reveal that they play a wide variety of roles related to ICT leadership in their schools. Nearly two-thirds of the 1,696 media specialists responding to a national survey reported serving on their school technology team, 32% are part of their district technology team, 45% maintain the hardware, and 52% maintain the software in their media centers, while 18% manage the hardware and software for their entire school (Brewer and Milam, 2006). Additionally, in a prior national survey of 1,571 media specialists, 31% reported maintaining their school's Web site (Brewer and Milam, 2005).

Although school ICT coordinators and media specialists represent just a small number of people in a school, the largest group of people that may be used to provide support in any school is often its students. A national survey of school districts in the United States found that 54% of them reported having students provide some technical support in their schools. Most commonly, such support included troubleshooting problems (43%), setting up equipment and wiring (39%), and providing technical maintenance (36%) (National School Boards Foundation, 2002). Students tend to be well-suited for such tasks as inspecting and cleaning equipment, manning a help desk, providing frontline support and troubleshooting, updating and upgrading hardware and software, testing Web site links and access, create or update frequently-asked-questions databases, and providing training for teachers (Apple Computer, 2004). Students may benefit from participating in such a program by acquiring twenty-first century skills, increasing confidence and engagement in schooling, gaining workforce skills, obtaining industry-recognized IT certifications, and engaging in service learning (Apple Computer, 2004). Advisors of students participating in such programs and students themselves report their technical knowledge and skills, as well as their communications and leadership skills increased as a result of spending a year in a student technical support program (Schneider, 2006). Additionally, students sometimes play the role of tutor to their teachers because they often have ICT skills their teachers lack. This role may exist in many countries, but was specifically found to occur in the United States, where students have helped over 40,000 teachers learn and integrate ICT since 1996 in one project (Generation YES, 2007), in Germany, where one national survey of computer coordinators found that 24% of male students and 8% of female students tutored teachers (Schulz-Zander, 2001 as cited in Schulz-Zander et al., 2002), and Israel, where students not only tutored their teachers but also assisted them in planning and implementing ICT-based lessons (Mioduser et al., 2002).

The School ICT Coordinator

Duties and Skills

The school ICT coordinator performs a wide variety of duties, and their job descriptions vary a great deal. Therefore, the position has been conceptualized in many different ways depending on local needs. Synthesizing the work of Moursund (1992), Harrison (1998), and Frazier and Bailey (2004) produces a fairly comprehensive and overlapping picture of the duties and responsibilities of the school ICT coordinator. Additionally, ICT coordination in primary schools in UK appears to be largely in agreement with these frameworks (Harrison, 1998). As a leader who interacts with teachers, administrators, and curriculum coordinators, ICT coordinators provide timely help to teachers and students, work with other school leaders, help teachers integrate technology and develop curriculum materials, provide professional development, and are responsible for the hardware, software, and networks of their schools (Moursund, 1992). They help to create and implement policies related to ICT, manage budgets, and help with administrative computing as well (Harrison, 1998).

A variety of knowledge, skills, and dispositions needed by coordinators are described in the literature. Strudler and Gall (1988) identified a group of technical and interpersonal skills needed to do the work of a coordinator in their detailed case studies of three school ICT coordinators. Interpersonal skills identified included being supportive, being collaborative, having “interpersonal ease,” communication, being able to confront someone without generating negative affect, being able to mediate conflict, and being able to build trust and rapport. Additionally, Strudler and Gall found that coordinators needed to be able to delicately balance their technical and interpersonal skills to be the most successful.

School ICT coordinators have been identified as change agents – people working to achieve positive changes in a school’s culture and in teaching and learning within a school – by researchers in the US (Strudler and Gall, 1988; Strudler, 1995–1996) and in New Zealand (Lai et al., 2002). By providing leadership, vision, professional development, and support, coordinators work as part of a school's community to facilitate exemplary use of ICT (Dexter et al., 2002; Lai et al., 2002; Matzen and Edmunds, 2007).

Use of Time

Ronnkvist et al. (2000), reporting on their 1998 survey of 1,215 schools, with responses from 467 technology coordinators in the USA, found that there was a difference in the amounts of time spent on various tasks depending on whether the coordinator was full or part-time. Summing the hours full-time coordinators reported spending on nontechnical support tasks (supervising classes, supporting and training teachers, planning and running staff development, and aiding teachers with technology integration), the researchers found that coordinators spent a total of 30 h, on average, each week performing such tasks. In contrast, they spent 19 h per week on technical tasks (installing and troubleshooting and selecting hardware and software). The single greatest use of time reported by full-time coordinators each week (17 h) was for supervising classes (Ronnkvist et al., 2000).

However, other studies have consistently reported that coordinators spend the majority of their time on technical support, rather than instructional support tasks. In a study of six coordinators working in middle schools in the American State of North Carolina, Moallem and Micallef (1997) found that 75% of their time was spent on technical support tasks, despite the original instructional purpose of their role. A similar study of five coordinators working in US state of Georgia revealed that some coordinators spent more than 90% of their time providing technical support (Proctor and Livingston, 1999).

Strudler et al. (2005) studied the population of elementary school-level coordinators in a large southwestern school district from 1999 to 2004. They found that the percentage of time their participants reported spending on technical support tasks started at 30% in 1999 and increased incrementally to 60% in 2004. In contrast, the researchers found that the percentage of time participants spent on professional development and other curriculum support tasks started at nearly 58% in 1999 and decreased incrementally to 30% in 2004. Hearrington (2006), studying elementary coordinators from the same district, found that they reported spending 61% of their time on technical support tasks, with coordinators at the middle school (62%) and high school (67%) reporting spending a bit more of their time on technical support tasks. Overall, coordinators at all levels in this study reported spending 20% of the time on staff development and instructional support tasks (Hearrington, 2006). As was the case with Moallem and Micallef (1997), the goal for the ICT coordinator position in this district was primarily to provide instructional support, but the proliferation of ICT was making that difficult to achieve (Strudler et al., 2005; Hearrington, 2006).

Madsen (2005) compared the local job expectations of school ICT coordinators to the duties they actually performed each day. Studying one school's community and its coordinator, Madsen (2005) found that coordinator spent nearly 39% of her time on technical tasks. Additionally, she found that teachers, administrators, and other staff members at the school expected the coordinator to perform technical tasks, despite the job description that called for the emphasis of the position to be geared more toward instructional support than technical support.

A survey of 129 school-level coordinators spent performing the tasks of their job revealed a similar, but less pronounced, imbalance toward technical support. Hawkes and Brockmüller (2003–2004) reported that participants in their study spent an average of 45% of their time on technical support tasks and 39% of their time on curricular support tasks. Interestingly, they disaggregated their time data by gender to reveal that male coordinators spent more of their time on technical support tasks (47%) compared with female coordinators (43%), while female coordinators spent more of their time on curriculum support tasks (43%) than male coordinators (36%).

Professional Learning Communities and ICT Support

It seems clear on the basis of the research reviewed that school ICT coordinators working alone often have to focus their attention on technical support tasks. ICT has become so important in schools today that it simply must be functional. Everyone relies on the technology to work and when it does not the coordinator is the first person to respond. The integration of ICT in schools has been compared with the integration of a social organization with a technical system (Davidson and Olson, 2003). Technical systems are complex and require people with a variety of technical and social skills to function. In this way of thinking, social organizations, such as schools, require people who can *translate* and facilitate communication with the technical system. Because technical systems and social systems are complex, many people are needed to serve as translators. In terms of ICT in schools, coordinators translate between technicians and technical functionalities to help teachers and administrators understand and use ICT. Most principals and teachers do not understand computer networks, for example, so the coordinator has to translate the concept of a network in ways that help the school use the technology to its potential. In the absence of other translators in schools, it appears that the most critical translation needs – technical support – becomes the primary focus of the coordinator.

However, when there are other translators besides coordinators working in schools, transformation has been more rapid and powerful in terms of collaboration and school culture. Examples of such translators would include teachers who have expertise with using ICT to teach specific skills or subject areas, administrators who have expertise with using ICT to facilitate a professional learning community, and technicians who can explain and configure technologies in ways that meet the needs of schools (Zhao et al., 2002; Davidson and Olson, 2003).

As part of a multiyear qualitative study of ICT support, Davidson and Olson (2003) began with a four-school cluster in 1995 and continued their study as the number of schools expanded to 17 in 1998. Their study, which ended in 2001, was conducted in US Department of Defence schools serving the children of US military families stationed in Germany. As a result of technology integration into the schools, three major changes came about due to translation activities: (a) new roles emerged, (b) old roles were repurposed, and (c) new collective roles were created (Davidson and Olson, 2003). New roles that emerged included the educational technologist (ET), similar to the role of the school ICT coordinator discussed here, and the administrative technologist (AT), a technical support provider. Indeed, after the first year of the program revealed the heavy technical support burden on the ET, the AT position was established the next year (Davidson, 2003).

Existing roles were repurposed as the individuals had to reexamine their roles in light of the technology, requiring them to develop new skills and outlooks. For example, principals, who were not prepared to understand ICT, learned to collaborate with the ETs and ATs because of their translation skills. Teachers developed new knowledge as the technology took hold, resulting in greater collaboration with other teachers and more technology-enriched instruction. Distributed leadership and support developed because no one person could fill all of the roles of a translator in all of the needed areas.

Finally, new collective roles were implemented as a result of ICT implementation teams. Often group of members from across schools, implementation teams, established goals, and developed policy for ICT usage. Teachers, administrators, parents, and others comprised these teams. ETs served as consultants and staff to the teams (Davidson and Olson, 2003).

The roles of the ET and AT are virtually identical to the roles of the Local School Technology Coordinator (LSTC) and the Technology Support Technician (TST) created in a school district in USA (Cypert, 2004; Madsen, 2005). Indeed, this school district also formed these two roles in response to the proliferation and integration of ICT, and formed a very similar team structure to support ICT in their schools. Schools in this district have formalized technology teams, which include the LSTC, the TST, the media specialist, an administrator, and other teachers as needed (Cypert, 2004; Madsen, 2005).

Using the four indicators of quality support (robust access to technology, technical and pedagogical support, professional development, and resource utilization) identified by Ronnkvist et al. (2000), the state of Texas in the USA, conducted the Technology Immersion Pilot (TIP) project at 22 schools. Baseline data on the four indicators of quality support were taken at the start of the project and after one year. The project started in the fall of 2004. Many of the schools in this project had partial or minimal support from part-time coordinators. Data from the five schools with a full-time coordinator supports earlier findings that a coordinator, working alone, often ends up overwhelmed with technical support tasks. Two schools hired a second full-time staff member to provide only instructional support to compliment the coordinator who provided primarily technical support. Schools were judged to have *full immersion* if they scored highly on measures of each of the four indicators of quality support. Schools with full immersion predictably showed greater use of technology, intellectually challenged their students to a greater degree, and had positive changes in school culture such as innovation, collaboration, leadership, parent and community support, and students' school satisfaction (Texas Center for Educational Research, 2006).

The context required for these sorts of innovative uses of ICT in schools clearly requires a robust human infrastructure, including people who can translate and help others make use of ICT (Zhao et al., 2002; Davidson and Olson, 2003). Results from international studies of innovative uses of technology to support pedagogy in the SITES-M2 studies have all revealed the important role a school's community plays in successful implementation of ICT (Ainley et al., 2002; Bryderup and Kowalski, 2002; Harris, 2002; Mioduser et al., 2002; Schulz-Zander et al., 2002). A professional learning community approach, when supported by a team of people who provide quality technical and instructional support, seems to be most conducive for facilitating the effective use of ICT. Indeed, the literature points to greater collaboration, focus on learning, innovative curriculum, and communities of teachers seeking best practices in schools when high quality ICT support is available.

Conclusions

Our review of research points to some clear trends. Schools are increasingly relying on a sophisticated array of ICT tools and quality technology support for teachers is urgently needed. At the most basic level, the equipment, plain and simple, needs to work. With the proliferation of ICT in schools, attending to that basic support function is presenting a major challenge to ICT coordinators, who are primarily responsible for technical support. Although effective ICT coordinators use various skills to keep the equipment functioning, a team approach to technical support appears to be more in line with the proliferation of ICT and the accompanying needs of users.

When we look beyond technical support issues to broader concerns involved with teaching and learning with ICT, the challenges become that much greater. Expectations for whole-school participation increase the scope of what it means to help teachers in their work with ICT. High quality support requires robust access to technology as well as effective technical and pedagogical support, professional development, and resource utilization. Although technology coordinators seek to help meet these needs, evidence suggests that the optimal strategies should include a team approach situated in a professional learning community. If all of the best practices for ICT were established and ready to be disseminated, then perhaps a more limited approach might be feasible. But it appears that there are a multitude of *promising* ICT practices, and teachers need collegial interaction and support as they experiment with finding the *best practices* for their school context. Overall, this is the essence of quality support for ICT – helping teachers identify promising practices in their areas while also providing for the essential conditions that support effective school-wide implementation.

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6.4

DISTRIBUTED LEADERSHIP AND IT

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Introduction

When we talk about leadership we usually equate it with the activities of a particular individual who holds a senior position within an organization or within the wider society: chief executive officers, senior politicians, senior military officers, principals and head teachers are all typical examples. However, there are other ways in which we can think about leadership, and other ways in which we may use the term, often almost unconsciously. Leadership can also be exercised quietly, and come from all kinds of unexpected sources. In this chapter, we will look at the basic characteristics of leadership, using the traditional view of *leadership from the top*, before moving on to explore the characteristics of an analysis of leadership that has become much more widespread in education – *distributed leadership*. Then we will consider circumstances that can help or hinder the exercise of distributed leadership within a school, before concluding with some thoughts on how working through a perception of leadership as a distributed property might assist teachers with IT responsibilities to review their responsibilities and their relationships with their colleagues.

Analysing the Elements of 'Leadership'

In its most basic form, *leadership* involves trying to influence others to do things that they might not otherwise do. At one level, it might simply involve getting someone to agree to undertake a specific task that is not normally part of their job description; at another, it might involve persuading other people to accept the leader's interpretation of events, such as the task that President Bush and Prime Minister Tony Blair faced over the Iraq War. Leadership can involve anything from trying to influence specific actions to trying to influence what we think.

Embedded in this paragraph are several important elements that need drawing out: power and compliance, legitimacy, and good leadership. However, first we must

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recognise that people do not exercise leadership alone, but in a relationship with others. Leadership requires followership: it is a relational activity.

Once we have acknowledged this, we can go on to explore three other sets of questions. First, what enables people to exercise leadership? Why are some leaders successful and others are not? Why are some successful on some occasions and not others? Second, why do we regard some attempts to exercise leadership as legitimate but not others? And third, what is 'good' leadership? These questions involve us examining the concepts of power, influence and trust.

Key Element 1: Power and Compliance

The essential elements in the exercise of leadership are the two opposites of power and compliance. Educators tend to shy away from the idea of power, and to use the term in a derogatory sense: 'they' – government departments, local authorities or curriculum bodies – exercise it over 'us'. However, when we look at the nature of the relationships between teachers and pupils, or between teachers within a school, we can see the same basic characteristic as we can identify between *the school* and *the department/authority*: that is, an asymmetrical relationship in which one party has more power than the other – there is a *power disparity*. National examination boards can prescribe the subject curriculum for teachers to follow, and this can include pedagogic requirements, such as demanding some original research by the candidate. On the one hand, teachers working on examination classes have no choice in what they teach, but they can decide which elements of the syllabus to stress, which to leave out and how they are going to approach teaching them. On the other hand, as Ribbins (2007) demonstrates, heads of department can be very directive in requiring teachers to follow particular pedagogies.

Although relationships are asymmetrical, both parties may be able to exercise power over the other. For example, if we view a classroom as a relationship between a teacher and the pupils, it is an interesting question as to which party has more power. The same question applies in one-to-one teaching relationships – if a keyboarding student fails to practise between one lesson and the next, his/her (in)action can negate the apparent power that the teacher has to provide instruction and set tasks. Grint (1999) argues that in a leader/follower relationship, it is ultimately the followers who have the most power, as their refusal to obey – to comply – can leave the leader powerless. This ignores the longer-term consequences that a larger system can bring to bear on those who refuse, but in the immediate term it is a basic and important point: Wellington could not have won the Battle of Waterloo if the soldiers had refused to obey orders.

It is also possible to distinguish between different kinds and sources of power, and these can affect the distribution of power in a relationship. Put simply, some kinds of power are more powerful than others, and which kind has the upper hand is quite likely to depend on both the relationship and the circumstances in which it exists.

Forms of Power

Hales' (1993) analysis of power is highly relevant to our discussion of distributed leadership and the organizational characteristics that can help or hinder its development. He suggests that we view power as a resource that we can deploy in a particular situation.

Power resources represent things that are scarce, or desired, or both, in that situation. They may not be relevant in other situations. Hales identifies four kinds of power resources: physical, economic, knowledge and normative. Each can be used in positive or negative ways, and can produce different kinds of compliance or non-compliance. It is appropriate to explain each kind of power resource briefly before going on.

Physical power is exactly what it sounds like: the ability to use physical force to influence another's actions. At first sight, it may be seen as bad, but it need not be – restraining someone who is about to jump in front of a train would be an example of the positive use of physical power resources (though this might not be the view of the person who is restrained). However, in the context of most organizational activity, it is usually negative.

Economic power resources are usually the property of individuals by virtue of their particular role or position in an organization. These resources can include the capacity to provide or withhold resources and materials, or to determine salaries and hire or fire others. They are very powerful indeed: IT coordinators who have ultimate control over the budget are likely to be on the receiving end of a lot of lobbying from their colleagues about which resources they should buy, and their decisions will have a major effect on how IT is used in the classroom, possibly despite the wishes of their colleagues – and, indeed, of the school administration. However, if IT coordinators are seen by their senior leaders or administrators to be abusing their budgetary control, they may well have it removed, demonstrating the role-based nature of economic power.

Knowledge power resources are possessed by individuals without any necessary connection with any post they may hold, although they will often have acquired them through their experience in a post or series of posts. The potential knowledge that comes from experience within a field is one major reason why most teachers in England are opposed to non-teachers being appointed to headships, although this is not actually a legal requirement. Hales uses the term *knowledge power resources* to refer to all the forms of knowledge and expertise that individuals can bring to a situation: they may be *technical*, in that they relate to the work that people are doing – the range of ways in IT can be used in the classroom is a particularly *technical* form of pedagogical knowledge, for example – or *administrative*, in that they relate to the workings of the organization. Knowledge of administrative procedures is one reason why experienced colleagues who 'know the ropes' can be very influential, even though they may not hold very senior formal positions within the organization. Indeed, this argument can go further and identify individuals who, although they are not formally senior members of the organization, nevertheless, have very high status, which we can equate with 'senior positions' within the informal 'hierarchy' of relationships that permeate any organization (Bolman and Deal, 2003).

At first sight, IT specialists might see technical knowledge resources as their key source of power and influence within school. They have an input into all areas of the curriculum through the increasingly central role of technology in classroom practice. Their knowledge is important to every teacher. IT technicians who are able to operate sophisticated hardware and software can provide important support to their teaching colleagues and be seen as crucial members of the school staff, despite their holding what is formally a *non-professional* status that is *below* that of the teachers whom they help.

In addition, the knowledge an IT technician may have of how to acquire resources or support from the district office or the local authority, or of the informal procedures that can access materials and support quickly, is invaluable administrative knowledge that should not be underestimated.

Normative power resources are the most difficult to explain, but are probably in the longer term the most important as they exercise their influence at a much deeper level than the other three. Hales (1993, p. 22) defines them as ‘scarce or desired ideas, beliefs, values or affects’. Individuals may have ideas or beliefs that others find attractive, or may simply influence others’ behaviour because they are well-liked and popular people. Normative power resources are essential to effective political and religious leaders, for example, because ultimately we follow them through an emotional attachment to what they say or represent – even if we claim that it is a rational and intellectual response. An IT specialist with a particular vision of school and classroom culture and the place of IT within it is likely to be guided by this vision in deciding which resources to purchase and the kinds of training provided for non-specialist colleagues. When colleagues share this view of classroom culture and practice, they are likely to see the coordinator’s use of economic resources as supportive, and the IT coordinator will develop normative power resources. Normative power resources will not develop between the IT coordinator and colleagues who do not share the same view. When the normative resources available to IT coordinators are weaker than those available to colleagues who promote alternative visions of “proper” educational practice, they will not be able to obtain the deeper acceptance of their leadership that normative resources bring. In this situation, the IT leadership has to draw on other power resources. We will examine this further when we consider the issue of compliance.

By viewing power as a set of resources that relate to a specific situation and draw their strength from the fact that they are scarce or desired in that situation, possessed by some individuals but either wanted or needed by others, Hales demonstrates why there is considerable potential for the development of distributed forms of leadership rather than seeing it in traditional, top–down forms. However, we also have to go beyond this to consider the question of when power resources are seen as positive and negative: in other words, what makes their usage legitimate.

Key Element 2: Legitimacy

In a nutshell, leadership becomes legitimate when it is seen to derive from power resources that are acknowledged to be proper and are deployed in ways that are deemed appropriate. The two are connected. Certain forms of power resources will almost always be seen as non-legitimate, the most obvious being physical force. Associated with physical force, though Hales does not discuss it, is the kind of psychological force that is associated with bullying. Exercising such forms of power may produce compliance, but it will also alienate colleagues. At the other extreme, normative power resources are almost always seen as legitimate, even though they rest on the characteristics of individuals rather than their formal position. We accept and comply with the exercise of normative power because it asks us to take actions that we agree with, or that we agree are appropriate even if we find them distasteful. Economic and knowledge power lie between these two extremes.

Why should we acknowledge and see the exercise of these other forms of power as legitimate? Both can be used negatively as well as positively: withholding resources from a colleague is exercising economic power resources, just as providing resources is, whilst knowledge can be used to assist or to prevent colleagues to complete a task. As indicated earlier, this can make the ways in which IT specialists use economic and knowledge resources critical to the culture of the school and the success of individual colleagues. Hales (1993) suggests that the exercise of economic and knowledge power resources gets legitimated by the consequences of their being exercised, initially on a situation-by-situation basis. If resources are both promised and provided, we are more likely to agree to the person exercising economic resources in the future, and the more this continues, the more legitimate their exercise becomes. Similarly, if a person's knowledge of administrative procedures turns out to be consistently correct, or the pedagogical advice on handling classroom problems is usually helpful, then we are more likely to accept that that person's knowledge is valid. In Hales' terms, we move progressively from a calculative compliance –'is it worth my while?' – to a committed compliance – 'I believe that she will deliver on her promises and therefore I accept what she says'. This deeper sense of the legitimacy of power can develop in relation to both the positive and negative exercise of power: if a teacher always carries through a threat to discipline a student then the student is likely to move beyond mere calculation – 'if I do this, then I might get away with it or I might be caught and suffer the consequences' to a negative form of commitment – 'I will not do it or I will suffer the consequences, and I know what the consequences will be'. Conversely, if a colleague's advice never seems to produce the promised results, you are increasingly unlikely to follow it, your calculative compliance falls away, and their use of power resources loses its legitimacy.

Calculative compliance, then, develops on a situation-by-situation basis. Moving from this to compliance based on commitment is a major step, as it takes the relationship away from one that is contingent upon the situation, and when we do not know what to expect will result if we comply, towards one in which the situation is defined in terms of what we expect of our students or our colleague. The more consistently individuals deliver on their promises, particularly when these are helpful or constructive, the more likely we are to move from calculative compliance towards compliance based on commitment. And eventually, says Hales, we move beyond commitment to a broader relationship in which we trust the other party.

As compliance moves through commitment to trust, we move away from responding to economic and knowledge power resources. As we develop trust in the other person, we move towards a relationship in which their power becomes normative rather than based on economic or knowledge resources. However, as soon as we start to examine the workings of trust and normative resources, we run into the issue of what we mean by *good* leadership. Is normative power necessarily good? History tells us that it is not. So what makes leadership *good*?

Key Element 3: What Makes 'Good' Leadership

One way of defining good leadership is to ask if it is effective. From this perspective, an IT coordinator whose policy of deploying resources through the school to promote improved performance in specific targeted areas has proven to be successful would be seen as providing good leadership. However, we might also ask if the resources were used in ways that are morally acceptable. If the IT policy directed resources solely into activities concerned with remediation, or solely into the development of higher-order thinking, then the IT coordinator's decisions might be challenged as morally unacceptable even if the target group's performance improved substantially. Those who challenged this policy would argue that one group – the more able or less able – should not receive a disproportionate amount of time and resources at the expense of others. The two interpretations are compatible: the difference lies in the judgement we make about how the objectives are achieved and whether they are morally acceptable. The moral dimension of leadership has always been acknowledged (Bottery, 1990), and has recently become more strongly emphasised by leading scholars in the educational leadership field (Fullan, 2003).

In the development of good leadership in the moral sense, an important element is the development of trust between leader and leader. Bottery (2004) and Macmillan et al. (2005) have both developed typologies of trust that, although they use different names for the elements, they are strikingly similar in form. They suggest that, just as compliance becomes more committed over time, so our trust in others deepens from a calculative response on the situation-by-situation basis described earlier to a level in which we can anticipate their reactions to situations and work in the secure knowledge of how they will act. Such *deep* trust can lead to highly skilled individuals deferring to a colleague, even though they are of similar ability.

Moving on from 'Top–Down' Leadership

If power is analysed as a set of different kinds of resource, then particular kinds of resource, either alone or in combination, may be relevant to certain situations and irrelevant to others. This leads us to ask who possesses these power resources and how they can best be accessed and deployed. Traditional views of leadership answer this question in two ways. In one view, power resources are possessed by individuals who have reached senior positions in the organization, because by working their way up they have gained a sound knowledge of all the different aspects or "functions" of the work being done there: production (teaching), finance, personnel or human resources. In return, the people who have reached the top through this bureaucratic view of leadership development delegate much day-to-day work to more junior staff, leaving themselves free to undertake strategic decision-making. However, alongside this view of expertise, there lies a second one: the idea of charismatic leadership, which develops when an individual is able through force of personality as well as knowledge resources to generate a high degree of followership from colleagues. A good example of this is the approach that is often adopted in England to "rescuing" or "turning round" a school that has failed its inspection – a new "superhead" is appointed to generate new practices and overhaul the school. This is widely seen as successful, but there is evidence that when the "superhead" leaves after two or three years, the school's performance falls back because insufficient attention has been paid to developing power resources that other staff can use by *building capacity*, so there is enough leadership potential or experience to sustain the changes that have been made.

This is not to argue against strong personalities taking leadership roles. Indeed, charisma is an important dimension of good leadership as it can help to promote normative power resources, and thence trust within the school (Fineman, 2003; Conger, 1989). Further, Harris (2002) argues that such strong leadership from the headteacher or principal – she calls it 'moral ruthlessness' in that it sets clear moral boundaries around activities that define acceptable practice within the school – is an essential part of any school development activity. Collaboration, according to both Harris (2002) and Fullan (2003), has to take place within clearly defined moral boundaries and in pursuit of a vision that is articulated primarily by the headteacher and *sold* to the rest of the staff.

Having established the key elements of leadership, we now turn to two important concepts that are becoming increasingly popular in analysing it. The first is *distributed leadership* and the second is *teacher leadership*. In relation to the work of IT specialists and coordinators, particularly in school systems where there is a strong differentiation between administration and teaching, both of these views of leadership may be helpful in analysing their potential practice, especially when they are analysed in terms of the power resources that are available.

Distributed Leadership

Distributed leadership is not a clear-cut concept. Not only do we need to differentiate it from more traditional views of leadership, but also we need to decide whether it is to be differentiated from teacher leadership, an idea that has received little attention in England until recently but which has been widely discussed in the USA. We can distinguish two broad schools of thought about what distributed leadership is: one deriving from the work of Gronn (2000, 2003) and the other from the work of Spillane (Spillane et al., 2003; Spillane, 2006). A literature review led by the author (Bennett et al., 2003) suggested that the concept has three basic linking ideas.

Distributed Leadership as an 'Emergent Property'

The idea of distributed leadership as an *emergent property* is that leadership exists in the interaction of groups of people rather than the actions of individuals. Gronn distinguishes between what he calls *additive* and *conjoint agency*. Additive leadership is little more than a form of delegation in which individuals undertake actions with leadership elements within them, but without any necessary collaboration or sharing. Conjoint agency occurs when individuals do collaborate and bring ideas and expertise together so that their collective action achieves more than their individual actions would have done. Spillane et al. (2003) give an example of how the progress of a professional development meeting can be expedited through such conjoint agency or, as he puts it (2003, p. 538) "collective leading", to coenact a particular leadership task. The principal chaired the meeting and kept it to task and timetable; teacher one led the discussion; and teacher two defined terms, clarified others' contributions and recorded the discussion. Thus, the three teachers worked interdependently, drawing on particular expertise to discharge related activities that made the meeting more effective.

Distributed Leadership Stretches the Boundaries of Leadership

Stretching the boundaries of leadership is the idea that instead of leadership being exercised by a small number of individuals in an organization, leadership roles should be spread wider and made more inclusive. However, there is no agreement in the literature about where the boundaries of leadership responsibilities should be drawn. Most writers draw the boundary around the teaching staff, but there are also other important adults in the school who might be placed within the boundary, and, perhaps even more controversially, there are pupils and students. Spillane et al. (2003) go further, to suggest that artefacts such as textbooks and interactive whiteboards can be included within the boundaries of leadership, as teachers can defer to the structure of a textbook in planning their lessons on a topic even though, left to themselves or with a different book, they would choose to approach the topic differently. He also extends the discussion of leadership beyond the more contingent approach offered above, which suggested that different forms of power resource influence the degree of power disparity in a given situation and therefore help to locate leadership within it, to argue that the situation is a fundamental component of practice rather than an independent variable that influences it.

This raises the question of what individuals within and outside the boundary do. Traditional bureaucratic or charismatic views of leadership see the task as direction setting, values-creation and taking decisions that others act upon. Distributed leadership suggests that not only are the boundaries within which leadership is exercised wider than in traditional models, but also that the nature of leadership itself may be different. For example, school principals who publicly espouse the doctrine of distributed leadership frequently point to the existence of pupil councils in their schools. However, an analysis of these schools in terms of the extent to which distributed leadership exists would need to ask to what extent these councils are involved in providing leadership in the sense of taking initiatives and putting them into operation. Do they exist simply to act as a conduit between senior staff and students, bringing up issues from the students and commenting on issues that are brought to them by the teachers or the principal? Are they expected to act as role models for their fellow-students, providing leadership in the sense of emphasising behaviour that staff wants to see? Such questions raise the more general issue of when leadership is about taking decisions, when it is about taking action and requiring others to act, when it is about collaborating in the process of decision making and the actions that result and when it is participating in more informal ways through providing information. This suggests that distributed leadership, exercised within wider boundaries than traditional models draw, is actually a different understanding of what leadership activities are as well as a different understanding of the structural arrangements within which they are carried out. Instead of being located in a hierarchical setting and relating to forms of instruction and direction that derive their legitimacy from a person's formal role, leadership becomes more concerned with promoting collaboration and sharing expertise in the wider interest. Distributed leadership assumes a willingness to debate possible actions openly and concede others' points of view.

This analysis re-emphasises the potential for generating calculative compliance as a basis for deeper commitment. It also stresses the importance of knowledge power, which must be to the potential advantage of IT specialists whose work is not only complex but also curriculum-wide. However, as mentioned earlier, the headteacher or principal is likely to play a pivotal role in determining the boundaries within which distributed leadership can take place. What he or she does not do is determine how tasks should be carried out, or by whom.

This point is picked up by Leithwood et al. (2007). They assign the jobs of deciding on the organization's vision, including its core values, determining the overall strategy to achieve the vision and ensuring that the structure of the organization supports the strategy to the so-called 'top leaders' (Locke, 2003, cited in Leithwood et al., 2007, p. 46). Leithwood et al. refer to this process as one of 'planful alignment'(p. 40). In their analysis, distributed leadership moves towards the work of giving advice and developing creative and collaborative responses to strategic decisions that are taken by senior staff ('top leaders'). Instead of widening the boundaries of leadership, it moves us towards a concept of distributed leadership in which collaboration occurs within clearly defined limits. This conceptualisation can be viewed as closer to task delegation, and has striking similarities with the view of management articulated by Mintzberg in the 1970s (Mintzberg 1990), which sees management not as the faithful implementation of the requirements of policies laid down from 'on high' but as an essentially creative activity that includes leadership within it.

Leadership on the Basis of Expertise, not Role

Distributed leadership on the basis of expertise, not role, resonates very strongly with the concept of knowledge power resources and emphasises that they can be widely spread. Indeed, Hales' analysis of power prepares the ground in many ways for the concept of distributed leadership by differentiating between power resources that are likely to be exercised by senior individuals, who work within a tightly-drawn leadership boundary and achieve compliance through formal systems, and those that are likely to be exercised within a much broader leadership boundary and achieve compliance through the consent of their colleagues without reliance on formal systems. However, it also re-emphasises the collaborative or, in Spillane's terms, 'coenacted' nature of leadership, as demonstrated in his example (Spillane et al., 2003, p. 539) of a meeting between a school principal and the language arts coordinator and a teacher, at which the teacher's instructional plans for the year were discussed. He shows how the two senior staff drew on different kinds of technical knowledge power resources to 'execute the leadership task': the principal knew of the district's accountability measures, whilst the language arts coordinator was familiar with instructional strategies and subject resources.

The Question of Accountability

The three characteristics of distributed leadership – coenactment, 'stretched' boundaries of leadership and leadership on the basis of expertise – have important implications for both the structure of organizations and the relationships between the individuals and groups that make them work. First, there is the issue of accountability. A formal bureaucratic structure creates clear lines of accountability through a line management system from the 'front-line workers' through to the chair or chief executive officer and thence to the external body that exercises overall governance: shareholders in a public company; the school governors and the local authority or school district in education. This is typical of western capitalist systems; in other cultures this arrangement may be unknown. Bryant (2003) reports on decision making among Native American peoples in which the position of 'the leader' was a transient one, and moved between individuals dependent on the situation: a structural realisation of the analysis of power provided by Hales (1993). In these peoples, accountability was to the community as a whole, not through some form of representative democracy but on the basis of the community as a *polis* analogous to the political system of ancient Athens (but without the slavery).

This raises the question of who or where one is accountable to in a system of distributed leadership. Bickmore (2001) examined this in a study of 'peer mediation' in elementary schools, where pupils were given the roles of helping to sort out problems between fellow-students. Where the peer mediators were appointed by the students and given 'scripts' – formal procedures – that they had to follow, they were seen by their peers as just a preliminary stage in the process of referral to the teacher and on through the system to the principal, and they were neither respected by their fellows nor seen by the teachers to be effective in reducing behavioural problems. However, in two schools where the principal decided to let the pupils elect their own mediators, gave them room to define their own procedures, and made it clear that a problem could be referred to the teaching staff if the mediators decided this was the right way to handle it, Bickmore's data suggest that the pupils respected the mediators they chose (some of whom were pupils whom the teachers would never have dreamed of selecting) and abided by their decisions. She also found that these mediators set themselves and their colleagues much stiffer standards than the teachers in other schools believed were achievable.

This example shows that accountabilities that are recognised by members of a group or organization are likely to be more powerful in defining 'proper' behaviour than those imposed upon them. Distributed leadership has to acknowledge the tensions that may arise from competing perceptions of accountability. Most teachers acknowledge their formal accountability through the school to the educational system, but it is commonly the case that they also feel a professional accountability to their colleagues as educators (Kogan, 1986). This has the potential to provide opportunities for significant leadership outside the formal structures of the school; it also provides a strong basis for rejecting such leadership if professional accountability is interpreted as individual professional autonomy. It is in the relationship between knowledge power resources and individual needs for them that this particular tension gets addressed.

Teacher Leadership: Is it the Same Thing as Distributed Leadership?

This discussion of distributed leadership has indicated both its broad characteristics and the potential for interpreting these in different ways. Leithwood et al. (2007) elide teacher leadership and distributed leadership by differentiating between leadership being exercised by ‘non-administrative leaders’ – defined (pp. 49–50) as teachers – and holders of traditional administrative roles – principals and staff at district level. Firestone and Martinez (2007) use the term distributed leadership as an analytical construct to discuss how school districts influence practice, but their analysis focuses almost entirely on teacher leadership within the district. Harris, a leading English scholar in the field of distributed leadership now differentiates between them, arguing that teacher leadership is more of a subset of distributed leadership, sharing the characteristics of fluid and emergent collaboration but being ‘concerned exclusively with the leadership roles of teaching staff…[whereas]…many practical operationalisations of distributed leadership…have often concentrated on formal positional roles’ (Muijs and Harris, 2007, pp. 112–113) – a characterisation of distributed leadership that is well reflected in the examples from Spillane et al. (2003) we have cited. However, this is not universally shared. Patterson and Patterson (2004) present a litany of tasks for teacher leaders that are concerned with creating a school culture that can ‘face down and survive challenging circumstances’ by staying focused on what matters most, remaining flexible about how you get there, taking charge, creating a climate of caring and support, maintaining high expectations for students and adults, creating meaningful and shared participation, and maintaining hope in the face of adversity (Patterson and Patterson 2004, as summarised by Bennett 2005). This view of teacher leadership differs profoundly from the emphasis on distributed leadership needing to be developed within clear moral boundaries and in pursuit of a vision clearly articulated by the principal that underpins Harris’s (2002) discussion, the comments of Locke (2003, p. 273, quoted in Leithwood et al. 2007, p. 45) that ‘no successful, profit-making company that I know of has ever been run by a team’, and the emphasis on the active encouragement of distributed leadership by principals that is widely emphasised in the literature (Day and Leithwood, 2007).

It is appropriate at this stage to revisit our earlier discussion of power resources and consider how these might be deployed. This involves our examining the distributed/teacher leadership issue in the light of the organizational structure within which they are located.

Distributed Leadership, Teacher Leadership and the Structure of Schools

An important element of the apparent disagreement about the nature of distributed and teacher leadership just outlined lies in the structure of the English and American educational systems. The division between administrative and teaching staff in USA, which leads to the principal being defined as an administrator rather than a teacher, creates a tendency to distinguish much more sharply between the two sets of roles than is the case in England. One consequence of this divided set of responsibilities is that, as Patterson and Patterson (2004) state, principals are seen as part of the district office staff rather than members of the school staff, and tend to be moved from school to school much more frequently than the teachers in response to the need to address perceived problems which arise from the unsuitability of the principal to deal with the particular needs of the school (or, perhaps, their incompetence). Consequently, it is the teachers rather than the administrators who give the school its stability and continuity. Further, by creating the stronger division between teacher and administrator, the degree of hierarchy within the teaching staff is reduced compared with that found in England. The English system shares with USA the role of departmental chair or subject leader, but roles with a wider, whole-school role, which are more typically taken by administrative staff in North America, are part of the career progression of English teachers through Assistant Headship to Deputy Headship and eventually to Headship. The National College for School Leadership, which has overall responsibility for school leadership training in England, reflects this structural framework in its five-stage leadership development model (NCSL, 2002). Another relevant distinction between the two systems is that in England the school governing body makes all staff appointments, including that of the head teacher. Consequently, head teachers are members of the school staff, and not members of the district office. An important consequence of this is that it can reverse the source of staff stability. Headteachers in England typically stay in post for as long as individual members of staff, if not longer, which gives them more opportunity to promote distributed leadership – increasingly referred to as *building capacity* (Mitchell and Sackney, 2000; Harris and Lambert, 2003). Thus, any study of distributed leadership that looks across two or more school systems has to recognise the implications of differences that might emerge as a result of the very substantial differences between them.

It will be clear from this that both the expectations that teachers have of their principals, head teachers or other senior leaders and administrators, and their perceptions of their own role and career, will be influenced by these structural differences. Literature from the USA has a strong focus on principals creating a culture within which distributed or shared leadership can develop. More than half of the case studies in Chrispeels (2004) are concerned with principals trying, despite the restrictions of district structures and their own formal accountability, to create school structures that emphasise teachers collaborating in decision making. Chrispeels' (2004) examples sometimes seem to resemble representative democracies. Much of this appears to create formal arrangements that validate and encourage what may previously have been informal and unrecognised leadership from within the *non-administrative* staff. It reintroduces the issue of accountability that we referred to earlier: how much autonomy does a school principal or head teacher have to restructure the school and distribute leadership, either as the distribution of tasks or through the coenacting of leadership activities discussed by Spillane et al. (2003).

Different internal organization structures create different valuations of power resources and different degrees of power disparity. Formal hierarchies are likely to inhibit the development of distributed leadership because they emphasise the degree of power disparity between role holders, whereas looser, less rigid structures tend to reduce power disparity between individuals. Nevertheless, as the above discussion indicates, it is not only the internal structure that matters: the wider structure within which the organization fits is also significant. Spillane's view of distributed leadership as coenactment fits more easily into a relatively flat internal structure that exists within a relatively tight external accountability system than into a formal system because it emphasises knowledge resources more strongly. Against this, external pressures can drive a strong formal hierarchy towards a system that appears to distribute leadership more widely: the national inspection system in England (Ofsted) emphasises school leadership and management, and looks at both the extent to which the head and the senior leadership are providing strategic leadership and have a sound knowledge of practice and the ways in which subject leaders and others provide leadership within the school.

School Culture and Distributed Leadership

We have emphasised two issues in this later discussion: accountability and organizational structure. We also need to draw together the several references we have made to a third major issue: school culture. Culture, structure and power are inextricably linked in any analysis of organizations (Bennett, 2002). Our discussion of structure has implied that it is something static, but the reality is that organizational structures are created and are susceptible to change. Without this, attempts to create distributed leadership or build capacity would be inevitably doomed to failure. Similarly, organizational culture – 'the way we do things around here' (Bower, 1966) – is also a dynamic element that is susceptible to change and development (Dalin, 1993; Bate, 1994; Fullan, 2007, Harris and Lambert, 2003). Schein (2004) suggests that creating and managing culture can be interpreted as the only key thing that leaders do, and that it is what differentiates leadership from administration. The case studies in Chrispeels (2004) that are concerned with structural change are also concerned with trying to create cultural change in the sense that attitudes and perceptions of individuals' roles are changed. This, again, indicates that the extent to which individuals have the capacity to influence how others think and act – power – is a crucial dimension of school development. Distributed leadership depends on the effective exercise of power. Authors who see organizations as political arenas, such as Ball (1987) and Blase and Blase (1999), see power as available widely through the organization. Others, who prefer to see organizations in less conflict-ridden terms, may emphasise the importance of the formal senior leader in culture creation. What is important for this chapter is that both structure and culture must not be seen as fixed and immutable but as fluid and dynamic, and therefore open to influence.

So What? Distributed Leadership and IT in Schools

This chapter has focused on the nature of distributed leadership, how it fits into wider discussions of leadership and how its development and exercise depends on the interrelationship between individual power resources and organizational structure and culture. It has pointed out that writers on distributed leadership argue that strong leadership from the principal does not necessarily contradict the operation of distributed leadership, and that some of them argue that it is essential. It has also pointed out that distributed leadership differs from traditional forms of leadership, which are located in formal hierarchical structures and rest on command and compliance, in that it presumes the possibility of collaborative action and a willingness to seek consensus. To conclude, we should consider how the ideas involved in distributed leadership and teacher leadership might assist the teacher(s) and other school staff with responsibility for developing and implementing technology innovations. In particular, how can technology innovations be introduced without the support and understanding of the principal or head teacher? Clearly, a school where the existing culture and structure facilitates distributed leadership will be an easier place in which to achieve this. However, the fluid nature of both structure and culture gives more room for change than sometimes might appear to be the case. This chapter concludes by suggesting one or two strategies that might assist IT-related staff in this task.

It is suggested that there are two key activities that IT-related staff should focus on. The first is to review the nature and extent of their power resources and seek to increase them; the second is to work through those resources to try and change how 'leadership' is understood by their colleagues, including the senior staff. Let us look at each in turn.

Exploit Power in Collaboration with High-Performing Staff ('Teacher Leaders')

A review of the particular power resources IT specialists possess and their strength will help to identify where in the school they might be used most effectively, and we have given some examples of ways in which different resources might be used. It is important to remember that they can derive from both formal role and personal capabilities and characteristics. Increasing the nature and the strength of the power resources of IT specialists makes it more likely that they will be able to influence the culture and structure of the school. If the school has a formal goal of developing a stronger technological presence, then an IT specialist or coordinator has a handle on cultural change even if the goal is not being addressed in practice. Even if this is not the case, the teacher in charge of any subject or curriculum area should be able to call on the knowledge resources of the IT specialist. In the first place, therefore, the IT specialist who is working alongside teachers, especially those who are given senior roles as pedagogical experts, can provide an opportunity to deploy those knowledge resources and begin to promote the perception of leadership as collaboration that underpins distributed leadership. Working with and alongside such formal role holders to deploy individual subject or technology-related knowledge power resources can strengthen the status of an IT specialist in relation to the formal structure of the school and start to put pressure on senior leaders to change their policies and provide more support for IT development and use.

Assisting colleagues in the classroom is an obvious and hardly earth-shattering suggestion, but put in these terms it indicates how individual knowledge power can be used to augment the capacity of formal role holders and so improve performance. It does assume, though, that other teachers are willing to seek, accept and share suggestions. Working forward from those colleagues who either seek or accept suggestions, and publicising successful innovation, is one way of developing stronger knowledge power and achieving more extensive and committed compliance. If the ideas or the technology work, then more people will use it, and spread the word of its success among their colleagues. Over time, this will generate a deeper commitment from colleagues, which will provide further support for the IT coordinator who is trying to gain more resources for technology-related activity.

Promote Pressure Through Success

A second possible approach that derives directly from the first is to work round any concerns that senior staff or administrators may have through not understanding or sympathising with new technology by demonstrating its effectiveness in terms of achieving learning goals. If it is possible to demonstrate that individual teachers find it helpful, it improves student engagement and performance, and has wider effects on school activity, then the power resources available to the technologist increase further. Knowledge of technology then becomes knowledge of practices that improve overall performance, in terms of both measurable outcomes and other aspects of school reputation.

And Finally…

Both of these strategies, if successful, will increase the potential of an individual or group to promote change and a wider take-up of the kinds of technological innovations that are being discussed. But something else is implied in the second. If suggestions are to be successful, then the specialist must be ready to offer continuing support and advice. This can be time-consuming, but as Fullan (2007) among others points out, innovation is only successful when changed practice becomes institutionalised as the norm. To increase influence and go beyond compliance to commitment to ideas and suggestions for changed practice, it is essential to provide the ongoing support that will help demonstrate that ideas work and continue to work.

These suggestions provide means by which individuals can to some extent decouple their exercise of power resources from formal roles within the school. In this sense, leadership becomes coenacted on an informal basis. Effective leadership from outside the formal structure, which does not challenge the structure and formal leaders but provides support and demonstrates knowledge and expertise, is an important way of developing from within a school culture that can promote the more formal acceptance and implementation of distributed leadership within the school.

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6.5

TOTAL COST OF OWNERSHIP AND TOTAL VALUE OF OWNERSHIP

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Introduction

Schools, individuals and governments in the twenty-first century are making considerable investments in information technology (IT). Associated with these expenditures are widespread policy and societal expectations that school leaders must be able to build the capacity of their school communities where contemporary learning theories and practices include learning with technologies. At the same time, economic and educational purposes are articulated in school education policies in both developed and developing nations (cf. Association for Progressive Communications (APC), 1999–2007; Australian Ministerial Council on Education, Employment, Training and Youth Affairs (MCEETYA), 2005; Department for Education and Skills (DfES), 2005; United States Federal Department of Education, 2004). To meet the emerging educational and economic purposes articulated for schools and their students, these policy initiatives are leading to requirements for whole-school reform where there is a reshaping of the context and nature of school leadership and management. Furthermore there is a growing demand from communities, governments and other funding bodies for schools to be able to justify the costs of integrating technologies into educative processes not only for their intrinsic value, but also for instrumental, particularly economic purposes.

Many school leaders however are unsure of how data can be used to inform their work, what decisions concerning technologies they should make or what types of decisions require their direct oversight (Moyle, 2006). Nor are they aware of what data they should collect and use to inform their decision-making processes, particularly in relation to the deployment and integration of technologies into teaching and learning within their schools. These dilemmas are among the driving demands for the development of school-based data-driven decision-making models (cf. Gipson, 2003; Hallinger and Snidvongs, 2005; Sayed, 2002; Whitty and Edwards, 1998). Approaches

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to determining the costs and benefits of technologies afforded through total cost of ownership (TCO) and value of ownership models are being adapted from the business sector in the quest to assist school leaders meet the varying demands placed upon them.

It is against this complex, multi-dimensional backdrop then, that this chapter examines a range of recent activities aimed at using data to inform leadership and management strategies in schools as they pertain to teaching and learning with educational technologies. The "conceptual space" for this paper sits at the intersections of teaching and learning with technologies, schools' IT infrastructure requirements, their strategies for organizational and cultural development and their finance and asset management strategies. The dual foci of "education" and "technical" issues are emphasized in this chapter, where "education" refers to the structured personal and social pedagogical processes undertaken in schools to foster the development of children and young adults; and the "technical" refers to the IT infrastructure and physical deployment requirements associated with integrating technologies into the teaching and learning in schools.

Policy Contexts

Before exploring approaches to data-driven decision-making in relation to technologies in schools, it is worthwhile examining the global and nation-state policy contexts that are influencing the deployment of these technologies. School-based decisions are often made within broader social and cultural environments. Understanding these policy contexts can provide insights into the drivers for local decision-making and the approaches to be used.

School education is one of the major levers societies have for reproducing themselves. Policies are the mechanisms by which societies enact those levers. Many national school policies around the world are identifying both economic as well as educational purposes for school education. Indeed, there appears to be an increasing homogenization of the policies that pertain to the deployment of technologies in schools emerging in the national policies of countries around the world, and in those from international agencies such as the Organisation for Economic Cooperation and Development (OECD, 2002).

Consistent themes in these policies include:

1. The articulation of both intrinsic and instrumental purposes for school education and the role of technologies in achieving these dual purposes.
2. Moves towards school reforms that are increasing the autonomy of individual schools within centrally-administered accountability frameworks, in the name of meeting the demands of the "knowledge economy".
3. The promotion of better management of finances and other resources in schools.

These three themes are now briefly discussed to expose the fabric of the policy contexts, and to highlight the emerging importance of data decision-making models in schools that are informed by information about the costs and benefits of technologies in teaching and learning.

Intrinsic and Instrumental Purposes of School Education

The school education technologies policies in OECD countries share similarities and have several overlapping and interwoven themes (cf. OECD, 2002). One such theme evident in these policies links teaching and learning with technologies to both the intrinsic benefits for the individual and to economic benefits for society. The Australian national policy, the *Adelaide Declaration on National Goals for Schooling in the Twenty-First Century* for example states:

> Schooling should develop fully the talents and capacities of all students. In particular, when students leave schools they should:…
>
> 1.5 have employment related skills and an understanding of the work environment, career options and pathways as a foundation for, and positive attitudes towards, vocational education and training, further education, employment and life-long learning; [and]
>
> 1.6 be confident, creative and productive users of new technologies, particularly information and communication technologies, and understand the impact of those technologies on society… (MCEETYA), 1999, p. 1).

Strategies promoted for meeting the individual and economic purposes of school education include using educational technologies to improve students' learning outcomes, increasing the personalization of teaching and learning, raising the standards of students' outcomes from schooling and supporting students to achieve their full potential. These aims are particularly evident in the policies of the USA, UK and Australia (cf. Australian MCEETYA, 2005; DfES, 2005; United States Federal Department of Education, 2004). Although these aims are commonly articulated, there are however differing views about the impact of technologies on students' educational outcomes, and whether these technologies provide an acceptable return on investment. Debates about the cost, value and impact of technologies in school education then are generating demands for research.

School Reform

Another consistent policy initiative emerging in countries including Australia, USA and UK is the use of data by school leaders and teachers to inform their decision-making. In these countries decisions previously made centrally are being moved to the local level. Often missing from this policy work, however, have been considerations about the leadership and management responsibilities within schools concerning the interrelationships that exist between the necessary infrastructure and financial models required to include technologies in teaching and learning. Indeed, a tension for school leaders is the drive for local decision-making about teaching and learning with technologies in the context of centralized IT policies about curriculum and IT infrastructure, where IT deployments within education systems occur beyond the individual school level. Understanding the costs and value of technologies in schools though is important for school leaders so that they are able to lead strategic planning processes in their schools and to accommodate these policy contradictions. Data-focused models for planning and setting school priorities are therefore an emergent requirement for school leaders.

Furthermore, school leaders are seeking assistance in how to interpret centralized policy decisions in order that they can lead and manage school-level decision-making about the selection and deployment of educational technologies in schools (cf. Gipson, 2003; Moyle, 2006; Bialobrzeska and Cohen, n.d.). School reform literature tends to focus upon the changes required at the local level to implement local management within the context of broader policy and accountability requirements (cf. Caldwell, 1998, 2004; Hallinger and Kantamara, 2002; Sayed, 2002). One of the justifications for school reform that is aimed towards increased accountability at the local level has been the perceived widening gap between the past, traditional role of schools compared with the emerging requirements of the "new economy" or the "knowledge economy" (Hargreaves, 2004). Until recently, however, in those countries where their national policies directly address local school management and school reform, these policies have tended to be silent in identifying financial and accountability expectations or approaches concerning technologies in learning at the local level. There are therefore gaps between policy rhetoric and the experiences of schools. These gaps are drivers for schools to examine and adopt business models for measuring the costs and benefits of the technologies deployed.

Financial Accountability

The inclusion of technologies into the daily lives of schools is resource intensive. These costs are placing new requirements on schools' financial accountability methods as governments and individual schools account for and justify the expenditures. But at the local school level, little research has been undertaken to investigate models of financial management and accountability that take into account the life cycles of educational technologies. Similarly, in any given country it is difficult to determine with accuracy the extent of the investments made in educational technologies or to make international comparisons based upon either costs, impact or value of technologies in schools.

It is within this set of complex policy contexts then that schools and school systems require data upon which informed decision-making about deployments of technologies can be based. Academics, governments and teacher professional associations are starting to turn their attention to the issues of what data, how to collect it, the relationships between different data sets and how to interpret the data in order that improvements in student learning outcomes can be achieved. Business models that measure the costs and benefits of technologies (such as TCO and total value of ownership) are being examined for fit for purpose in the schools sector.

Data-Driven Decision-Making

Data-driven or data-focused decision-making models are premised on the thesis that the collection, analysis and synthesis of data available primarily within a school can inform school improvement processes, including teaching and learning, strategic planning, organizational development and procurement processes. That is, the data are collected and used to make decisions about administrative and pedagogical systems in order to improve and promote student achievement and school processes. Putting in place efficient processes that enable schools to harvest and interpret the data and to get alignments between the data collected and the outcomes sought, however, have tended to be difficult and time-consuming for many schools.

A broad range of data can be used to inform decision-making processes and outcomes. The nature of the data collected, however, is dependent upon what decisions are required. Data, including student records of academic performance, attendance records, student demographics, school purchase and expenditure patterns, teacher capability assessments and so on can be used. Depending on the nature of the decisions to be made, appropriate data can be collected and analyzed in ways that administrators, teachers and parents can accurately assess the information in order to inform their decision-making. Challenges for implementing data-driven decision-making models include identifying:

- What is it we want to know,
- Why do we want to know it,
- What data are required in order to address the questions we have identified,
- How will the data be collected,
- Over what timeframe will the data be collected,
- How will the data be analyzed,
- How will the findings be fed into the decision-making structures of the schools in ways that will be beneficial,
- How will we know the data has made a difference to the decision-making processes within the school.

While data-driven decision-making would appear a rationale course of action for informing school improvement processes, to determine workable models of data collection and analysis that pertain to the deployment of technologies in schools in teaching and learning is complex.

Measuring Data

Data-driven decision-making models are based upon the collection of data that can be measured. Data measurement processes presuppose that what is to be measured can be defined. Often indicators are used to illustrate what is intended by a particular concept or term, but the use of indicators in ways that are meaningful "requires a conceptual framework within which they can serve to assess a current state, to measure linkages between policy and outcome variables, and to assess policy options" (Grootaert, 1998, p. 10). It follows, therefore, that defining the indicators to be used in gathering data for measuring the cost, impact or value of technologies in schools requires the establishment of a conceptual framework and the acceptance of a language that brings with it shared understandings about the meanings of key words and phrases. An overview of the frameworks that are being used to scaffold approaches to data collection for measuring the cost, impact or value of educational technologies in schools will be outlined shortly, following a brief exploration of the importance of language in the measurement and interpretation of data.

Language

Discussing and implementing measurement strategies requires clarity about the meanings intended so that the inputs and the outcomes from the measurements undertaken have veracity and hold meaning. If the methodologies of measurement are inadequate, the results from them are bound to lack authenticity. If there is a lack of clarity about what is the meaning or definition of the factors being measured and what the central outcomes are supposed to be, then confusion rather than clarity will be at the heart of the findings. Indeed, even defining what is intended to be counted, or defined as "educational technologies" in schools can be problematic. Questions arising include "do 'educational technologies' include bandwidth?" "Are mobile phones to be included?" "Are desktop and portable computers counted in the same ways?" "Do peripherals such as printers and digital cameras get counted as educational technologies?" Definitional issues such as where do the boundaries lie concerning "what are educational technologies?" then, generate definitional and methodological issues requiring resolution.

What is Being Measured?

To meaningfully interrogate data about deployments of technologies in schools requires an examination of the relationships between teaching and learning with technologies; the infrastructure required for deploying the technologies; the costs of ownership; the value on the investments in educational technologies in schools and the outcomes achieved by students as a result of including the technologies into their learning. Studies particularly in the USA and UK (British Educational and Communications Technology Agency, BECTA, 2004; Institute of Education Sciences, 2007) seek to link technologies directly to students' achievements, including on standardized tests. The findings from these studies, however, vary and often produce inconclusive results. A recent study from the US Institute of Education Sciences (2007) found for example that the "test scores were not significantly higher in classrooms using the reading and mathematics software products" (Institute of Education Sciences, 2007, p. xiii) than those in control classrooms. But when reading these studies it is important to understand the types of data collected and the definitions used in order to understand the conclusions found. Similarly schools must understand the nature of the data required and the analytical approaches necessary to enable them to gain meaning from their financial and IT deployment data.

Tangible and Intangible Assets

In the private sector, recent descriptions of IT deployments include references to both "tangible" and "intangible" assets. "Tangibles assets" are those items that have traditionally been measured and are usually defined as physical assets owned by an organization or individual that can be seen or touched. IT tangibles include objects such as computer hardware, technology peripherals and telecommunications costs. Tangible assets are covered by the Framework of International Accounting Standards. The worth of such assets is usually presented in quantitative terms. Schools can determine the costs of the purchases of the IT tangibles from their financial records and can map these costs over time.

More recently, the onset of the "knowledge economy" has facilitated the notion of "intangible assets." In the business sector, these assets include "goodwill," brand names and the social capabilities of employees and strategies such as organizational learning. Stock markets for example have highlighted that companies such as Microsoft can be valued at a price many times the value of their tangible assets (Roos et al., 1997), and it is the intangible asset of the *Microsoft* brand name, that in part makes Microsoft so valuable. Related to the concept of "intangible assets" are employees' competencies. In accounting terms, the notion of financial worth is applied to intangible assets such as goodwill in relation to the worth of an organization in much the same quantitative manner as that used for tangible assets.

Intangible assets are increasingly being recognized in the business sector as critical to the success or otherwise of an organization (Kaplan and Norton, 2004a). The value of intangible assets vary, however, depending upon the worth put on the assets themselves in given contexts. Measuring the value of intangible assets therefore is important information to be able to take into account in the work of strategic planning and organizational improvement. Unlike physical assets, intangible assets while difficult to quantify, can be worth more to the value of the organization than the physical assets. But measuring the value of intangible assets is problematic. A challenge for managers is if they "could find a way to estimate the value of their intangible assets, they could measure and manage their company's competitive position much more easily and accurately" (Kaplan and Norton, 2004a, p. 52). These authors combine intangible assets into three major groupings: human, information and organizational capital. They use the following definitions:

– Human capital refers to the skills, knowledge and talent of the people in the organization's workforce.
– Information capital refers to the information held in databases, networks and in the technological infrastructure of an organization.
– Organization capital refers to the organization's culture, leadership, the ability for staff to share information and how the human capital (i.e., the people) is aligned with the strategic goals of the organization (Kaplan and Norton, 2004a,b).

In light of the work by Kaplan and Norton (2004a,b), questions for the schools sector then include the following:

– Is it possible to apply the question of value to schools?
– What is the value of educational technologies in schools?
– Does the value of educational technologies in schools match the findings on student learning outcomes?

In 1964, Drucker made the following observation that may be worth transposing to schools:

> Other resources, money or physical equipment, for instance, do not confer any distinction. What does make a business [school] distinct and what is its peculiar resource is its ability to use knowledge of all kinds – from scientific and technical knowledge to social, economic and managerial knowledge. It is only in respect to knowledge that a business [school] can be distinct, can therefore produce something that has a value in the market place [to students and the community] (Drucker, 1993/1964, p. 23).

The concept of "intangibles" has long been the purview of behavioural scientists. The advent of the Internet and more latterly the "knowledge economy" has provided developed nations with the opportunity to explore the ways in which intangible assets can add value to organizations.

Governments and organizations worldwide are experimenting with standards that might be applicable to establishing baselines for the management, valuation and use of the knowledge, social competencies and various intelligences as indicators of economic wealth. At this stage though, there are no international agreements for the measurement of baseline standards, nor are there models for measuring the intangibles evident in schools.

Cost, Value and Impact

Three concepts though that have underpinned measurement activities in relation to the inclusion of educational technologies in school education are "cost," "impact" and "value." These three terms are now used in this chapter to structure the forthcoming discussion about what is being measured and what measurement strategies are best associated with investigating school-based models of IT deployment.

During the past decade, schools and departments of education, particularly within UK, USA and Australia have been trialing and using different approaches to measuring IT in schools. These activities have involved examining the costs, impact and value of integrating IT in school education. The purposes for which schools in each of these three countries have been collecting "cost," "impact" and "value" data have included:

- To enable data-driven decision making by school leaders about the costs of deploying educational technologies in schools.
- To inform school planning processes about the nature and extent of IT deployments over time.
- To provide accountability statements to central or regional departments of school education; and
- To inform approaches for strategic planning and improvements in school education that includes educational technologies.

An overview of some of the work being undertaken in these three countries addressing questions of measurement of the "cost," "impact" and "value" of technologies in and on students' learning is now presented and examined here.

Cost

The costs of IT in schools are probably the easiest measures to determine, although they are not without definitional and methodological issues. The most simple way a school can determine the costs of IT is to come to an agreed definition about what constitutes "IT costs" and then count the expenditure according to those definitions, over predetermined periods of time. Another method of counting the cost of IT deployments is to apply a TCO measurement approach.

Total Cost of Ownership

Over the best part of the past decade, TCO measurement tools (both hardcopy and online) have emerged in the USA, Australia and the UK to assist school leaders to make decisions concerning IT deployments in their schools. The phrase "total cost of ownership" was originally developed by Gartner, Inc. Gartner promotes itself as the world's largest private IT research and advisory company (Gartner, Inc., 2006). Gartner created the phrase "total cost of ownership" to refer to all the costs associated with the use of computer hardware and software, including the administrative costs, licence costs, deployment and configuration requirements, hardware and software updates, training and development, maintenance, technical support and any other costs associated with acquiring, deploying, operating, maintaining and upgrading computer systems in organizations (Kirwin, 1987).

The TCO model was developed by Gartner based upon assumptions applicable in private businesses in the corporate sector. Over the past few years, schools in the USA, UK and Australia have been investigating, independently of each other, how the Gartner TCO model or variations thereof can be applied to their particular contexts at the local and regional levels. Since 1999, for example, the Consortium of School Networks (CoSN) in the USA has offered TCO support and advice to schools. A web-based tool has been available in the USA since 2003 and is being used by 1,800 schools and school districts to calculate the TCO of educational technologies through the CoSN initiative: Taking TCO to the classroom (CoSN, 2006; www.classroomtco.org). CoSN worked with Gartner to build this online TCO tool for schools. In the USA, schools have been applying the Gartner TCO tool to assist in the management and decision-making about the cost of deploying IT in their campuses.

Similarly, in Australia, the South Australian Department of Education and Children's Services has piloted models of data collection consistent with the Gartner TCO approach. In 2003 a TCO analysis was conducted in one school to determine the comparative costs of deploying proprietary software compared with open source software (cf. Moyle, 2004). Subsequent TCOs have been used in South Australian government schools to inform the IT infrastructure requirements of schools. The TCO model in this jurisdiction is also heavily based upon the Gartner model of TCO.

In the UK, schools and agencies have also been investigating models and tools to assist in TCO calculations appropriate to their respective settings. BECTA has developed an online tool to assist in the gathering of cost-based data called the "ICT investment planner" (BECTA, 2006). This BECTA tool is designed to allow schools to gain an in-depth view of technologies costs over a three-year period. The tool shares similarities with the Gartner TCO tool, but the BECTA tool includes both mechanisms for collecting financial data and also includes a questionnaire for staff to ascertain teachers' perceptions of IT reliability, access to facilities and services, and an evaluation of the ease of use of the IT tools for teaching and learning purposes (BECTA, 2005b). Schools can use this planning tool to assist them to make decisions about the nature and extent of IT deployments.

It has become apparent through the TCO work in schools to date, that the focus has been upon accounting measures focused on structural inputs. The use of TCO tools in schools thus far then has mainly contributed to understandings about tangible assets. While some would argue that the current TCO tools available go some way to measuring intangible costs such as peer-to-peer tutoring and professional development, often these approaches are based upon business models where profit is the overall motive rather than teaching and learning. What TCO tools do not indicate for the schools sector though are the intangible benefits associated with the tangible assets, nor do they identify the benefits associated with the deployment of technologies for teaching and learning purposes.

The respective TCO models used in the USA, UK and Australia then have offered schools the capacity to quantify data previously left uncollected and analyzed. Little research, however, has been conducted in the school sector, evaluating the TCO approach as it is applied to IT measurements in schools; nor about the appropriateness and value of the TCO model to schools or the school sectors. Now schools and school sectors in these countries are moving their investigations about measurement of deployment of technologies to analyze not only "cost" but also questions about the "value" of their investments. They are identifying the benefits of information a TCO brings but are also recognising the limitations of TCO analyses. As a result, a tri-nation project involving Australia, USA and UK has been established called Measuring the Value of Educational Technologies in Schools. The model underpinning this project has been developed based upon adaptations of the work by Kaplan and Norton (2004a), which articulates measures of the value of IT in private sector companies. The purpose of the Measuring the Value of Educational Technologies in Schools project is to investigate in what ways tangible and intangible assets are linked with and contribute to the value of educational technologies in schools.

Value and Impact

There is little systematic, school-based research as yet investigating the question "What is the value of educational technologies in schools?" Some projects have purported to be measuring "value" but have instead measured "impact."

The concept of "impact" tends to be based upon a determinist assumption that, of themselves, technologies have an impact on the learning of students. The main aim of many impact studies is to determine the degree of impact technologies (of themselves) have made on students' learning. The concept of "impact" is grounded on the notion that because educational technologies are an "add-on" to classroom practice, their impact can be individually measured. The question of the degree of impact of educational technologies on students' learning is one that aims to assess end points only. In comparison, measurements of the value of technologies to students learning focuses both on questions of pedagogical processes as well as the outcomes achieved.

Value

The concept of "value" gives rise to questions such as:

– Value for whom,
– What value,
– How is the value expressed,
– How do we know if the value has been achieved

The value propositions against which to measure the value of the "intangible assets" of schools pertain to the ways in which students achieve their learning outcomes with educational technologies. Measuring "value" means making judgements about the degree to which outcomes statements that include statements of value compare with the evidence that those value statements are being fulfilled, and to how well-aligned a school is in being able to meet the values they espouse. Values are framed in discourse, and are "in the eye of the beholder." Hence the value of educational technologies in schools rests in what is articulated as being "of value" and the carriage of those value statements throughout the practices and organizational processes of the school. There are therefore two big pieces to the "values puzzle" for schools to be able to measure the value of educational technologies in school education: The value of "educational technologies" and the role played by "intangible assets" such as teacher competencies and organizational learning.

Kaplan and Norton (2004b) suggest that measuring intangible assets is problematic if attempts to measure the intangible assets occur on a "stand alone" basis. They argue that the value of intangible assets sits within the context and strategic approaches of an organization. As such, measuring the value of intangible assets in schools would involve estimating how closely aligned their intangible assets are to the school's strategic approaches to their work. That is, if the intangible assets and the school's strategic operations are closely aligned then the intangible assets will create value for the school. To systematically measure the alignment of a school's human, information and organizational capital and link these to a school's strategy and performance in order to determine strategic readiness and the value of these intangible assets to the school forms the basis of the aforementioned Measuring the Value of Educational Technologies in Schools project.

The capacity of a school or school district to achieve their value statements can be tracked organizationally through policy statements and strategic planning documents, and synthesized with evidence collected through:

– Cost of the investments made (as can be seen through TCO reports),
– Teacher self-assessment skills surveys,
– Interviews,
– Analysis of teacher program plans and students' work.

The achievement of value statements can be seen in evidence such as clear links between:

– What teachers set out to do (as demonstrated in their teaching program plans and assessment requirements) and
– The final examples of students' work.

In 2003, the Australian Ministerial company *education.au ltd* commissioned research concerning measurement of "intangibles" in knowledge asset measurement (Palmer, 2003). In 2006, CoSN launched a new project investigating "value on investment" (VOI) for measuring the value of specific educational technologies projects (see http://edtechvoi.org). CoSN sees this work as a critical companion effort to its TCO work, where the VOI work aims to help schools understand the "value" of their investments in educational technologies and to develop metrics to measure progress. They have found that while schools articulate visions around the value they get from technologies, they tend to have no real metrics identified to calculate their progress.

There is a growing awareness in the school sector that social and human capital have critical links to structural inputs and policy outcomes. There are moves away from only measuring resource investments to including measurements of processes, "distance travelled," outputs and outcomes. Schools are adopting "whole school approaches" to strategic planning and to measurement. The theoretical and practical dimensions of the interactions between the tangible capital and assets, and the intangible social, cultural and behavioural actions relevant to school performance, however, require better understanding. Questions of value and the measurement of "intangibles" as part of those measurements are emerging as issues for schools as well as for governments.

Impact

It was argued earlier that to attempt to measure the direct impact of technologies on students' learning was to take a deterministic view of the role of educational technologies in teaching and learning. The question of "impact" relates to questions of "value" only in that "impact" could be considered to be one indicator of an achievement of value. But attempts to isolate the impact of technologies from pedagogies or other influences on student learning such as the teacher is a risky business. Nonetheless researchers have attempted to do so.

In 2002, reports emerged in the UK, USA and Australia about the impact of technologies on students' learning (cf. Harrison et al., 2002; Johnston and Barker, 2002; Newhouse, 2002). Each of these projects included approaches to the measurement of the impact of technologies on students' achievements. The UK report was funded by the DfES and was managed by BECTA. It involved 60 schools and used sample data to undertake statistical analyses of students' attainment linked to IT experience (Harrison et al., 2002). The Office of Educational Research and Improvement in the US Department of Education commissioned the USA report. This project identified seven outcomes from technology integration for teachers and students and investigated evaluation strategies within each of these seven fields (Johnston and Barker, 2002). In Western Australia, Newhouse (2002) developed a framework for schools to be able to articulate the impact of technologies on learning.

Several other research projects from BECTA over the past five years have also addressed the question of "impact" of technologies on students learning. BECTA has indicated that "there is a growing body of evidence relating to the positive impact of technologies on learner attainment and other outcomes" (BECTA, 2005a, p. 4). BECTA argues that one impact of technologies has been on students' motivation for learning where that learning includes technologies. Reviewing research about technologies and students' motivation, BECTA has reported that there is evidence to suggest that the technologies can have a positive effect on students' enjoyment and interest in learning. The key benefits for students identified BECTA were:

- Increased commitment to the learning task,
- Increased independence and motivation for self-directed study [and]
- Enhanced self esteem and improved behaviour (BECTA, 2003, p. 1).

A 2004 report by BECTA indicates that the use of IT varies according to subject areas of study with more use of technologies being made in mathematics, science, computing studies and English than in other subject areas. This report indicates that "there is substantial evidence from smaller focused studies of the contribution of specific uses of technologies to students' learning. These include the use of simulations and modelling in science, ICT and mathematics, and the use of word processing in English" (BECTA, 2004, p. 5). Further, BECTA has reported that "many small studies have shown consistently positive results over the last twenty years, but this [the results] does not yet extend to all types of IT use, nor does it exclude the input of the teacher" (BECTA, 2005a, p. 4). BECTA reports, however, that there is an emerging body of knowledge about the effects of specific types of technologies such as email and the World Wide Web on student achievements. They report though that the evidence of the effects of these is not yet seen to be consistent or extensive (BECTA, 2005a). BECTA also suggests that as a result of these different applications of technology within specific subjects, there is a greater number of digital resources available to these subject teachers; there is a greater body of knowledge in these subjects about pedagogical practices concerning teaching and learning that includes technologies, and there is also therefore a greater body of evidence of the effects of technologies in these subjects' time (BECTA, 2004). BECTA reports that the positive impact on attainment is greatest where digital resources have been embedded in teachers' practices over a period of time (BECTA, 2004).

But the connections that can be drawn between integrating technologies into teaching and learning, improving student learning outcomes and the costs involved in deploying technologies in schools still seem tenuous. At the same time, and in the context of scarce resources, school superintendents, school boards and policymakers increasingly want to know answers to questions such as "what is the value of technologies in students' learning?" and "what is the return being gained from investments in technologies?" These questions allow an examination of both the tangible and intangible costs and benefits, and represents spaces for new research.

Conclusion

This chapter has reflected upon the national policy directions driving the concurrent policy directions of school reform and deployments of technologies in schools. It has brought together for investigation the relationships between the following fields within school education: pedagogy, IT infrastructure, organizational development, asset management and school financial models. While TCO measurement tools are being used in the USA, UK and Australia, it has been argued that although these TCO measurements enable the collection, sharing and analysis of costs of educational technologies, further work is required on the interpretation of that data and related data so that future directions in schools concerning the value of investing in technologies for teaching and learning can be determined. Such analyses will require symbiotic interpretations of the data by educators, so that costs and value measurement work can interact iteratively.

While data-focused models for analyzing the costs of technology have been evolving to incorporate the concept of "value" as a key metric, the complex issue of valuation of tangible and intangible IT assets in schools is only now being researched in the context of self-managing schools. Yet school leaders nonetheless are required to make financial, infrastructure and pedagogical judgements and accountability statements about the value of educational technologies in school education. Measurements of assets are built into the financial, regulatory and reporting requirements pertinent to the school sector but the place of tangible and intangible IT assets remains problematic.

Intangible assets are increasingly being seen to be important for the success of schools and their students. However traditional financial accounting systems do not provide a suitable foundation for measuring the value created by enhancing these assets. Yet at both the micro and macro levels within school education intangible assets can drive long-term value creation.

A challenge for schools into the future is to focus and align their value propositions with their strategic approaches. As such, approaches to develop and trial the application of measurement systems that are focused on school strategies in relation to integrating educational technologies into teaching and learning and with seeking evidence of the outcomes from that strategy, particularly those related to student learning, are beginning to gain traction in education communities. To measure the value of educational technologies in schools, however, more research is required in order to shed light on the degree of alignment between a school's value propositions and its actions.

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6.6

THE LOGIC AND LOGIC MODEL OF TECHNOLOGY EVALUATION

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Introduction

Evaluation is an unavoidable task for schools as they embark on the journey of adopting technology programs. The various stakeholders want to have answers to their questions concerning the program. The funding agency, be it the community, a government agency, a private business, or a charitable organization, wants to know if its investment is worthwhile. The school governing board and parents want to know if the program will help or hinder the education students receive. The teachers and other staff want to know how the program might affect their work. And of course the students, although often overlooked in many evaluation efforts, are entitled to know if and how the program might lead to more effective and efficient learning.

But evaluation is not an easy task. The multiplicity of stakeholders, the complexity of the context where the program is implemented, and the ill-definition of outcomes complicate the matter tremendously. Different stakeholders have different views of "the value or worth" of the same program, which is usually affected by the various factors of the school context and the program itself. Adding to that complexity is the fact that technology is often asked to simultaneously produce many outcomes, some of which are not well-defined or lack precise measures. Consequently evaluation has to serve many purposes (U.S. Department of Education, 1998):

- Provide information to funding agencies so that they can determine whether to continue the funding or invest in similar programs in the future.
- Provide information to school leaders so that they can decide whether to continue the implementation and engage in similar ones in the future.

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- Provide information to teachers and school staff so that they can decide whether or how they might to support and participate in the program.
- Provide information to program staff so that they can take actions to improve the program.
- Provide information for future evaluation efforts.
- Provide information to the general public.

Depending on its purpose, evaluation can be formative or summative. Formative evaluation is intended to provide ongoing information about whether things are proceeding as planned, whether expected progress is being made, and if any changes need to be made. The purpose of summative evaluation is to provide information about the program's overall merit or worth.

A recent evaluation study of technology in education exemplifies the various issues surrounding evaluation. In April 2007, the U.S. Department of Education released a report entitled "Effectiveness of Reading and Mathematics Software Products: Findings from the First Student Cohort" (Dynarski et al., 2007). This document reports findings of an evaluation study that intended to assess the effects of 15 computer software products designed to teach first and fourth grade reading and sixth grade math. It found that "test scores in treatment classrooms that were randomly assigned to use products did not differ from test scores in control classrooms by statistically significant margins."

As soon as it was publicly released, the report caught the attention of the media. A day after the release, for example, the *Washington Post* published a report about the study with the eye-catching title "Software's benefits on tests in doubt: Study says tools don't raise scores" (Paley, 2007). The influential education magazine *Education Week* published an extensive story on this study a week later under the title "Major study on software stirs debate: On whole, school products found to yield no net gains" (Trotter, 2007).

The software industry and supporters of educational technology quickly responded to this study as well, challenging it from every possible angle. For example, the Consortium for School Networking (CoSN), the International Society for Technology in Education (ISTE), and the State Educational Technology Directors Association (SETDA) issued a joint statement two days after the release, cautioning readers of the report "to scrutinize the findings carefully, as even the U.S. Department of Education states that the study "was not designed to assess the effectiveness of educational technology across its entire spectrum of uses." The Software and Information Industry Association (SIIA) also responded with a statement about the study: "As this study recognizes, proper implementation of education software is essential for success. Unfortunately, it appears the study itself may not have adequately accounted for this key factor, leading to results that do not accurately represent the role and impact of technology in education."(Nagel, 2007).

The treatments this report received reflect the very issues of evaluation of educational technology. First, there is much demand for serious evaluation of technology in schools. Uncertainty about the effectiveness of technology still exists despite (perhaps because of) years of heavy investment and widespread euphoric claims about the power of technology for transforming education. The public, policy makers, and education leaders are in desperate need for sound evidence to guide their investment decisions. Second, evaluation of the impact of educational technology is not easy, to say the obvious. As critics of the study pointed out, there are many factors affecting the effectiveness of any given technology. It is very difficult if not impossible to isolate the effects of technology from those of the uses and the people who use them. Moreover, technology is a catch-all word that can include all sorts of hardware and software. Hence it is unwise but easy to do to over-generalize the results of one or two applications to all technologies. Furthermore, the impact of technology may not necessarily be on test scores. Thus selecting the desirable outcome measure becomes another issue when evaluating the implementation and impact of technology.

A Critical Appraisal of the Evaluation Literature

In the short history of studying technology in education, there has never been a lack of evaluation studies that are intended to gauge the impact of technology on education. No matter what form technology took (from Skinner's teaching machine to radio and television) and in what way it was employed (face-to-face or distance learning), few technologies and technology applications have not been evaluated. When it comes to modern information technologies that are represented by personal computers, the Internet, and a variety of mobile electronic devices, there is no exception. Globally, the movement of infusing information technologies in schools has lasted more than a decade. This continuous investment is accompanied by all kinds of evaluation efforts that have increasingly become an inseparable part of many educational technology programs.

From 1995 to 1998, the European Commission funded the Targeted Socio-Economic Research Programme whose focus was specifically on studying the results of those projects that were involved in ICT-supported learning innovations (Barajas, 2003). Case studies were conducted in OECD countries to examine the impact of information technology on teaching and school improvement (Organisation for Economic Co-operation and Development [OECD], 2000). The Second Information Technology in Education Study Module 2 (SITES M2), a project of the International Association for the Evaluation of Educational Achievement (IEA) that involved research teams from 28 countries in Europe, North America, Asia, Africa, and South America, took an in-depth look into how curriculum was influenced by technology (Kozma, 2003). In the United States, with the push from the federal government for scientific research, a growing number of studies have been conducted or are under way, which involves randomly assigning research participants into a control group in which people do business as usual and a treatment group in which technology is integrated into curriculum (Dynarski et al., 2007). Although there is a great variety among nations with respect to educational system, technological infrastructure, and resources for technology integration, the evaluation efforts are strikingly similar in terms of what questions they intend to answer and how evaluations are approached and conducted.

These evaluation efforts, plus countless smaller scale studies conducted by researchers in universities and research institutions, constitute a significant part of the rich repertoire of evaluation on the relationship between technology, learning, and teaching. A review of this literature suggests that while previous evaluation efforts have certainly contributed to our understanding of the role and impact of technology in education, there are a number of fundamental problems that must be addressed if we wish to make evaluation more useful practically and more insightful theoretically.

Flawed Question

In spite of the fact that a wide variety of questions are explored by evaluators, the evaluation efforts of technology and education is largely driven by the so-called "works" question, which often takes the form of "does technology work" or "is technology effective?" Though phrased differently, in essence, they are all concerned about one thing: Do students using technologies perform better on a certain outcome measure than those who do not. Studies trying to tackle this question often employ experimental or quasi-experimental design and later become the data source of meta-analysis (Kulik, 2003; Murphy et al., 2001; Pearson et al., 2005). The "works" studies flooded the educational technology literature, especially in a special field of educational technology: distance learning, where the research is dominated by studies trying to answer whether a significant difference exists between distance learning and face-to-face learning (Russell, 1999). The "works" research directly addresses policy makers' concern about the efficacy of investing money in technology. In addition, it is often perceived by many to be methodologically easy to conduct. However, a careful examination reveals that it is not only theoretically impoverished but also methodologically problematic.

Epistemologically, the question of "does technology work" assumes that technology either produces expected outcomes on some preconceived outcome measures or not. This notion is troublesome in two aspects. First, it assumes that the effect of technology is largely invariant or at least consistent regardless of population, specific technologies, and the context in which it is used. However, synthesizing research (Kulik, 2003; Pearson et al., 2005; Waxman et al., 2003; Zhao, 2005) has repeatedly observed large variation of outcomes existing within the technology treatment groups, which sometimes could be even larger than the between-group variation. These results have led researchers to believe that a dichotomized answer is not attainable and the effect of technology depends on how it is used and for what purposes. Second, in contrast to the varied effects and diverse goals of technology integration, outcomes in the "works" research have been mostly defined and exercised as standardized test scores. On the one hand, this narrowed view deemphasized other expected outcomes that deserve attention. On the other hand, it prevented us from examining unexpected outcomes that could be equally or even more important.

Methodologically, the question of "does technology work" cannot be successfully answered because it in fact encompasses two distinct questions whose answers confound each other. Decades of research suggests that technology could lead to improved learning outcomes if used appropriately (Educational Testing Service, 1998; Fouts, 2000; Wagner et al., 2005). At the same time, there is evidence showing that appropriate technology uses are associated with conditions for technology uses (Dexter et al., 2002; Mann, 1999; Noeth and Volkov, 2004; Penuel, 2006; Zhao et al., 2002). Taking these two important findings together, it is not hard to notice that a significant difference in the "works" research is the result of two occurrences. First, certain technology uses are supported in a school environment. Second, those certain technology uses are effective in producing desired outcomes. Thus, "does technology work" is really asking (1) are certain *technology uses* effective, which has been extensively studied in the past and (2) can those effective technology uses survive in a certain school environment, which has recently drawn a growing amount of attention. Therefore, a significant effect means not only a certain use is effective but also the use is achievable in a particular school environment. Similarly, a nonsignificant result could be that the use is realized but not effective or the use is effective but not achievable.

Simplistic Approach to a Complex Phenomenon

The predominance of the flawed research question has several unhealthy ramifications to the evaluation of educational technology. One of them is that researchers are often confined to take a simplistic approach to studying educational technology. After years of exploration, it has been widely recognized that technology integration is a continuing process, which usually involves setting goals, laying out an action plan, implementing the plan, and making adjustments during the implementation. The effect of a technology program depends on what happens in the integration process, which has been identified to be nonlinear (Molas-Gallart and Davies, 2006) and dynamic (Mandinach, 2005), and this process could be complex and messy (Zhao et al., 2002).

One of the major weaknesses exhibited in many evaluation studies is the obsession with assessing outcomes in the end. When attention is placed on the final outcomes, what happened during the process is often ignored. As a result, all the complexities and richness embedded in the process are lost in the examination of a technology program. Analysis of the final outcomes, no matter how sophisticated and valid, can only provide a technical account of how those numbers that symbolize program effectiveness are obtained. However, what is needed for decision-making is a cultural story of what brought us to the results. For example, when evidence unfavorable to technology is present, it is important to know whether technology was appropriately used and what physical and social conditions prohibited the appropriate uses. Without cultural annotations to these questions, a nonsignificant finding is evidence without context and can be misleading.

The complexity of technology uses as a social phenomenon lies in not only the dynamic process but also the fact that a technology program often pursues multiple goals. Educational technology researchers have long been aware of the important role objectives and goals play in technology integration (Noeth and Volkov, 2004). A clearly articulated goal could have significant impact on how technological resources are allocated, how technology is used, and how the effect of technology is evaluated. In practice, technology is employed to pursue a variety of goals. Depending on the goals of technology integration, outcome measures could be test scores or other measures of performance, college attendance, job offers, as well as various skills such as higher-order thinking skills, communication skills, and research skills (Noeth and Volkov, 2004). They could also be perceptions about implementation benefits, attitudes toward learning, motivation, self-esteem, and engagement levels (Silvin-Kachala and Bialo, 2000).

Given its legitimacy and importance, research that investigates whether technology improves student achievement is still limited. When student achievement is the locus of attention, most studies relied on performance on standardized test as indication of student achievement. Standardized tests have been extensively criticized to be inadequate for the purported function (Popham, 1999). What have worried people even more is that standardized test cannot reflect improvement in many traits benefited from using technology, such as higher-order thinking skills, creativity, and broadened horizons. In addition, standardized tests are incapable of measuring unexpected and unwanted outcomes. As pointed out by many researchers, while empowering teachers and students by providing them with unprecedented opportunities, technology can also introduce many problems and complex issues into education (Lei et al., 2008). For example, problems in classroom management, cheating and plagiarism, and access to inappropriate web content have been repeatedly reported in the media and research studies. These negative effects of technology have significant implications to education. However, a narrow focus on student achievement in evaluation efforts has prevented exploration and exposition of these issues.

A comprehensive understanding of technology calls for diversified methods that address different questions. All valid evidence should be treated seriously. However, greater, if not exclusive, weight has been placed on experimental or quasi-experimental design that is deemed to provide the most valid answers to "works" questions (Mageau, 2004). While acknowledging randomized experiments as the gold standard for causal inferences, there is a general consensus that traditional experimental designs are limited for dealing with the complexity of technology integration (Heinecke et al., 2000; McNabb et al., 1999; Melmed, 1995). Alternative methods are essential if program effectiveness is to be determined and understood (Slayton and Llosa, 2005).

Inconsequential Policy Implications

Evaluation or research on the impact of technology does not seem to have had much impact on policy. The failure or success of past technology does not seem to have affected the policy decisions about future investment in technology. For example, heavy investment was made in the 1990s in connecting schools to the Internet and putting computers to schools despite the failed attempts of introducing earlier technologies such as film, radio, and television. Today, while schools have more technology than what was believed to be necessary to realize the dream scenario, which has been used to justify the billions of dollars in education technology(McKinsey and Company, Inc., 1995), it would be quite difficult to find many meaningful differences in how and what students study in school today and how and what they studied in school in 1996, the year when major investment in connecting schools to the Internet began in the USA. The third National Educational Technology Plan released by the U.S. Department of Education in 2004 quotes Education Secretary Rod Paige:

> Indeed, education is the only business still debating the usefulness of technology. Schools remain unchanged for the most part despite numerous reforms and increased investments in computers and networks. The way we organize schools and provide instruction is essentially the same as it was when our Founding Fathers went to school. Put another way, we still educate our students based on an agricultural timetable, in an industrial setting, but tell students they live in a digital age. (U.S. Department of Education, 2004)

It would be unfair to categorically characterize technology investment as a complete waste or to suggest that technology has no educational benefits. In fact, there are plenty of "success stories" and empirical studies to show that when used properly, technology does lead to a wide range of educational benefits (for example, see U.S. Department of Education,2004; President's Committee of Advisors on Science and Technology (Panel on Educational Technology), 1997). The problem is that the effects seem to be confined to a very small number of schools. Somehow, unlike hardware, connectivity, and software, the practices that lead to positive educational outcomes have had a difficult time to spread across classrooms and schools to lead the promised transformation.

In stark contrast to the great cost savings and improved efficiency in other industries due to the Internet, education has not benefited from this revolutionary technology. Schools have neither become more efficient, that is, operating with less cost, nor more effective, that is, improving learning, due to the deployment of the Internet. On the contrary, the Internet seems to have increased costs of running schools in a number of ways. First, in addition to the initial investment in putting computers in schools and wiring them to the Internet, schools have to constantly spend on maintenance and updating the hardware and software. Thanks to the rapidly evolving nature of technology, schools have to not only upgrade software, but also buy new hardware almost every 3–5 years just in order to keep the same level of access.

Given the considerable magnitude of the investment in technology, schools must also exert efforts to ensure that the technology is somehow used. Otherwise it would be difficult for schools to answer to the public that has agreed to pay for it. The costs in terms of money, teacher time and energy, as well as the lost opportunity for teachers to engage in other potentially more beneficial activities can be significant.

Finally, schools have to also exert efforts to deal with the undesirable uses by students and staff. The Internet and computers are just information and communication technology and just as any information and communication technology, they enhance the way we access, process, store information, and communicate with others without differentiating the quality of information and communication. Thus schools have been drawn into numerous legal, ethical, and ideological battles over the uses of the Internet and computers. In addition to compliance with the U.S. federal Children's Internet Protection Act (CIPA), schools must also deal with state and local regulations. More importantly they must address the potentially harmful or distractive effects of technology: hacking, computer viruses, cyber bullying, equipment vandalism, etc. The concern over misuses of the Internet and potential harms it may bring to students is so grave that many schools have taken an overly cautionary approach by limiting access to websites and completely blocking other forms of online activities, especially synchronous communication (e.g., chat) and publishing on the Web (e.g., blogging and access to social websites such as mySpace and Face Book), which in essence makes it impossible to materialize what was envisioned in the first place.

Neither the repeated unfulfilled promises of technology nor the unintended consequences of technology seemed to have curbed the enthusiasm of policy makers. Today, schools continue to invest in technology. Over the past few years, student computer ratio continued to drop, suggesting that schools have been buying more computers. And more significantly, there is a growing trend for schools to equip every student with a computing device with wireless connection. Currently at least 33 states in the USA have one-to-one laptop programs, ranging from individual schools to school districts to state-wide projects (Lei et al., 2008). Most telling of this continued faith in technology is the recent U.S. National Educational Technology Plan entitled *Toward a New Golden Age in American Education: How the Internet, the Law, and Today's Students are Revolutionizing Expectations*, which promises:

> As these encouraging trends develop and expand over the next decade, facilitated and supported by our ongoing investment in educational technology, and led by the drive, imagination and dedication of a reenergized educational community at every level, we may be well on our way to a new golden age in American education. (U.S. Department of Education, 2004, pp. 8–9)

Why then has not evaluation or research made much difference on policy decisions? The answer is actually quite simple: Policy decisions by and large are made based on the perceived value of technology. But the perceived value is not necessarily entirely educational, that is, benefits to the students, often times, it is political, that is political benefits to the decision makers.

Failures in Evaluating the Practical Value of Technology

The value of technology in education can be interpreted in two ways: practical and symbolic. The practical value comes from the utilitarian role technology plays, such as the problems it can solve. For example, a distance learning system helps students in remote areas obtain education they need without spending time and money on transportation. The symbolic function of technology is what symbolic benefit a technology can bring to the adopter or the institution. For instance, having sufficient instructional computers in a school shows that the school is incorporating cutting-edge technology for teaching and learning purposes. Images like this can serve as advertisements and help improve the reputation of the school or the school district.

Although it seems the practical function of technology is the most important since it is the practical functions that help improve teaching and learning, the symbolic function of technology plays an equally, if not more important role in the decision-making process because most, if not all, large technology investment decisions are made for political reasons, not necessarily based on scientific research. We started equipping technology in schools not because there was any conclusive evidence that showed that technology improved teaching and learning, but because it was a politically correct and the right thing to do. Information and communication technology has been viewed as a magical tool that has the potential "to widen access to education at all levels, to overcome geographical distances, to multiply training opportunities, and to empower teachers and learners through access to information and innovative learning approaches – both in the classroom, from a distance, and in non-formal settings" (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2003, p. 9). How could any one who cares about the future of our children resist such magical tools?

Because the decisions to invest in technology are political, which often are made in a hasty fashion and driven by vision and speculations, the investment is often in what is visible (e.g., hardware) and standard (a computer for every class). What is not visible, such as support, professional development and content is often ignored. The local context and differences in schools are not considered. More importantly, political decisions tend to go after the immediate image and cash in the symbolic value, and thus short-term outcomes are sought after without considering the long-term implications.

Consequently, there are important details that have been ignored. Technology is often believed to be able to cure all education ills and achieve all the goals such as to greatly facilitate education reforms, improve student achievement, and thus solve social problems and achieve democracy and economic competency (Zhao et al., 2006). However, technology "in and of itself, is not a magic wand" (U.S. Department of Education, 1996). Its effects depend on how it is used by whom for what purposes. Educational benefits depend on uses and implementation. Teachers and students need a reason to use technology. As something newly introduced to classrooms, technology has to be able to connect with existing practices to be integrated into teaching and learning. Computers need support infrastructure, maintenance, and upgrades because computer hardware relies on a host of peripherals and software to operate and it breaks down. It takes time to see the effects of technology. Changes are gradual. It may take three years, five years or even longer to observe the effects of using technology.

These details are what truly affect the outcome of technology investment because technology implementation is largely guided by pragmatic constraints in the local context, social interactions in a school, and experiences of the user. Therefore, sufficient emphasis on these details and a sound understanding of how they affect technology implementation can not only provide reliable and valid information on the impact of previous technology efforts, but also offer valuable guidance to future technology investments.

However, in pursuit of immediate effects and symbolic values of technology projects to support politics-based decision-making, the current technology project evaluation practices have failed to produce and accumulate such knowledge due to a number of reasons:

- Project evaluation has been largely "summative." For many project evaluations, a major goal was to find evidence to prove the worthiness of the investment, or the lack thereof. In fact this objective is of not much value because no matter what the results demonstrate, the investment decision has already been made and the money spent.
- Short-term project evaluation fails to examine more important long-term effects. It takes time for a technology project to have any impact and it takes even longer to observe the impact. When an evaluation is part of a technology project, the evaluation ends when the project ends; therefore, it can only evaluate the short-term impact or even just the concurrent changes, which may or may not be caused by the technology project. Moreover, because of the time it takes to detect the impact, short-term technology project evaluations often report "no impact" findings. By only examining the short-term impact, these project evaluations fail to capture the long-term real changes caused by technology.
- Individual project-dependent evaluation lacks generalizability. Current technology evaluation is normally focused on specific projects in specific contexts and thus cannot be generalized to a broader context. Schools differ drastically from each other in many ways and technology implementation is influenced by the dynamics of the technology, the school system, and the users in particular schools; thus it is very difficult to replicate one school's experience in another school. In addition, technology changes very fast, and schools are always trying to catch up with the latest technology development. By the time the evaluation of a technology project is completed, schools are already purchasing different new technologies and implementing different projects. It is therefore very difficult to apply what we learn from a specific technology to other technologies.
- Project evaluation with very narrow focus cannot provide a comprehensive picture of the impacts of technology investments. Educational technology projects aim to effect sustainable and systemic changes. Project evaluation studies generally focus only on the intended outcomes, and ignore the unanticipated, sometimes even more important outcomes; thus cannot provide a full picture of the changes effected by the project implementation.

As a result, although much effort has been put on evaluating the effects of educational technology investments, we have not gained much knowledge of our educational technology investments and how we can take advantage of existing technology.

Where Are We Now?

Faced with an uncertain answer about the return of the investment in technology, what should policy makers, educators, and the public do when it comes to decide whether to continue to invest in technology or what to do with the existing technology? Should we continue investing in technology in schools, or stop at where we are now? There are a number of options.

First, we can of course try to increase the use of existing technology. This has to be approached from a number of dimensions. First, to maintain and upgrade hardware, software, and the infrastructure. As current technology continues to advance at a tremendous rate, schools are under great pressure to keep updated with current technology development. Therefore, technology facility issues such as when to buy technology and what technology to buy are not simple issues that can be solved once and for all. Schools often make the mistake of spending all or most of the money on purchasing hardware and leaving little to no money for maintaining and upgrading technology (Ringstaff and Kelley, 2002).

Second, we need to provide and improve teacher professional development. Teachers have long been identified as a key factor that influences technology integration in schools because they decide whether, what, and how technology gets used in classrooms and therefore decide whether or not the potential benefits of information technology can be reaped by students (Conway and Zhao, 2003). Research also shows that helping teachers learn how to integrate technology into the curriculum is a critical factor for the successful implementation of technology applications in schools (Coley et al., 1997), because "When teachers are not trained to use new technology, computers end up being just souped-up typewriters" (Cuban, 2001).

Third, we must also increase meaningful use of technology by students. We know that the same technology can be used in many different ways and for different purposes, and some of these uses are good meaningful uses and some are not helpful or even are harmful to learning. Teachers, parents, and schools need to encourage good uses and discourage bad ones.

Fourth, we need to find the right problems. There can be many different reasons for the under use of technology, such as insufficient technical support, low technology proficiency, lack of peripheral technology, incompatible teaching or learning practices, and unsupportive management. The specific reasons might be different in different cases, and the right problems must be identified to improve the situation.

All the above approaches to increasing the use of technology need research-based evidence to guide our decisions. For example, to keep technology updated, we need to understand when to buy technology and what technology to buy. To increase student meaningful use of technology, we need to learn from experiences to find out what technology uses are good and what are not.

Another option is to stop at where we are now. However, an examination of the consequences of doing so rules out this possibility. First, the new wave of educational technology planning and investment is pushing technology development in a new direction that we cannot afford not to follow. While the first and the second waves focused on mainly technology access and integration issues, a third wave has begun to pay more attention to how school cultures with their history of deeply embedded practices involving older technologies can more effectively integrate digital tools into the daily fabric of teaching and learning, and use digital tools to change existing school practices (Conway et al., 2005). If we stop now, we not only waste what has already been invested, but also miss the opportunity to achieve the goal of investing technology in education we set out in the first place.

Second, technology is developing at a staggeringly rapid pace, and quickly becomes obsolete, which requires schools to change accordingly. "For an evolutionary system, continuing development is needed just in order to maintain its fitness relative to the systems it is co-evolving with" (Van Valen, 1973). Now we find us caught in a situation similar to the one of the Red Queen in the "Through the Looking Glass" by Lewis Carroll that "in this place it takes all the running you can do, to keep in the same place." Therefore, even if we just want to stay where we are now, continuing investment is required to keep already purchased technology up-to-date.

Apparently, we are in a bind. On the one hand, we cannot afford to abandon technology because of previous investment and the great potential technology promises even though there is no clear evidence that previous investment had made significant contribution to the core business of school, i.e., improving student achievement. On the other hand, if we continue to push technology uses, we will need to invest more in technology but remain uncertain about its return. How can we get out of this bind?

A Proposal for Moving Forward: A Logic Model for Evaluating Technology

To get out of this bind and move forward, we need data-driven policy making that is based on evidence provided by scientific research, to learn from history, from successes and failures made by previous efforts, and to make improvements in every effort we attempt in the future. The most critical step is to view different technology investments as experiments from which we can accumulate knowledge to learn what and how to do better. Therefore, we need serious evaluations that can capture the long-term comprehensive impact of technology investments to provide scientific research evidence to support a data-driven policy making. Specifically, we propose a number of approaches to conduct serious technology project evaluation:

First, support sustained "formative" evaluation of technology investments to focus more on the process of project implementation. Technology or funding alone does not lead to improved education. It is how the funds or technologies are used that will determine the degree to which the potential of funding or technology is translated into desired educational outcomes; therefore, the evaluation should not only study the products of the program but also the process to investigate how the project is implemented, the ways the funds are deployed, what technologies are deployed, and in what ways the technologies are used. Formative evaluation effort can provide timely, relevant, and useful information to identify and correct problems during the implementation stage and gather valuable information about effective strategies to use the funds and technology. The evaluation should provide reliable and valid information on whether the program works but also under what conditions what uses of the technology works better.

Second, support longitudinal evaluation studies to be independent from specific technology projects. To examine the long-term impact of technology, we need longitudinal evaluation studies that do not end when the projects end, but continue collecting and analyzing data to identify how technology can be used to have real, long-term payoffs for improving student learning. Project-independent evaluation can also increase the generalizability of the results and shed light on different technology projects in different contexts.

Third, support large-scale comprehensive evaluation: Technology provides great opportunities for education but at the same time also poses new challenges. Too often it is the good things technology can bring that are talked about but the pitfalls ignored. This omission can cause serious problems. Therefore, the evaluation must be able to capture both the anticipated and unanticipated, and the desirable and undesirable changes a technology project may bring about. After reviewing 17 recent impact studies and surveys carried out in Europe, Balanskat et al. (2006) suggest that research should include wider topics and find instruments to capture and detect unexpected results and processes. The evaluation should use a variety of strategies to detect changes in students, teachers, administrators, parents, and the public, and also use a variety of indicators to measure the breadth and depth of impact of the technology projects on individuals and institutions. For example, the outcomes of the project can be expressed in terms of student academic achievement, attitude toward learning, learning behaviors, social connections, and physical well-being. There can also be changes in teachers' pedagogical behaviors, attitudes toward technology, and professional growth. Additionally, the project can affect administrators effectiveness in providing leadership and support for an effective teaching and learning environment. The project can also be expected to influence curriculum and the general culture of the school and district.

Fourth, build independent mechanism for data collection, analysis, and reporting. To conduct large-scale longitudinal evaluations that can capture the comprehensive long-term effects of technology, we need to establish independent mechanism for data collection, analysis, and reporting so that the evaluation process will not be affected by specific technology projects or policy changes. Independent evaluation process and reporting can also provide unbiased information to help policy-makers and administrators to make better informed and just technology decisions.

Fifth, gather cumulative information to support local decision-making. Sporadic evaluation information collection can only provide one-time snapshots without accumulating and connecting information, and thus can hardly provide clues for future development. Therefore, cumulative information on changes in student achievement, teaching and learning practices, school culture, and local community needs to be collected, and ongoing data analysis needs to be conducted and reported to help administrators make well-informed technology decisions that can best meet the needs of their local schools and communities.

Finally, establish formal mechanism for advising policy making. Technology policy-making and decision-making should be supported by evidence found in scientific research. Formal advising mechanism should be established as a bridge between scientific research and policy making to help translate scientific findings into practical suggestions and to advise policy-making.

A few research groups and organizations have been moving toward these directions in one way or another. For example, the large-scale SITES study investigates the nature, process, and innovative practices of ICT use in education from an international comparative perspective. Similar approaches can be applied to studying technology uses in the same educational system. *Education Week*'s yearly Technology Counts report collects data on technology integration at national and state level. Such longitudinal data at micro level (e.g. school district, school, and student) are also much needed.

One way to help implement these recommendations would be to adopt a logical model approach to evaluation. Logic models emerged in 1980s to address problems in previous evaluation approaches. The W.K. Kellogg Foundation Logic Model Development Guide defines the logic model as "a systematic and visual way to present and share your understanding of the relationships among the resources you have to operate your program, the activities you plan, and the changes or results you hope to achieve" (W.K. Kellogg Foundation, 2004, p. 1). A logic model approach has been adopted in some major technology evaluation studies such as The Impact of Information and Communications Technologies on Pupil Learning and Attainment (Becta, 2006) and the E-learning Nordic study (Ramboll Management, 2006). Yet, different studies often use different terminologies and emphasize on various aspects in relation to evaluation goals. Synthesizing studies that employed a logic model approach, a more general account of the model is detailed below to facilitate model adoption with adaptations subject to local context.

The classical logic model consists of three components: inputs, outputs, and outcomes. Inputs are the human, financial, organizational, and community resources available for the implementation of a program. As a neutral concept, inputs post affordances as well as constraints and provide a context for a program. Outputs deal with program implementation. On the one hand, outputs include activities, services, events, and products involved in the program implementation. On the other hand, they are also concerned with how those activities, services, events, and products are utilized by participants or the targeted population. Outcomes are the results or changes for individuals, groups, organizations, communities, or systems. Outcomes include both short-term impacts and long-term impacts, and can either be positive or negative, pre-conceived, or totally unanticipated. From inputs to outputs to outcomes, the three components are linked by assumptions and theories. The classical logic model is illustrated in Figure 1.

Using this model, evaluators can take a careful look at all three components of a program and try to understand the complete picture. In this process, theories and assumptions affect how data are collected and analyzed, and at the same time are revisited with the gained understanding. This process is ongoing with frequent data collection and analysis, and flexible with continuous revisions of theories and

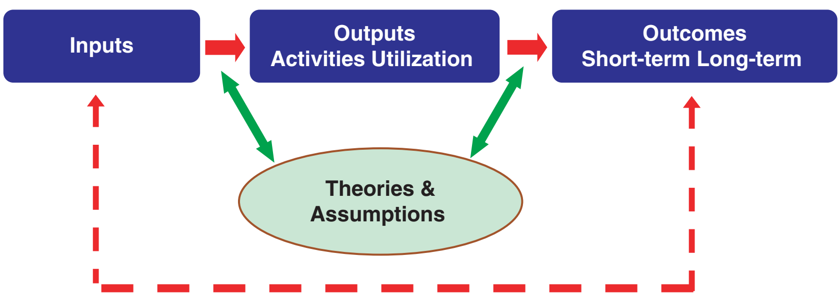

Fig. 1 Illustration of a logic model

designs. In addition, this process is cyclical. The outcomes observed at one cycle of evaluation become part of inputs of the next cycle of evaluation.

For the purpose of evaluating technology programs, the above classical logic model was translated into the model presented in Figure 2. As shown in Figure 2, evaluation of a technology program focuses on five topical areas: context, program implementation, short-term impact, long-term impact, and broader impact. This figure highlights the breadth and depth of the possible impacts of the program as well as its long-term nature. The figure, however, only lists possible positive impact of the program while it is foreseeable that the program may also bring some undesirable changes that need to be avoided. In the following explanations of the figure, we include both positive and possible negative changes.

Context. The evaluation begins with an assessment of the context in which the technology program is to be implemented. Contextual factors include the basic school characteristics such as size and location, current technology conditions (infrastructure, hardware or software, uses), student characteristics (free-reduced lunch population, technology proficiency, access to technology, academic performance, etc.), teacher characteristics (years of teaching, technology proficiency and uses, academic background), and institutional support or expectation for technology uses (policy related to technology, professional development efforts, and resources for teachers). Contextual factors will likely influence the effect of the program and will be used for interpreting future changes.

Program Implementation. Program implementation is of three concerns. First, it is important to find out what practices and strategies are cost-effective in deploying technology. Second, measures need to be taken to provide timely information about program progress and performance for adjustment. Third, close attention needs to be paid to the program deployment data so as to help interpret the impacts of the program. Program implementation factors fall in three categories: deployment (how are purchase decisions made, what procedures and strategies are used to distribute purchased technology, what training is provided to target users), uses (how frequent do target users use purchased technology, what kind of uses do they make of the technology, and what are their attitudes toward the purchased technology and the program), and sustainability (how does new technology supported by the program fit with existing infrastructure, what kind of policy changes are needed, and how schools resolve practical issues brought about by the program).

Short-Term Impact. As discussed before, evaluation of any technology program should take a systemic approach and examine its impact on the whole learning environment. Therefore, it is important to study both long-term and short-term effects. The short-term impacts will be on things that are relatively easier to change but they are necessary to lead to long-term changes. Teachers are the first group of people who need to change because ultimately their teaching style and practice affect the effect of technology on student learning. The easiest to change is teachers' technology proficiency and then attitudes toward technology, which is necessary to lead to changes in teaching style and practice. If the program is effective, changes in teachers' use of technology in their teaching, professional activities, and communication with parents, students, administrators, and colleagues are also expected to be

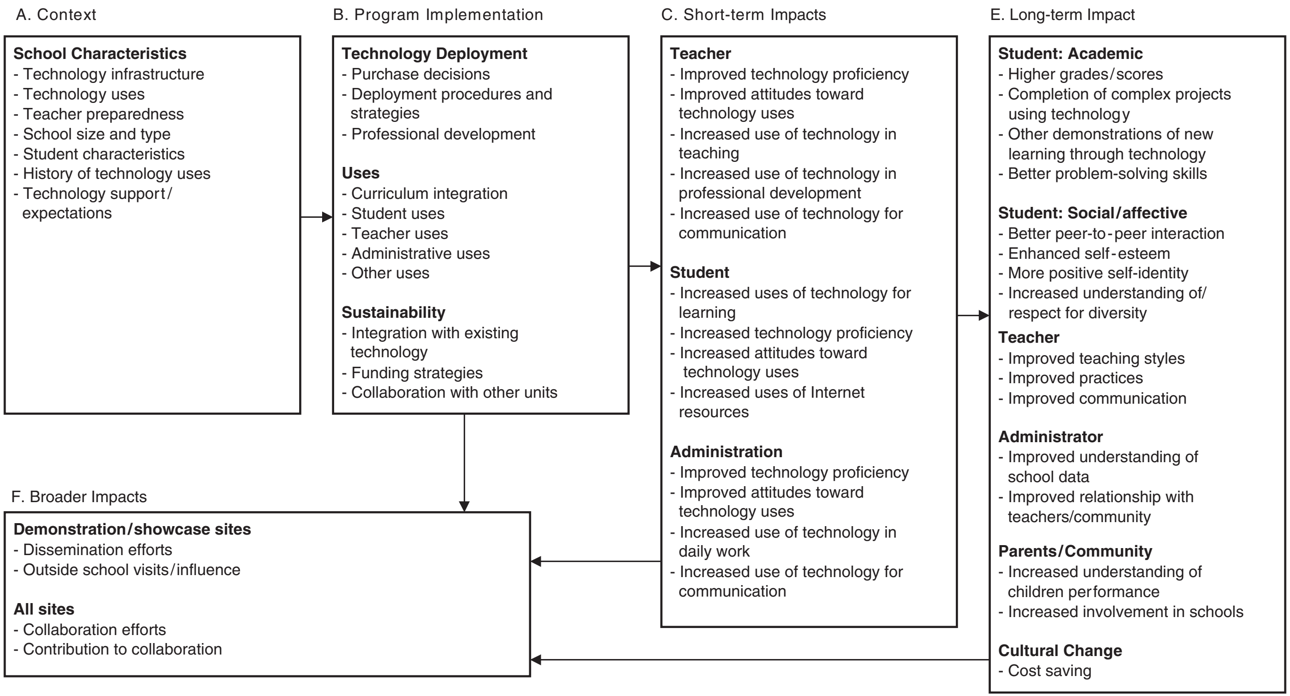

Fig. 2 Logic model for evaluating technology programs

observed. Other short-term impact include student technology proficiency, attitudes, and uses, and administrators' technology uses.

Long-Term Impact. Ultimately, the evaluation should focus on the long-term impact. If the program is effective, it should help improve student academic performance, which can be demonstrated in higher grades and test scores, or new forms of learning. In addition, students might become better communicators, develop more respect for diversity, and broaden their horizon. They might be better equipped to live in a fast-paced world where technologies are ubiquitous and being able to use these technologies becomes basic life skills. It is also expected that teachers will teach better with technology and administrators will lead the school better. With the assistance of technology, instruction turns into student-centered and learning becomes differentiated; school administration is no longer mainly based on perceptions and anecdotes, but is data-driven instead. Additionally, technology might bring the community closer to the school through better communication.

Broader Impact. Because the program might be used for demonstration for the sake of dissemination, it is helpful to assess to what degree the program sites could serve as demonstration or showcase places for other schools. It is important to understand to what extent the understanding gained from evaluation at the program sites could be transferred to other schools and generalized to a broad range of context.

This evaluation design requires both qualitative and quantitative data and a series of data-collecting strategies. Table 1 details the data-collection framework for studies of this design. As depicted in Table 1, data will be collected from qualitative methods (interviews, observations, student products, documents) for in-depth understanding of the process and outcomes of the program. There will also be quantitative data (surveys, test scores, grades, and records) for assessing the effectiveness of the program.

The logic model proposed earlier poses great challenge to data collection and analysis. To assess change, it becomes essential to gather longitudinal data for a host of measures at different levels on a frequent basis. It is vital that these data can be linked together so that they can be studied collectively. Since the enacting of the No Child Left Behind Act in the USA, strides have been made at the state level to build data systems for accountability, evaluation, and planning. In 2003, 36 states already provided data to administrators and teachers for decision-making (U.S. Department of Education, 2007). Many districts are also building their own data warehouse to store and process longitudinal data. However, these data are predominately information of student characteristic and student achievement measured by standardized tests. Though enormous in quantity, these data compose only a small chunk of the data that are necessary for a comprehensive evaluation. It is critical to develop a strategy from which other data can be collected timely and at a low cost. One possible solution is to build tracking and assessment modules in technology products so that a large proportion of data could be automatically collected almost immediately. Researchers need to employ value-added models (McCaffrey et al., 2003) to make use of all the information accumulated over the years. In addition, data collected at multiple levels make it possible to use hierarchical linear models to estimate effects within and across levels.

Table 1 Data collection methods and strategies

Topic area	Data sources	Method	Mechanism
Context	School administrators School documents	Surveys Document analysis	Online survey Program manager meetings
Program implementation	Project team Students Teachers Administrators	Surveys Interviews Observations	Online survey Video conferencing Video/pictures Manager meetings
Short-term impact	Students Teachers Administrators	Surveys Interviews Observations	Online survey Online journal system Video conferencing Site visits Local program documentation
Long-term impact	Students Teachers Administrators	Surveys Interviews Observations	Online survey Online journal system Online portfolio management system
	School records	Record/test/ products analysis	Local program documentation
	Standardized tests Student products		
Broader impact	Students Teachers	Surveys Interviews	Online survey Community statistics records
	Administrators School records Community records	Observations Record analysis	

Since the logic model is determined to provide continuous feedbacks for program adjustment, frequent communication is expected between evaluators and those who are responsible for implementing the program. The timeliness and effectiveness of the communication is largely dependent upon availability, convenience, and communication format. With that in mind, this model is more practicable for medium- or small-scale programs that are conducted locally. Also, when the implementation of a program is adjusted based on evaluation results, the subsequent evaluation often needs change accordingly. In this regard, this adjustment is similar to the iterative changes in design experiments (Brown, 1992; Cobb et al., 2003).

Lastly, this logic model is by no means comprehensive and thorough for simple duplication. Rather, it is attempted to serve as a prototype that needs adaptation and adjustment. Evaluators must take program goals, evaluation goals, stake holders' interests, and constraining factors into consideration for designing their own logic model for a particular technology program. The adaptation and adjustment of the proposed logic model based on context is crucial for a successful evaluation effort because there is no best logic model (W.K. Kellogg Foundation, 2004).

Conclusion

Whether or not the human societies can make progress depends on our ability to learn from the past, so as to replicate, expand, and adapt successful experiences and to avoid repeating the same mistakes. In the past several years, we have been experimenting with investing technology in schools. These investments can serve as important steps towards better informed technology decision-making and improved technology investment efforts. When the evaluation of these investments is short-term project-dependent evaluation, it is very difficult to capture the long-term payoffs of these investments and learn from the process. We need serious scientific evaluation to examine the comprehensive effects of our technology investments and to support data-driven decision-making. Based on what we have learned from previous investment efforts, we can not only make better technology investment decisions on what to invest, when to invest, how much to invest, and how to invest, but also on how to best implement technology projects so that we can receive the educational returns we hope to obtain from our continuous investment in educational technology.

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Section 7

IT AND DISTANCE LEARNING IN K-12 EDUCATION

7

IT AND DISTANCE LEARNING IN K-12 EDUCATION

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Distance education (DE) is defined by Moore (2003) as "all forms of education in which all or most of the teaching is conducted in a different space than the learning, with the effect that all or most of the communication between teachers and learners is through communication technology" (p. xiv). The history of distance education in the form of correspondence education could be tracked back to the early 1700s, and technology-based DE, marked with the introduction of audiovisual devices into schools, to the early 1900s (Jeffries, 1993, p. 1). Nevertheless, today's K-12 DE is fundamentally unique (Cavanaugh et al., 2004, p. 6). The profound developments in computer networking and telecommunications in the last decade created a powerful technological base for DE, which offers various possibilities for compensating the distance – global reach of people, unlimited access to educational resources, rich possibilities for distance communication and collaboration, and design of virtual learning environments.

This section deals with ICT-supported DE in K-12 (i.e. primary and secondary school). It includes six chapters, complementing each other in order to provide an overview of the main issues in today's K-12 DE and to identify future trends and research directions. A variety of representations of ICT-supported DE in K-12 have been observed: from enrichment of traditional learning, through blended learning (Singh, 2003, p. 2) models to virtual schools (VS). Whatever the context and format, DE in K-12 phenomenon poses new challenges and new requirements to all players in the process – students, teachers, administrators, and parents. Though there are a number of "best-practice" examples for student-centered DE, in the mass scale teacher-centered and material-centered learning designs still dominate. Another concern about present K-12 DE is that despite the technological developments, which allow more flexible and active learning arrangements, this potential has not been fully utilized yet.

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Chapter 7.1 discusses the role of ICT as a catalyst for a global educational reform in schools aimed to break the monopoly of the print-and-paper-based education. It is characterized by the use of virtual learning environments that do not put a clear boundary between physical and virtual worlds. The effectiveness of ICT-based DE is discussed and its future is considered in the context of the so-called Web 2.0 schools.

Chapter 7.2 presents an overview of pedagogical issues in the online classroom, with a focus on the communication component. Strategies for enhancing teaching and learning in a collaborative online environment are discussed. Past experiences are reflected upon and current challenges for effective use of technology as a tool in the online classroom are emphasized.

Chapter 7.3 zooms into the virtual school phenomenon. After defining VS characteristics and configurations, a number of important VS issues are reviewed from program, student, teacher, and policy perspectives. Finally, recommendations on research and policy issues related to the future of VS are provided.

Chapter 7.4 focuses on the DE-Enrichment model. Definitions and examples of the concept are presented using the experiences of Hawaii and Pacific/Asian regions. Alternative models and techniques are presented as well.

In Chapter 7.5 the concept of open learning is elaborated. Particular attention is given to the emerging field of Learning Objects and open educational resources. Their potential for K-12 education is considered.

Finally, in Chapter 7.6, online professional development for teachers is discussed. Virtual learning environments are seen as an effective way for spreading teacher education and supporting professional development. Models for online professional development are presented and trends in content development are identified. Lessons learned from Asia/Pacific, as well as examples from Europe (Hungary), are presented.

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7.1

DISTANCE EDUCATION IN SCHOOLS: PERSPECTIVES AND REALITIES

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Introduction

The phenomenon of Distance Education (DE) in schools is strongly related to the rapid developments in the area of Information and Communication Technologies (ICT). During the last two decades, an immense number of students and teachers got access to advanced ICT and this dramatically changed the ways they communicate as well as use and create information. ICT creates conditions for technology and minds to work together, and the capacity of this synergetic system could be much higher than the single mind. The school is no longer the sole and most attractive source of information and knowledge. Quick access to unlimited sources of information is obtained due to modern technologies. The traditional concept of literacy has been gradually extended to *multimedia literacy* referring to students' abilities to read, write, and communicate with digitally encoded materials – text, graphics, still and moving images, animation, sounds (Nikolov, 1997). Mioduser, Nachmias, and Forkosh-Baruch (2008) in this handbook extensively discuss the so-called new literacies for the twenty-first century.

The technological developments provide a ground for an educational reform that can help citizens prepare better for living in the global information society (see also Anderson, 2008 in this handbook). Such a reform will break the monopoly of the *print- and paper-based educational system* and will rely on learning environments incorporating *asynchronous space and time, interactivity, and virtual reconstruction* (McClintock, 1992a). The main characteristic of such a learning environment is the virtual reconstruction of the school space by building virtual places: auditoriums, labs, workshop rooms, cafes, libraries, etc., where students and teachers from different locations can meet, interact, and work together, as if they were face-to-face.

Looking back at ICT history one can clearly notice that the main attention of researchers and technologists has gradually moved from hardware to software, next

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– to human–computer interaction, and recently – to social issues related to global communication and collaboration (Nikolov, 2001). Communication is the most typical activity in a community. Computer-mediated communication may support the establishment of virtual communities, which are formed on the basis of common interest, collaborative work, or other joint activities (Fernback and Thompson, 1995). These communities are transnational and transcultural and need reconceptualization of the social life, including education.

A core assumption in education is that learning is a social process, rather than an individual one. Therefore, DE in K-12 education, facilitated by ICT, may foster the creation of learning environments where communication is easy and leads to meaningful learning activities closely related to the predefined educational goals.

Defining the Area

The rapid development of ICT and their applications to teaching and learning has led to evolution of terminology (see also Voogt and Knezek, 2008). Terms that are not yet well defined and are still part of scholarly debate are used in practice by policy makers and professionals. *Distance education* is defined by Moore as "*all forms of education in which all or most of the teaching is conducted in a different space than the learning, with the effect that all or most of the communication between teachers and learners is through communication technology*" (Moore, 2003, p. xiv). Moore's definition comprises the use of ICT as a means to realize teaching spatially separated from learning, which distinguishes DE from the distance correspondence mode, which was common practice before the widespread infusion of ICT in society. In addition to Moore's definition, Butcher and Wilson-Strydom (2008) in this handbook also added temporal separation between teachers and learners. By adopting the above definition, we accept *distance education* as a generic term that emphasizes on the separation (in space and time) of learners and teachers, and includes the wide use of ICT. According to Moore, most other terms used in the literature express subordinate concepts related to different aspects of DE but they are not considered as synonyms of DE. Because DE nowadays is closely related to the use of ICT, other terms have emerged as well. For instance, *online learning, e-learning*, and *telelearning* emphasize the use of a particular communications technology; *distributed learning* and *distance learning* focus on the location of learners; *open learning* and *flexible learning* point out the relative freedom of learners to exercise more control over their learning than is normal in conventional education. Butcher and Wilson-Strydom (2008) in this handbook illustrate the confusion that can be generated when concepts such as distance education/learning, open schooling, and open learning are used interchangeably. They argue that DE can be very much instruction-driven, not allowing learners to take control of their learning, and therefore could not always be a convincing example of open learning.

Another term that is closely related to DE in the school setting is virtual schooling, which is defined as "an educational environment in which K-12 courses and other learning activities are offered mostly or completely through distance technologies"

(Roblyer, 2008, in this handbook). A similar concept is open school which could be defined as "… an educational institution delivering primary and/or secondary education, providing courses and programmes predominantly through use of distance education methods" (Butcher and Wilson-Strydom, 2008, in this handbook). According to Roblyer (2008), the rapid growth of virtual schools in the last decade has become an unanticipated success story in the history of ICT integration in education. Roblyer also argues that the spatial and temporal separation of teaching and learning, as main features of DE, also cause problems such as a high dropout rate. This was one of the reasons for mixed forms to emerge and the term blended learning was born. Singh defines the features of blended learning: "Blended learning programs may include several forms of learning tools, such as real-time virtual/collaboration software, self-paced Web-based courses, electronic performance support systems (EPSS) embedded within the job-task environment, and knowledge management systems. Blended learning mixes various event-based activities, including face-to-face classrooms, live e-learning, and self-paced learning. This often is a mix of traditional instructor-led training, synchronous online conferencing or training, asynchronous self-paced study, and structured on-the-job training from an experienced worker or mentor" (Singh, 2003, p. 51). Blended learning is typically associated with corporate training and higher education, but it quickly penetrates the school education as well (see for instance: http://en.wikibooks.org/wiki/Blended_Learning_in_K-12). "It is also possible that the blended model may prove to be attractive to K-12 schools, especially those that are struggling with issues of online learning quality, student readiness, and teacher professional development" (Picciano and Seaman, 2007, p. 20).

In summary, the evolving definitions and terms show the dynamics in the DE area of research, as well as the common understanding that the main feature of DE is the use of ICT to facilitate the teaching and learning process when teachers and learners are separate in terms of space and time. In this chapter we will use the term ICT-based DE for distance education which uses ICT for facilitating the teaching and learning process.

The Phenomenon of ICT-Based Distance Education in K-12 Schools

ICT-based DE is considered "*the most significant development in education in the past quarter century*" (Moore, 2003, p. ix). According to Powell and Patrick (2006, p. 3), there were more than 500,000 enrolments in online courses in grades K-12 and more than one third of public school districts offered some type of e-learning in the USA during the 2005–2006 school year. A study of the North American Council for Online Learning, which surveyed over 30 countries, showed a fast growth of ICT-based DE initiatives in many countries, such as: Australia, Canada, Japan, China, Kazakhstan, Nepal, New Zealand, Singapore, Zimbabwe, etc. (Hedberg and Ping, 2004, pp. 200–205). The United Nations Educational Scientific and Cultural Organization (UNESCO) has established a database with 90 ICT in education projects in Asian countries (http://www.unescobkk.org/index.php?id=1562).

Based on this database, the countries in this region could roughly be categorized into three types:

- Countries already integrating the use of ICT into the education system and increasingly delivering education online, facilitated by wide access to the Internet (Australia, South Korea, Singapore). South Korean schools, for example, have universal access to Internet.
- Countries that are starting to apply and test various strategies (China, Thailand, Japan, Malaysia, the Philippines, and India). Online learning (ICT-based DE) in these countries is still not widely applied.
- Countries that have just begun and are more concerned with ICT infrastructure and connectivity (e.g., Vietnam, Cambodia, Bangladesh, Maldives, Bhutan). There are countries, especially in the Pacific, which have not started online learning yet.

Delrio and Dondi (2008) in this handbook describe several ICT-based DE initiatives of the European Union as part of their chapter of the ICT policy of the European Union.

The ICT-Driven Educational Reform

McClintock describes the emergence of the traditional print-based school system as follows: "Around 1500, a major pedagogical transition began as printing with movable type made an unprecedented era of educational development possible. But the transition was not a quick and simple change: to bring it off, innovators had to develop a complex of different, yet interrelated, educational strategies, which together eventually made mass schooling for all a practical reality" (McClintock, 1992a, p. 3). The main features of this educational system are: using printed textbooks; grouping children primarily by age, and secondly by ability, dividing curriculum into subjects, packaging the subjects into annual installments, and mapping them onto a sequence of grades the students should climb up. The basic unit of the school space is the classroom, where one teacher teaches about 25 students. The time units of such schools are: school period, school day, and school year. McClintock considers the traditional schools as a logistic construction to ensure (in most cases) students and teachers to be at the same place at the same time. In his words, the school is "a means for synchronizing diverse activities in space and time. That is what scheduling is all about, and within a particular class, a teacher needs diverse arts for synchronizing effort on the subject at hand" (McClintock, 1992a, p. 52).

ICT-based DE in schools is conceived as a phenomenon that catalyzes new educational reforms all over the world. It is also driven by three major factors – asynchronous space and time, responsive environments, and virtual reconstruction, which can "*powerfully transform the way schools work*" (McClintock, 1992a, p. 52):

- *asynchronous space and time* – the ability of people, who are not synchronized in the same place at the same time, to easily communicate with each other in a variety of responsive ways. This means that the classical schools would gradually lose their role as instruments for synchronizing the school learning activities.

- *responsive environments* – interactive learning environments, customized to the learners' needs, which will help them to learn and communicate better. "*Such personalization of the electronic environment can carry over from the personal computer to a network. When the user logs onto the network, he activates configuration programs that set the environment to his style and need, regardless of where in physical space the workstation may be*" (McClintock, 1992a, p. 54). Punie and Cabrera further develop the concept of *learning spaces* as one of the main features of the future learning (Punie and Cabrera, 2006, p. 12). Downes also analyzes the future role of the personal learning environments: "*The idea behind the personal learning environment is that the management of learning migrates from the institution to the learner*" (Downes, 2007, p. 19).
- *virtual reconstruction* – the ability to use interactive multimedia components to redesign and reconfigure the human experience of existing physical spaces without physical or structural changes in buildings. The virtual spaces could complement the physical spaces when designing an effective, student centered, learning environment.

The beginning of the new educational reform could be found in the late 70s, when worldwide the introduction of computers in education started. As Aston reports, microcomputers have been used in schools since 1979 (Aston, 2002, p. 62). An example of an early project in ICT-based DE is the project of the Research Group in Education (RGE) in Bulgaria, carried out between 1979 and 1988 (Nikolov, 1987, 2001; Nikolov and Sendova, 1988); see Figure 1 for a description. The RGE project did not change substantially the Bulgarian educational system as a whole, but it gave rise to several innovative educational initiatives and projects both at school and university settings. The early RGE experiences of IT in schools were embedded in the traditional concept of schooling where the printing technology and textbooks were still dominating and the (physical) classroom was the main place where learning activities took place. Some explanations of the RGE failure to achieve a complete educational reform in Bulgaria could be found in the words of Seymour Papert, whose book "*Mindstorms: Children, computers, and powerful ideas*" (Papert, 1980) and the experience of his research group at MIT substantially influenced the RGE experiment. Papert argues that "*the shift from a stance of reform to a stance of evolution does not exclude active intervention, but the role of the change agent becomes less like the architect or builder and more like the plant- or animal breeder whose interventions take the form of influencing processes that have their own dynamic*" (Papert, 1997, p. 421). He also states that many components of the educational system have to be appropriately changed and this would need time.

RGE introduced some principles of pedagogical re-engineering, which characterize ICT-based DE now. The RGE experience also proved that the educational innovations related to the ICT-driven reform could hardly be revolutionarily implemented, but

The Research Group on Education (RGE) carried out a large scale experiment in twenty nine schools in Bulgaria between 1979 and 1988. The main assumption in the experiment was that due to the advent of mass produced microcomputers the educational system should be reformed as a whole as to embed their potential in education as an integrative component. A major educational principle of RGE was the integration of school subjects and enabling students to see world objects and phenomena from many sides while learning. Students looked for answers in various fields of human knowledge; took the role of researchers and experienced that knowledge was infinite, changing, and that nobody could possess it totally, including the teacher. A learning environment was created in which different activities were mixed in a mosaic that kept the students interests awake. The students learned individually and in teams, solved problems, designed, drew, played, sang, and used computers. The new role of the school was defined as to guide students how to learn by themselves. Learning was defined as an active process. The interaction in class was considered as a way for students to overcome the information overload with the help of teachers and their schoolmates. The teachers and learners were given more freedom, but their responsibility increased. A learning environment in informatics was created as an integrated mix of computer equipment, information resources, educational software, textbooks and other learning materials. Although computer resources were limited by that time, some innovative approaches and school activities were introduced (Nikolov & Sendova, 1988), e.g. working on a project, collaborative learning, dividing students into groups of different size, collective discussions, experimenting in mathematics, filling up a database, language games, publishing a student magazine, students' software house, teaching students in a university laboratory, competitions, final students' computer performance, etc.

Fig. 1 Educational reforms in 29 Bulgarian schools with the help of microcomputers

should rather be a matter of evolutional changes at all levels of the school educational system.

Technologies have made a remarkable progress since the early days of ICT in education. The current ICT-based DE relies mostly on large online electronic libraries and rich multimedia resources rather than on printed materials. Students can study on their own using aesthetically formatted and interactive multimedia learning materials. They can construct their own knowledge, study individually according to their needs, learning styles, skills, interests, and cognitive characteristics, and *learn how to learn*. Students can control their learning process, work in teams with other students, take part in discussions, and search for effectiveness in the learning process. *Co-operative learning* dominates over *competitive learning* (McClintock, 1992a, p. 82). Today's student can work in a dynamic and interactive multimedia learning environment where aside from the tutor and the other students he/she can communicate and work with his/her virtual friends all over the world. A new feature of the current stage of the educational reform is defined by McClintock: "*Now, thinking about educational time and space leads to conceptions of flexible groupings, across ages and locations, as people interact according to their interests, needs, and curiosities*" (McClintock, 1992b, p. 34).

Virtual Learning Environments for ICT-Based DE

For teaching and learning to take place, a learning environment needs to be created. Lai (2008) in this handbook describes the relation between ICT and the learning environment. He notices that in ICT-based DE the learning environment often does not have a physical space but is a virtual environment designed and developed to facilitate teaching and learning when teachers and students are separate in time and place.

When designing a Virtual Learning Environment (VLE), one could use different mental images (metaphors) of teaching and learning. The Internet and the Web gave rise to the *cyberspace* metaphor, i.e., an extension and a substitute of a physical environment. Dillenbourg emphasizes that: “What is specific to virtual environments compared to any information space is that it is populated. The users are inside the information space and see a representation of themselves and/or others in the space. As soon as students see who else is interested by which information, the space becomes inherently social” (Dillenbourg, 2000, p. 5). Another metaphor for a learning environment is *place*, which could be defined (in the physical world) as the “setting that transforms mere spaces and activities into unique sociocultural events: the coming together of people to the same location, at the same time, for the purpose of participating in a common, authentic, one-of-a-kind, memorable activity” (Kalay, 2004, p. 195). The document metaphor (used by the designers of the Web) sees information as separate from the people who use it and from the environment in which it is used. Kalay makes a conclusion that “place-making, rather than page-making, is a more appropriate metaphor for designing cyberspace: in addition to communication and information management, this metaphor affords a contextualized locus for situating the activities themselves, much like physical places do. Thus, the virtual places will include socio-cultural and perceptual qualities, enriching them to the point where they may approach – perhaps even surpass – comparable physical settings” (Kalay, 2004, p. 196).

Gachev and Nikolova (2005) report results of a comprehensive survey of appropriate software tools to support learning activities in Web-based Collaborative Environments (CEs). CEs can be seen as one possible form of ICT-based DE. The analysis shows that the majority of CEs are *user-centric* rather than *task-centric*, i.e., they comply with the user needs, but tend to miss the learning activities and task compatibility. The main conclusion was that while *CE–to–user* interfaces are sufficiently well developed, *CE–to–task* interfaces still need substantial further development.

The emergence of adaptive and intelligent Web-based educational systems is observed as well. They “attempt to be more adaptive by building a model of the goals, preferences and knowledge of each individual student and using this model throughout the interaction with the student in order to adapt to the needs of that student. They also attempt to be more intelligent by incorporating and performing some activities traditionally executed by a human teacher – such as coaching students or diagnosing their misconceptions” (Brusilovsky and Peylo, 2003, p. 156). (See also http://aied.inf.ed.ac.uk/aiedsoc.html).

We can argue that ICT-based DE tends to be mostly related to designing and using VLEs. A very important role in effective use of VLEs is played by the instructional designers who should apply an appropriate learning theory in the design of the VLE.

There are many examples of pure VLEs, designed for ICT-based DE. However, in many situations, VLEs are also used to enrich the traditional school curriculum. In this case, VLEs integrate not only a variety of software tools but also all the physical tools that can be found in a classroom (Dillenbourg, 2000, p. 12), such as:

- A variety of noncomputerized learning resources: concrete manipulation tools, instruments, books.
- A variety of interactions that are not computer-mediated: face-to-face discussion among students, lectures by the teacher, group discussions.
- Traditional media – letters, TV, phone, and fax.
- A variety of activities that are not computer-based: field trips, role-playing, etc.

In the context of the above said, Nikolov and Nikolova (1996) proposed a conceptual model for *Virtual Environment for Distance Education and Training* (VEDET) that offers a comprehensive metaphor to be used both for human–computer interface and instructional design purposes. The model suggests restructuring traditional education and training by complementing traditional education with a virtual component. Thus, VEDET does not intend to replace the traditional school, university, or training department, but rather extend their facilities and tools and make learning activities more flexible and technologically enriched. As such VEDET is not an example of ICT-based DE in its pure form, but the model gave rise to a number of developments for reshaping academic practices through multi- and hypermedia (Nikolova, 1999).

The concept of VLE, either to be used in ICT-based DE or as an enrichment of traditional schooling, could be found in many research works and projects, as well as in many documents related to educational policy in schools. For instance, the British Educational Communications and Technology Agency (http://www.becta.org.uk) published an analysis of the current research related to the use of VLEs in education (British Educational Communications and Technology Agency [BECTA], 2003). The European School Net (http://www.eun.org/), a nonprofit consortium of 28 ministries of education in Europe, organized a survey comprising more than 500 schools and 17 ministries and national agencies for using VLEs in Europe (European Schoolnet [EUN], 2003). Some of the findings are (see p. 4):

- In-house development of VLEs is booming in the European school sector. Ten out of 17 national agencies fund the development and localization of VLEs at the national level, and about 60% of them have a high priority for VLEs in their national policies. About two thirds of responding schools use an in-house or open source VLE, whereas commercial products represent about one third of the VLEs in the field.
- Teachers in the secondary education use VLEs mostly with their pupils in classes, suggesting that teachers mix different teaching styles such as computer-supported teaching with face-to-face teaching. Teachers use VLEs more than students. Teachers use them for administrational tasks also, and as a means of communicating with other educational staff in both their own and other schools.

In many cases, this exchange takes place in the framework of international and European-wide school collaboration programs.

– VLEs are mostly used in teaching ICT and cross-curricular subjects. About 90% of teachers said that they teach ICT regularly and sometimes using VLEs, whereas for cross-curricular education, VLEs are used regularly by 44% and sometimes by 40% of respondents.

Pedagogical Dimensions for VLEs in ICT-Based Distance Education in K-12 Education

When designing VLEs, educators mostly refer to one of the three most popular learning theories: *behaviorism*, *cognitivism*, and *constructivism*. Dede (2008) in this handbook describes and discusses how different uses of ICT comply with these different approaches to learning. Nowadays many researchers and professionals refer to *constructivism* as the most popular theory in the area of ICT-based DE. The theory states that by reflecting on our experiences and participating in social activities we construct our knowledge about the world around (Duffy and Cunnigham, 1996). In a constructivist classroom, the teacher searches for students' understandings of concepts, and then structures opportunities for students to refine or revise these understandings by posing contradictions, presenting new information, asking questions, encouraging research, and/or engaging students in inquiries designed to challenge current concepts (Brooks and Brooks, 1993, p. 3).

Among the most important recently developed learning paradigms and theories, derived or related to ICT, are: *cognitive flexibility theory*, *anchored instruction theory*, and *minimalism theory. Cognitive flexibility* theory is a constructivist-based theory of learning and instruction that emphasizes on the real-world complexity and ill-structuredness of many knowledge domains (Spiro, Feltovich, Jacobson, and Coulson, 1992). Some of the basic assumptions in this theory are that understandings are constructed by using prior knowledge that go beyond the information given and the prior knowledge that is brought to bear is itself constructed, rather than retrieved intact from memory, on a case-by-case basis. The core of the cognitive flexibility theory is that "*revisiting the same material, at different times, in rearranged contexts, for different purposes, and from different conceptual perspectives is essential for attaining the goals of advanced knowledge acquisition (mastery of complexity in understanding and preparation for transfer)*" (p. 64). The authors claim that the design of hypertext learning environments could be done in a systematic way in order to make them "*sensitive to and dependent upon the cognitive characteristics necessary for advanced knowledge acquisition in ill-structured domains*" (p. 69).

Anchored instruction, also based on constructivist approaches to learning, is a learning theory which emphasizes on the importance of motivating learners by involving them in problem-solving (including by using technology) in a meaningful context (Bransford, Sherwood, Hasselbring, Kinzer, and Williams, 1990). The instructional designers should use "anchors" based on a concrete problem-solving situation where students are actively involved.

The *Minimalist* theory of Carroll is closely related to the constructivist approaches to learning as well. It was developed on the base of studies how people are learning to use a variety of computer applications, such as word processing, databases, and programming, and it has been applied to the design of computer documentation and training materials for computer users (Kearsley, 1994). The basic theory principles are: all learning tasks should be meaningful and self-contained activities; learners should be given realistic projects as quickly as possible; instruction should permit self-directed reasoning and improvising by increasing the number of active learning activities; training materials and activities should provide for error recognition and recovery; and, there should be a close linkage between the training and actual system. Hedberg and Ping emphasize that during the process of designing learning tasks, it is important to take into consideration when the knowledge and skills are going to be used (Hedberg and Ping, 2004). Instead of focusing on *just-in-case* learning, *just-in-time* learning may be more effective – it provides students with more personal and relevant reasons for learning.

Figure 2 provides an example of applying constructivist instructional strategies in the design of a VLE.

Changes toward the information or knowledge society (Anderson, 2008, in this handbook) also lead to views on learning. Siemens (2005) observes that in the information or knowledge society:

The VLE created in the frames of the European project WebLabs (http://www.weblabs.org.uk/) (Mor, Hoyles, Kahn, Noss & Simpson, 2004). The WebLabs learning model and the VLE supporting it, facilitate the scientist in the learner to be enhanced. 10-12 years old students, together with their teachers and geographically dispersed researchers are involved in science and mathematics explorations by means of technology (a software environment for visual modeling). The students are partners in a research process and get used to pose questions and search answers no matter how sophisticated they might be. They develop an understanding of mathematics as a science in which formulating hypotheses, carrying out experiments, and attacking open problems plays a crucial part. They communicate and share their experiences with peers, teachers and researchers locally and globally through wplone, a Web based collaborative system, by the so called Webreports (http://www.weblabs.org.uk/wlplone). During this communication they acquire specific social experience and are stimulated to build valuable personal skills such as:

- ability to generate and verbalize ideas;
- to present their results according to a concrete standard;
- to share their experience by means of electronic communication;
- to discuss their work and work in a team;
- to be (self-)critical to the work published in the virtual environment.

When facing a typical e-learning problem while trying to learn collaboratively over distance – the language problem - in an attempt to overcome it, the students reach(ed) the idea of designing a graphical scripting language, Weblabetics, for expressing and sharing their experience (Sendova, Nikolova, Gachev & Moneva, 2004).

Fig. 2 The European WebLabs project

– Informal learning is a significant aspect of our learning experience. Formal education no longer comprises the majority of our learning. Learning now occurs in a variety of ways – through communities of practice, personal networks, and through completion of work-related tasks.
– Learning is a continual process, lasting for a lifetime. Learning and work-related activities are no longer separate. In many situations, they are the same.
– Technology is altering (rewiring) our brains. The tools we use define and shape our thinking.
– The organization and the individual are both learning organisms. Increased attention to knowledge management highlights the need for a theory that attempts to explain the link between individual and organizational learning.
– Know-how and know-what is being supplemented with know-where (the knowledge of where to find knowledge needed just in time).

According to Siemens (2005), these changes might induce the development of new theories of learning, which he calls *Connectivism*, and this may also lead to new forms of ICT-based DE.

Effectiveness of ICT-Based Distance Education

The fast growth of the number of distance learning students and the well-recognized role of e-learning for education pose the need to carefully study the factors that influence student learning in an e-learning environment. After a meta-analysis of 19 experimental and quasiexperimental studies in K-12 schools, it was found that DE can be expected to result in achievement at least comparable to traditional instruction in most academic circumstances (Cavanaugh, 2001). Cavanaugh (2001) found an exception for three foreign language studies reporting that students learning with DE systems performed demonstrably lower than students learning in traditional classrooms. Generally, the meta-analysis showed that the DE programs could be used to complement, enhance, and expand education options for students, at least at intermediate, middle, and upper grade levels. ICT-based DE, particularly when designed in an interactive format, can be a vehicle for including the family and community in a learning conversation.

A case-based study aiming to examine the effectiveness of virtual schooling in comparison with conventional schooling was conducted in three conventional and six virtual secondary schools in Canada (Barker and Wendel, 2001). Effectiveness was defined as "*the degree to which the school is able to meet the differing and various expectations of both providers and users or clients*" (p. 6). It was reported that there was enough evidence that virtual schooling could provide excellent learning opportunities to all children and improve the process and content of learning. Students in conventional schools and virtual schools acquire the same curricular content but it appeared that they learn different skills. For instance, the students in virtual schools showed greater improvement than their conventional school counterparts in personal responsibility, critical thinking, researching, technological competencies, learning independently, problem-solving, creative thinking, decision-making, and time management. Less improvement was observed in the academic and communication skills of listening and speaking. The students in virtual schools could rely on quick feedback, instant work records, equal opportunity to participate in "class", increased access for students with special needs, greater opportunity for parental involvement, etc. In addition, all stakeholders in the virtual schools (students, teachers, parents, and administrators) declared that they were very satisfied with and enthusiastic about virtual schools. The most common reason for selecting a virtual program was dissatisfaction with conventional schooling. It was also found that the costs per student in virtual schools were less compared to the ones in conventional schools, e.g., the cost for the school staff was between 20% and 40% less.

According to Cavanaugh, Gillan, Kromrey, Hess, and Blomeyer (2004), virtual schooling, has had limited success in some situations. They found that students may feel isolated in an online environment; parents may have concerns about children's social development; students with language difficulties may experience some disadvantage in a text-heavy online environment; and subjects requiring physical demonstrations of skill such as music, physical education, or foreign language, may not be practiced well in a technology-mediated setting (p. 5).

Roblyer (2008) in this handbook points out that typically, among the students entering DE, most successful are those who achieved high in a traditional school environment and who are well self-organized, motivated, and technology literated. She argues that "virtual courses, like most other distance learning activities, are usually primarily text-based, which can present difficulties for students with lower levels of literacy, who are non-English speakers, or who have English as a second language." Roblyer also states: "As virtual schooling plays an increasingly large role in their total education options, students will need to make the transition from "learner" to "Information Age learner" and some will need help with this transition. Since distance learning is also growing in popularity in business and industry training, the ability to learn well in virtual classrooms is becoming a "basic skill" of the future." She also points out: "When the first virtual schools sought startup funding in the mid-1990's, they often cited the potential for increased access to high quality education for all students, regardless of their location or the quality of local resources. Some ten years later, it is still not clear that this promise has been fulfilled."

The Future of ICT-Based Distance Education

A future vision for the design of VLEs for ICT-based DE is the incorporation of the concept of *learning spaces* (Punie and Cabrera, 2006). Learning spaces are:

- *Connecting and social spaces*: Since learning is a social process, it needs to bring different actors together to share learning experiences. Learning spaces are both physical and virtual ones that favor a learner-centered learning model but connected with the other actors involved in learning and with other social networks. As such, learning spaces should also link learning individuals with learning communities, organizations, and even learning cities and learning regions;

- *Personal digital spaces*: Every learner should have a personal, digital learning space where all learning material is accessible anywhere, anytime, anyway (via multiple devices and media).
- *Trusted spaces*: Learning spaces should provide trust and confidence (e.g., on quality and reliability) in a world where learners are connected digitally, and where learning content is coproduced and shared.
- *Pleasant and emotional spaces:* ICT could make learning content more attractive (e.g., via media-rich virtual environments and simulations) and more emotional (e.g., by connecting people).
- *Creative/flexible spaces*: Learning spaces should be creative spaces, rather than focusing exclusively on reproducing knowledge.
- *Open and reflexive spaces*: Future learning spaces would need to be open and module-based, enabling people to plug in again whenever they can.
- *Certified spaces*: Future learning can only be different from learning today if the current accreditation systems and learning assessment systems are adapted to the requirements of the knowledge-based society. The acquisition of ICT skills, digital competence, and other new skills, be it through formal or nonformal education, should be demonstrated, evaluated, and also certified (see also Roblyer 2008, in this handbook).
- *Knowledge management systems*: The strength of most organizations lies in their people, hence the need to share experience and knowledge among colleagues, within the organization, and even across organizations.

The concept of learning spaces is built upon a learner-centered educational model. The new feature is that the learners are considered not only as consumers of learning content but rather as coproducers of such content. This concept is incorporated into the new generation of the Web, Web 2.0. Nowadays, Internet users can collaborate via getting access also to Web services, such as:

- Building digital collections and content (Wikipedia, Wikibooks, YouTube, Flicr);
- Joining and creating social networks (Linkedin, del.icio.us, MySpace, Facebook, Piczo);
- Publishing one's own journals (Blogger, RSS, LiveJournal).

Following O'Reilly's (O'Reilly, 2005), we define Web 2.0 Schools as "schools that use predominately Web 2.0-based educational applications and services in their educational activities" (Nikolov, 2007, p. 3). The Web 2.0 virtual learning environments provide opportunities for students, teachers, parents, and other stakeholders to contribute to creating useful and 24/7-available educational resources (Freedman, 2006). Students can produce a new resource or edit existing ones for other students while they are learning themselves. Even the well-known computer applications, such as word processors and spreadsheets, come to a new life in the Web 2.0 world. For instance, with Google Docs and Spreadsheets (http://docs.google.com/), one can get access to the nearest link to Internet computer and use them for creating and sharing documents in the global Web 2.0 environment.

A lot of Web 2.0 School-oriented portals providing access to Web services and content for educational purposes in different school subjects are emerging, such as: Schoolforge (http://www.schoolforge.org.uk), Change Agency (http://www.ed421.com/), Web 2.0 for the Classroom Teacher (http://www.kn.pacbell.com/wired/fil/pages/listweb20s.html), Shambles: Education Project Asia (http://www.shambles.net/), Edu 2.0 (http://www.edu20.org/), etc.

The fast growth of the new generation technologies in school education, such as the Web 2.0 technologies and mobile technologies, triggered a new wave of pedagogical research. (See, for instance, http://mlearning.noe-kaleidoscope.org/). The DE stakeholders should also use these technologies in order to harness their collective intelligence for improving the quality of education.

Conclusions

To make use of the new opportunities offered by ICT-based DE, educators should gradually improve the educational system as a whole. In a world with powerful instruments for producing and getting access to any kind of information at any time and any place, the knowledge structure and content as well as the skills of people, capable of effectively using this information, have to be different from the ones obtained through the traditional educational system. The developments in the technology suggest that a *re-engineering* of the education system is necessary, focusing on better integrating physical and virtual learning environments.

There are many concerns that the most important driver for ICT-based DE in schools is increasing demand rather than advanced pedagogical principles and best practices of DE in different settings. Virtual schooling attracts mostly students who are able to learn in any learning environment and not always those who are in disadvantaged position. Still worrying is the high dropout rate of virtual schooling. There are many cases for applying ICT-based DE in a teacher-centered and material-centered learning environment. Therefore, teacher education could be the major way to struggle for excellence in ICT-based DE.

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7.2

PEDAGOGICAL PRINCIPLES, PROBLEMS, AND POSSIBILITIES IN ONLINE GLOBAL CLASSROOMS

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Introduction

Already in 1981, forms of data communication were evident in universities and defense sites via a system called BITNET. Financial institutions, the travel industry, and telephone companies, all made use of "communication networks" with instant access to information from another location nationally and internationally. While this was happening in the world at large, various types of teleconferencing methods started to be used as a tool in the K-12 classroom and in the provisioning and delivery of education to remote locations. These included audio (where individuals could use a single handset, loudspeaker phones, or conference terminals to communicate with their peers in a remote site), audiographic (where the telephone was used in combination with any form of graphics communication such as facsimile, digital scanner, telewriter, slow scan television, etc.), and video (involving video and audio transmission). Teleconferencing as a management and training tool has been around since the 1960s, with numerous examples dating back to 1935. The "School of the Air" in Australia has been a very powerful initiative in overcoming the "tyranny of distance" with the idea being conceived as early as 1945 to enhance correspondence lessons (Robson, Routcliffe, and Fitzgerald, 1991).

The development of computer technology and its use in schools and homes brought with it public data systems such as The Times Network System (TTNS) in the United Kingdom in the 1980s, which could be accessed by those beyond commercial and government institutions. As these systems became more widely known, educators

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and school authorities began to explore their use for educational purposes. There were numerous early trials, mainly in the field of distance education. Schools were slow to dedicate a telephone connection as the modem was considered a luxury and, just to establish a connection, the networks required a long-distance dialup at an expensive cost. With the support of local telecommunications carriers, a few schools began to use technology in creative ways to establish national and international projects in which students could work collaboratively.

Recent years have seen rapid development of computer communication technologies. Various social software and Web 2.0 technologies such as blogs, wikis, YouTube, Facebook, and MySpace have made online communication much easier, faster, and on a larger scale. Many issues with which the pioneer educators were concerned, issues such as scaling up and finding ways to provide support for the "hub" person in a more "automated" way, have been superseded by the emergence of Web 2.0 technologies while at the same time, new challenges and possibilities have emerged.

This chapter aims to discuss several important pedagogical principles, challenges, and possibilities of communication technologies based on reflections from one of the pioneer global educational networks – "Computer Pals Across the World" (CPAW) (Beazley and Horsley, 1993). CPAW (http://reach.ucf.edu/~cpaw/index.html) is a non-profit global educational electronic network, which was cofounded in 1983 by Malcolm Beazley, an Australian educator, and James Erwin, a computer consultant from the USA. CPAW provides opportunities for people in educational and community institutions to share their experiences, ideas, and knowledge in a variety of collaborative learning environments to enhance global understanding. It is operated and managed in over twenty countries by dedicated educators and citizens who donate their voluntary services and expertise. Over the years, the network has grown with its successes and challenges. We hope that our reflections will provide a pragmatic basis for discussion and serve as a catalyst for further innovation and research into effective use of technology in global online learning environments.

Pedogogical Principles

Rapid developments in communication technology, have changed pedagogical implications of technology applications in teaching and learning. They offer new possibilities as well as place new demands and challenges on the teacher and learner. It was slowly realized that distance teaching and learning involves operating in different environments, often including different values, cultural mores, and text interpretations. In any successful application of technology to distance education, it is imperative to have a sound knowledge and understanding of what has been tried before and to build upon the best practices from those experiences. While there have been rapid advances in online technology over the last twenty years, there have not been equivalent advances reflected in educational applications of online technology in K-12 education. In this part, we will focus on four important aspects of pedagogical principles: context, commitment, collaboration, and curriculum integration. Attention to these aspects played key roles in the success of projects carried out in the CPAW global network.

Context

Cognitive scientists maintain that the context in which learning takes place is critical (Brown, Collins, and Duguid, 1989; Godden and Baddeley, 1975). Lave and Wenger (1991) suggest that all learning is contextual and embedded in a social and physical environment, and thus is situated learning. In contrast to traditional classroom teaching, situated learning assumes that the ongoing processes in which one is involved, for instance, the surroundings and social network of others doing the same thing, change the capacity for learning.

Any project using online communication in the teaching–learning process must take place in an educational context with defined strategies and outcomes. Vygotsky (1962) pointed out that one of the difficulties that a learner has in writing is that he or she addresses "an absent or an imaginary person or no one in particular" and thus has no motivation or feels no need to write, whereas in oral conversation "every sentence is prompted by a motive" (p. 99) to communicate to a person or audience. However, writing can be different in an online learning environment, where writing is usually intended for a finite number of participants and with particular purposes; the writing becomes a tool for exchanging information, interacting with the others, and challenging opinions among a group of learners. In essence, writing has an authentic purpose immersed in context.

The motives and context were present with CPAW from the very beginning. The potential for improving students' writing was realized with the availability and excitement of a real audience and so CPAW was born, starting with the early online exchanges between the Australian students and the Native American students.

CPAW was initially entitled "The AustralAskan Writing Project," wherein students in Alaska and Australia began by exchanging letters of introduction. The information in the letters provided a subcontext for a number of follow-up exercises to take place in the months ahead. First, there was report writing, wherein students could write in-depth on one or more of the topics mentioned in the initial letters of exchange. The topics included food, hobbies, sport, music, history, and other areas of cultural interest. Second, there was poetry writing, wherein students could write for an audience while learning about different poetic forms. Traditionally, many students in high schools did not always find the reading of poetry exciting, but poems written by someone they "know," (their virtual peer) proved to be more interesting. The third activity was electronic journalism as students reported on items of interest found in their local newspapers and in their schools, for instance, book reviews, television programs, travel information, and advertisements, and sent them online to their peers. These articles were collected by the respective students and the classes compiled their own monthly newspapers. The next activity involved students in written dialogue on social issues. The social issues were very different in the two cultures, but the sharing activities provided a chance to think about the pros and cons of the issues. The concept of family and related issues proved to be a popular topic for discussion as was the topic of whaling, particularly with Norwegian and Japanese students. Finally, students were encouraged to write scripts based on native legends familiar to them and to share them from their own perspectives. This activity provided multiple perspectives and interpretations of local legends (Black and McClintock, 1996).

The geographical context of an online activity would vary depending on the number of students involved in the collaboration. Students within regions, districts, or localities could be networked for collaborative practice. This was seen in many examples throughout the world including rural networks in the United States of America, particularly those in remote places like Alaska, Iceland, and the telecottage networks in Hungary and the indigenous community networks in the USA, Canada, New Zealand, and Australia. Each collaborative network had a distinct context and character which underpinned and influenced the educational activities.

While the Internet continues to evolve and a particular locus may not be as isolated as it once was, it is very apparent that one of the motivators for students continues to be the differences in context that students will discover, just by virtue of their social interactions.

Commitment

Paulo Freire (1971) posits that a democratic education cannot be conceived without a profound commitment to humanity and recognition of the dialectic relationship between cultural existence as individuals and political and economic existence as social beings. Freire writes about the level of commitment of both teachers and students in a literacy program that he co-created with the teachers and the students. It was obvious that the true commitment of the students in the program began when they realized the power that came with the new capability of being able to read (such as being able to vote and get involved in local politics and change the course of their own quality of life). The teachers also saw the positive impact that the learning could have on their students' lives. As a result, there was a commitment of the:

- students to the reading and writing of materials,
- teachers to the students' learning,
- students to their own quality of life,
- teachers to co-created the curriculum in a "live" fashion with the students,
- teachers to bring in relevant subject matter that would reinforce the positive, changing state of the individuals,
- participants to examine the contradictions in thinking processes,
- program sponsor's (Freire's) commitment to understand and reinforce rather than avoid what he saw happening on a larger level.

Commitment was critical in the successes of CPAW projects. The parties involved, whether they were students, teachers, or researchers must agree on a set of conditions on which the project would be based. These could include:

- duration of project,
- regularity of the communication,
- determining who will initiate the communication,
- some knowledge on the cultural background of those involved,
- knowledge of the general literacy level of students,
- ages of those communicating.

Often times a simple contract was enough to clarify what the participants were committed to. In CPAW projects, classroom to classroom exchange seemed to work more reliably and was sustained longer than individual to individual connections. This was because there was someone (usually the teacher) responsible for the operation of the projects.

Commitment can be made easier by the advances in technology. For instance, user-friendly technologies require less time, increase the span of control on the part of the participants, and facilitate collaboration and engagement.

Communication and Collaboration

Collaboration is the key to successful online teaching and learning in the K-12 classroom and beyond. In the CPAW projects, it has been found that one reason for not sustaining the communication is the difference in language abilities. If there is no comparable standard of the common language in which the parties are communicating, then one party feels inferior and does not continue to respond. Similarly, if one party is not confident in the use of the technology then there is a lack of self-esteem. This is particularly so in countries such as Japan, where there is a standard of perfectionism. Furthermore, Liao (1996) reports that "Chinese people in Taiwan prefer safe topics in talking to each other, especially in turning from unacquaintedness to acquaintedness. However, safe topics differ interculturally" (p. 1). Even with a perfect understanding of a singular concept, different cultures can often translate the goodness or badness of the situation differently based on their own prioritization of underlying values (Lin, 2006). Further cultural differences are highlighted by Marinho (2004) in her work with students from Brazil and Belarus. The differences in culture, language, generation, and learning styles will continue to present themselves as opportunities as well as challenges in online communication and collaboration.

Successful collaboration in global classrooms depends on the participants having a good understanding of the culture and diversity issues in communication. Communication using computers, generally known as Computer Mediated Communication (CMC), is a much more sensitive means of communicating than many realize. While a general knowledge of the cultural backgrounds of those communicating is important, the *lingua franca* can cause many problems. In 1990, during the United Nations' International Year of Literacy, much formal recognition was made of teleliteracy (Beazley, 1990). This refers to an understanding and appreciation of the idiom and nuances of the common language being used in the global classroom. Without this knowledge, communication can produce what has become known as "flaming," when heated exchanges and arguments can occur through misunderstanding of words and expressions. Emoticons such as :-) or :-(can be used to soften the impact of a word or expression if one is unsure as to how it will be received. Capitalizing an entire word can infer that the writer is "shouting." This is seen in certain cultures as impolite. One needs to be aware at all times that those communicating online are often from vastly different cultures (Scott, 1988). Teleliteracy acknowledges the need to read and write effectively in a global environment, using the technologies that make it possible to communicate with distant audiences.

In reviewing the impact of computer technologies on human development, Anderson (1988) commented how these technologies can change the lives of people. “Our tools,” he says, “shape and change the way we live, the way we look at the world, the language we use, and the way we interact with others”(p. 107). Similarly, the Canadian sociologist and media ecologist, Marshall McLuhan noted long before the widespread use of ICT – that “The medium is the message” (1962). McLuhan further explained that, “the personal and social consequences of any medium result from the new scale that is introduced into our affairs by each new extension of ourselves or the new technology” (1962, p. 17). The electronic medium changes the nature of the writing. In fact, a new language called “netspeak,” which is prevalent in younger generations because of frequent use of instant messaging contractions, has developed. E-mail (electronic mail), msg (message), asap (as soon as possible), fyi (for your information), imho (in my humble opinion), btw (by the way), u (you), cya (see you later), are but a few. In addition, the form of the electronic communication tends to be different from the conventional written communication as can be shown in a comparison of a convention letter and an electronic letter. Both the speed of writing owing to time constraints and the cost of communication have been responsible for these changes.

While the text has been the main medium for distance education, sibling technologies such as the telephone and/or video recording often complemented the text. In CPAW, this realization came during the first e-mail exchanges between the Australian and Alaskan students. The Alaskan students at first did not believe that the messages were being sent by real people. In fact, they were suspicious. To reassure them, audio conferences were established to support the written text. While the facelessness of the CMC is a positive factor in online communication for some learners, it can present an obstacle for others due to their different learning styles (Lin, Cranton, and Bridglall, 2005). The need for accent and pronunciation of the language could be best addressed via the oral or visual mode. For this reason, audio links often supported the written communication in a number of projects. This was particularly so in the projects between indigenous and nonindigenous students.

Further examples of the use of “sibling” technologies to support CMC were seen in the use of video exchanges. The video letter exchange project often ran parallel to the CMC communication; however, the communication time frame was much longer than the CMC communication. In their earlier stages, when bandwidth was not sufficient and the networks were not mature, a combination of technologies would be used in CPAW projects. For instance, video letters involving students speaking on a video recording were sent via conventional airmail. Video recordings were used as a tool in the classroom for the hearing-impaired students to capture their joy when communicating across the globe. Before the advent of this technology, hearing-impaired students had little opportunity to communicate as the telephone was the only distance education tool.

Web 2.0 technology and social software have dramatically changed and refined the way we communicate and collaborate in the global learning environment. However, as well stated by Ong, “new media do not cancel out the old. They build on them, reinforcing them… radically changing their mode of existence and operation” (Farrell and Soukup, 2002, p. 84).

Curriculum Integration

Many teachers remain hesitant about online projects, as they see them as additional work in the teaching–learning process. It is imperative that any use of the technology in distance education be integrated into routine classroom activities.

Several projects in CPAW successfully integrated online projects in classroom activities. These projects tended to fall into a number of categories based on the forms of communication that took place. The most common form of exchange was letter writing. Some teachers saw letter writing as the main form of communication and as an end in itself. As a result, they were not able to help sustain the communication between the students. When letter writing was carried out as a means to an end in the classrooms, or as a precursor to other projects, the communication became alive and continued. Information exchange was another form of communication which usually took place after the initial contact made through letter writing. Typically, students would work collaboratively from two or more locations in the world, focus on a specific topic, and share their ideas, perceptions, and research. These online activities were carried out in much the same way as they were in a normal classroom where group work was used as a strategy. The extended or global classroom provided an enriched environment for students as they had access to a wider range of ideas from different cultures. The third form of communication was the online survey. Collection of data from multiple sites provided rich information and knowledge. Students, using the online survey, would seek ideas for classroom debates on topics such as "Whaling is Not Necessary." Multiple views of students in different countries made the content of the debate more erudite and authentic. Students became aware of various stands on a topic. They could receive relevant information more up-to-date than if they had read from a textbook, which would result in a more informed argument in the debate. Their computer pals could even alert them to media articles on the topic, which would not be readily accessible and often unknown, if the students were to rely on resources in the traditional classroom.

Simulations provided another popular activity in the global classroom. Such activity allowed students to create imaginary environments that included their computer pals in other countries. Apart from providing sound and creative experiences, the activity imposed a certain discipline on the students as they had to make decisions on who could communicate with whom and under what conditions. The world of science fiction and other literary genre could be illuminated by this activity. For example, students might impersonate historical or fictional characters and communicate with their peers who had chosen another persona from the same novel or poem. This became a catalyst for interesting dialogue between the students as they were provided with an opportunity to think more carefully about the time, place, and characters of a story.

Furthermore, students engaged in conflict resolution scenarios based on issues in the real world. For many years, the online technology made it possible for students to ask an expert. There were a variety of projects based on this category. Students engaged with an expert or mentor to seek advice, information, and knowledge on topics. This category usually assumes an older/younger dynamic with an element of emotional support and understanding as well as guidance. In much the same way as parents and citizens have provided support in many traditional classrooms in literacy and numeracy, the extension of this to the online classroom allows for greater flexibility as students can use the computer to contact their mentor at any time. Homework Online has operated for many years. Many early trials of this activity were carried out in Washington State, USA. Teachers make an agreement with their students to contact them online, at a certain time in the evenings or during the weekend to seek help on a problem associated with their assigned homework. This does place extra demands on the teacher but many teachers are happy to offer this service.

The following show a number of applications, which have been used successfully by students in a number of countries over the years as part of or in association with the CPAW network:

- Remembering – a joint venture between CPAW and Chatback (an electronic mail network for children with disabilities based in the UK), where students swap interviews with war veterans.
- Acid Rain – students in Norway and Australia used specially designed technology to measure Acid Rain levels in their respective countries.
- Children's Millennium Challenge – the story of children's encounter with environmental problems in the world becomes the starting point for a discussion and "Children's Petition" to world leaders to save our environment before it is too late.
- From Bordeaux to Outer Space – French students from the southwest of France (near Bordeaux) prepare an exhibition about a trip into space and a miniature model of our solar system. Students throughout the world were asked to send photos and information about their towns, themselves, and their way of life.
- Building Electronic Bridges Between Generations – an intergenerational project where students and older persons engage in both written and verbal dialogue using computer and telephone technologies to discuss life in earlier days.
- International Writers' Week – an annual event where professional writers work with student writers to improve the craft of writing and to broaden their knowledge of literature. In addition, student writers share their writing with their peers in other countries and with the professional writers who participate.
- Environment Watch – a program which provided a context for students to isolate global and local environmental concerns, develop skills and mechanisms to investigate the issues, implement environmental action plans, and participate in the political process to lend support to the environmental cause.
- Singapore International Friendship Day – to promote world peace and friendship.
- Medicinal Plants Project – a comparison of plant species that can cure diseases with computer pals from a number of countries including Germany and South America.

The effectiveness of the CPAW is best summarized by Price (1988) who concludes, "The cultural exchange through writing and a variety of language-based activities have helped students develop a greater awareness of cultural patterns which are similar to and different from their own. The finer details of what to say, what to ask, when to write, how to respond, how to rephrase sentences and the need to select words more carefully, are but a few of the challenges that have played a major role in developing a greater understanding by individuals in their quest for knowledge" (p. 35).

In addition to theses applications, the network has grown to target different audiences, all aimed at unlocking the barriers of isolation and loneliness as people are connected with their peers, who share common interests and problems. These include:

- Children in Hospital – based on the "stranger syndrome" where people often share their worries and problems with people whom they meet casually and who may not know anyone in common. Likewise, children in hospital can communicate with other children in hospital to share their illness, treatments, concerns, and the like.
- Seniors – basically this involves a tripartite format, as senior citizens communicate with each other on a variety of topics of common interest, seek information from specialist sources, and/or communicate with students who are involved in intergenerational projects. Often seniors act as a mentor to students as they seek knowledge and advice under the supervision of the classroom teacher.
- Gifted and Talented Students – this has been of great significance for isolated gifted and talented students who need enrichment and challenge.
- Universities – empowering both preservice and practising teachers to use the online technology effectively to gain the best results in the K-12 classroom.

Experience in the CPAW project has revealed that the replication of certain projects is not always successful owing to the different variables in the participating partners. Each online environment is different in that it has individuals with different expectations, backgrounds, and demands. This does not mean that all categories of projects outlined above cannot be replicated year after year. Similarly, one audience may be a more successful match for a project than another audience.

Problems

Postman (1992) describes technology as a "Faustian bargain" in which we must be aware of not only where technology benefits, but also where it detracts. While the previous section listed many positive realities for technology-based learning, this section will address some of the problems that arise when using distance technologies in the classroom. Interestingly, when viewing the technology-related problems through the lens of history, it is apparent that some issues have changed while others remain steadfast. For example, in the CPAW project, problems were identified and became known as "dragons" akin to the dragons in the popular simulation "Dungeons and Dragons." While there are many dragons, the following sample includes problems that still exist today in classrooms:

- The I (inertia) dragon is one of the most frustrating of all the electronic dragons. The inertia prevents any real progress in communication. One sends an initial message seeking a cooperative partner for a project and there is a reasonably quick reply from the recipient to agree to online dialogue but then nothing ever eventuates.

- The V (verbose) dragon is one who is responsible for costing an online partner unnecessary time and cost, as he/she writes too much. To assist such dragons a "to the point" format is encouraged so that each main point in a message is numbered, 1,2,3, etc. to enable the recipient to read and respond to the contents more quickly.
- The N (not sustaining the communication) dragon writes infrequently, without informing the other party as to why.
- The R (response) dragon lacks the ability to synthesize or condense a series of messages from the same person and to respond to the salient points in one reply. The "to the point" format, which students in the CPAW network adopted, ensured that each point in a message or series of messages could be addressed in one reply. This is better practice than writing a number of different e-mails or replying to a number of e-mails separately.
- The P (procrastination) dragon is living in hope that something will happen. While the individual is keen and willing to establish sustained communication, nothing ever transpires. There are many variables which create this "dragon" such as the lack of cooperation from senior staff and/or colleagues, lack of funding, insufficient access to computers, and lack of confidence in the use of the technology or in the common language.

One particular problem that existed during the CPAW project that has changed is isolation. In the CPAW project, isolation of the teacher was a significant factor in the failure of online projects. The CPAW network addressed this issue by having a number of local/regional volunteer support people (mainly teachers) who would provide help to those in need in their region or locality. This local/regional technical assistance was the forerunner of today's "help desk" which service providers and institutions make available. However, if equipment had to be serviced in remote areas, the time for repairs to be made could be lengthy, which became a major impediment to a project. In any use of ICT in formal teaching–learning projects, a support structure was always necessary, particularly on the school campus, if possible. The more support a teacher could be given to prevent a feeling of isolation, the better.

With new media and technology, the isolation problem can be mitigated. Various new media and social software make it easier to provide a support structure for teachers. In addition, teachers can use new technologies to collaborate between themselves. Further, it is well documented that teachers who integrate and use technology tend to be more collaborative and less isolated or private than teachers who do not use technology (see Riel and Becker, 2008).

While there are a number of tactical problems that arise when using distance learning in the K-12 classroom, this chapter will focus on three of the most significant problems that arise: Internet safety, technology access, and curriculum integration. These problems are closely aligned with the above-discussed pedagogical principles – context, commitment, collaboration, and curriculum integration.

Internet Safety

First and foremost, the safety of the students who connect to the world via the Internet is of primary concern. Because distance learning necessarily requires students accessing and sending information over the Internet, educators must be diligent about their safety. As noted above, the context of the classroom has significantly broadened with distance learning. Much student work is completed outside the control of the teacher, which has many positive benefits but also potentially exposes students to inappropriate information. Further, the collaborative nature of Internet-based student work allows students to connect with others worldwide, but not all those who are on the other end of the cable have the students' best interests at heart. Finally, creative Internet-based projects, particularly those that include photographs or videos of the children, can clearly offer predators valuable information about the students. Overall, protecting students is an important feature of the distance learning classroom.

In early iterations of the K-12 distance learning classroom using email addresses, the CPAW project addressed Internet safety by using one email address for the whole classroom. The email address was monitored by a teacher because one central email address was seen as more reliable and secure than students having individual email addresses. To help reduce the teacher's load in managing the central email, some students were nominated to play the role of project assistants. These students were responsible for clearing the messages each day and then distributing them in hard copy to their peers in the classroom. This practice provided a safe environment in which students worked without being threatened by the potential dangers that are so much part of today's cyberworld.

Obviously, this method may not be efficient nowadays. Other technologies such as blogs, wikis, and discussion forums may provide a more open, flexible, and safe learning environment where the students can communicate freely and openly while at the same time monitor and be monitored by their peers. In addition, compared with prohibiting students from taking advantage of new communication tools, it is more important to help students understand the importance of protecting themselves and learn ways to protect themselves in online communication environments.

Recently, the concerns for children on the Internet appear in two forms: (1) protecting children from accidentally viewing inappropriate content on the Internet, and (2) protecting children from connecting via the Internet with people who aim to do harm to the child.

In 2001, the United States government, in response to concerns about students' safety online, implemented the Children's Internet Protection Act (CIPA) as a means to address the first concern, protecting children from accidentally viewing inappropriate content. Essentially under this act, schools and libraries that receive federal funds through the E-Rate program must have an Internet safety policy in place and use Internet protection measures such as Internet filters (Federal Communications Commission, 2006). E-Rate is a widely used federal program offering technology funding to schools and libraries in the United States. The legislation has been controversial for a number of reasons. Most importantly for this context, while students' information is filtered at schools and libraries, most home computers do not contain

Internet filters. Thus, students who have access to the Internet at home can view Web sites that are in fact appropriate but still blocked at schools and libraries whereas students without access to the Internet at home cannot. In essence, students' access to information can be based solely on economic status (Miltner, 2005). Further, while Internet filters may offer comfort to adults, the technology is not foolproof. Clearly, some appropriate and necessary content is ultimately blocked and some inappropriate content slips through the filter. Thus, the comfort adults feel may be misplaced and even detrimental if it is relied upon at the expense of a well-rounded educational effort to keep students safe (Miltner, 2005).

Further, in 2006, the United States government considered legislation entitled Deleting Online Predators Act (DOPA) that targeted the second concern noted above, protecting children from connecting via the Internet with people who aim to do harm to the child. The DOPA act again targets schools and libraries that receive E-Rate funding and aims to protect children by prohibiting those schools and libraries from allowing students access to social networking sites and chat rooms (Library of Congress, n.d.). Social networking sites such as MySpace and Facebook and chat rooms offer teens a space to connect with others and "try on" different identities (Donath and Boyd, 2004). Tapscott and Williams (2006) in their research on the Net Generation noted that networking is this generation's "modus operandi" and that social networking sites, chat rooms, text messaging, and more were clearly the means with which the generation accomplishes their goals. At publication, this legislation is still pending and thus has not been fully evaluated and studied. However, there are already signs that this legislation will be as controversial as CIPA. There are two main issues with the legislation. First, some argue whether this issue is as dire as proponents state. In fact, the mainstream media in the United States has capitalized on the fear of online predators with highly successful reality-based television shows like "To Catch a Predator," in which predators are lured out of their chat rooms with the hopes of meeting a child and then publicly arrested for the camera. However, others have demonstrated that children are statistically much more likely to be abducted or molested by people they know rather than people they meet online (Boyd and Jenkins, 2006). Additionally, Tapscott and Williams (2006) state that more articles have been written about online predators than actual reported incidents of those predators online. Further, the National School Boards Association (NSBA) (2007) recently released research regarding social networking finding through extensive surveys of students and parents that actual incidents of concerning behavior is low and that half of the students noted they used the sites to talk about educational topics. The second point of contention is whether the Internet filter is the best choice of action. Clearly, a technological solution is less labor intensive, but Boyd and Jenkins (2006) note that the broad definitions of social networking sites used in the legislation will filter not only MySpace and Facebook, but also legitimate and educationally appropriate blog sites and more.

In short, there are no easy answers to protecting children online. In fact, Warlick (2004) contends that protecting children from inappropriate information on the Internet is a literacy issue rather than a technology issue (see discussion under Possibilities below). Clearly, it appears that a judicious use of technology solutions along with ample education and communication may provide the most effective means of protection.

Technology Access

Access to technology continues to be an issue for schools. While some teachers are willing to commit the time and energy to a distance learning project, the lack of access to technology can stymie the best laid plans. Further, collaborative projects require disciplined access to technology that is not always possible. During the CPAW project, an online questionnaire was sent to a sample of 145 students with the majority of the issues identified pointing to access. Specifically, the following issues were identified from the survey: unreliable phone connections, particularly where there is no dedicated line for the computer; connections drop out during sending and receiving of text; modem difficulties and equipment servicing particularly in remote areas; lack of computer expertise in a school as many of the school-based online projects relied on a dedicated teacher and if that teacher moved to another location the school would not necessarily continue a project; and lack of technical assistance either in the school or the local community, which was a common difficulty in rural and remote areas where a small school might rely on one computer for access to a communication network. Further outcomes from the questionnaire included: changes in service provider costs and/or regulations; unexpected interruption to the normal school schedule; and family and personal illness, misfortune, or tragedy. On one occasion, the reason responses were not being received by a group of students was that the teacher coordinating the project at the other end of the communication had died suddenly. While the specific technologies have evolved past modems for many schools, an underlying issue appears to remain: access to fully functioning technology resources.

As with all pedagogy, distance technology's success in the classroom depends on appropriate levels of funding; this in turn depends on the political whim of the day. More specifically, it depends on the priorities of those in political control at the time. This has been very evident in the past few years in many countries. The erratic funding which has been available for projects and research into ICT in the classroom is reflected in numerous projects which have come and gone. For example, ACTEIN (The Australian Capital Territory Education Information Network), based in Canberra, Australia was one such project (Huston, 1994). It was a collaborative initiative of all the universities in Canberra to introduce the Internet to primary and secondary schools in the Australian Capital Territory. What was unique about this project was its strong emphasis on technical and training support to accompany low cost Internet access. With the exception of many private schools, there is still a concern about the lack of training and onsite support for teachers, which is addressed in the next section. Clearly, ACTEIN is the exception rather than the rule and schools worldwide continue to struggle to adequately fund technology.

Curriculum Integration

Because distance learning projects tend to connect students with others around the world, the cultural sensitivity of the communication can create issues. Clearly, students must be sensitized to other cultures and cultural norms. Further, collaborative and creative work typically takes longer than traditional lecture and textbook work and thus room must be made in the rhythm of the school for these types of projects. Finally, typical teachers' manuals and lesson plans available to teachers do not tend to make use of distance learning technologies. Therefore, teachers face many issues when attempting to integrate distance learning.

There is no doubt that the increasing access to the Internet in schools has given rise to a pedagogical revolution in the classroom but the emphasis continues to be on the information technology more than the communication technology. The CPAW project expanded well beyond the original genre-based writing program, as the potential was realized for it to be an important application to other lessons. The use of the Internet as a tool in the classroom has allowed for much more creative use of the technology and the development of critical literacy skills (see Mioduser, Nachmias, and Forkosh-Baruch, 2008). This is seen in a number of ways, particularly in Web design and showcasing of work by students. However, there is a lack of human interactive pedagogy as is evident in projects like CPAW, where the focus was on both "I" and "C" in ICT. The major use of the Internet tends to be for information seeking and collecting, with the only interaction being that between the student and the computer. While many students have their own email addresses, the educational use of this facility needs much more attention and research. The novelty of the Internet has superseded the technology which was used in the K-12 classroom of earlier days. There is a greater need to encourage the use of multimedia in the classroom to reflect the days when CPAW made use of the "sibling" technologies of the day to supplement the computer technology. Similarly, there is still a need for ICT integration in teaching and learning in the classroom.

When technology is available, it is historically made to conform to existing pedagogical practices rather than allowing those practices to transform the teaching and learning process. Indeed, Cuban (1986) documented a long line of technology, from the radio through television and to the computer that have held promise for education and yet fallen short. In fact, Cuban cites many of the same reasons noted here. Additionally, Cuban notes what might be called the rhythm of the classroom where teachers have found the most efficient uses of their time and resist efforts to change those practices. Further, Papert (1993) notes that schools tend to change technology by sequestering it into separate classrooms and creating a curriculum centered around technology use rather than allowing the power of the technology in the students' hands.

Finally, Fitzgerald (2005) sees that educators have still not met the challenges of ICT integration in the classroom. While accessibility to the technology is getting higher, the effective manipulation of it in the classroom is still a concern. The provision of appropriate and adequate training at both the pre-service and in-service periods of teacher education is imperative if technology-based pedagogy is going to have an impact on the curriculum. These are the challenges for the future, as educators build on the best of the past, to accommodate to the changing technology and contexts of the future. Research has shown that teachers need more than in-service training to fully integrate technology. They also need personal encouragement and mentoring, instructional mentoring, routine technical support, and administrative technical support (Gopalakrishnan, 2006). In other words, they need to feel fully supported in their efforts. This support is even more necessary with the wider use of the Internet in the K-12 learning environment. Often there is one teacher who has responsibility as system's administrator, in addition to a teaching schedule and related duties. As a result, the problems encountered in the early use of ICT in the K-12 classroom have multiplied in recent years. CPAW had major corporate sponsorship. A fully staffed secretariat was established in Sydney, Australia to provide both telephone and online assistance to teachers to ensure that the appropriate class to class matches were made (including student's age, interests, ability level, etc.).

Possibilities

Fitzgerald (2004) believes that ICT in the classroom offers opportunities for new types of learning and cognitive approaches (see also Dede, 2008). Clearly, using distance learning opens the many pedagogical possibilities listed previously in this chapter. However, it is only relatively recently that such research into ICT and education has been made possible through certain government-funded organizations. One such organization in Australia is The Learning Federation (TLF). This organization is jointly funded, on a fifty–fifty basis, by the Federal and State governments. The technology is increasingly being applied across the curriculum to involve students of all ages. This is evident in a number of trial projects, which include:

– Science, where students (Years 5–8) join a team of paleontologists working on a megafauna dig site. In this project entitled "Colossal Fossil," students excavate the sites and prepare fossils for removal, using suitable archaeological tools. By using appropriate dating techniques to ascertain the age of the fossils, students can identify the find.
– Social Studies, where students (Years 3–4) explore the life stories of a number of fictional characters, who live in the same house in Port Adelaide, over different periods of time between the 1850s and 1950s.
– Business and Enterprise, where students (Years 9–10) simulate the management and running of a muffin bakery over a period of five days. They are encouraged to explore factors that affect maximum profit.
– Art, Design, and Technology, where students (Years 7–8) bring new and different meanings to objects found in different locations as they reposition them in a new context of understanding and interpretation.

These are just a few examples of how the application of the technology has expanded from the early CPAW model to many more areas of the curriculum. In fact, the possibilities for distance learning in the K-12 classroom are vast, particularly if the above-noted problems are addressed. Three specific areas in which the possibilities are the greatest for distance learning in the classroom include engaging the new digital learners, developing new digital literacies, and using Web 2.0 to enhance socially mediated constructivist learning.

Nikolov and Nikolova (2008) in this Handbook specifically discuss the changes in learning that have stemmed from the information or knowledge society, specifically noting that technology use is "rewiring" our brains. Further, Prensky (2001a,b) describes young learners who have grown up with technology as "digital natives." These learners have preferences and characteristics such as viewing graphics before text, multitasking, and collaborative learning that maintains digital connections with others. The digital natives differ from "digital immigrants" who did not grow up with technology and even if adopted will always have the "accent" of an immigrant. Clearly, the pedagogical practices noted in this chapter will resonate strongly with the digital natives, perhaps sparking a lifelong interest in learning or in a particular subject matter.

Clyde (1999) noted that one issue for technology use is the changing nature of information technology skills necessary to function in society. These skills are not limited to psycho-motor skills or navigating an application. Instead, the skills necessary can be broadly conceived of as new digital literacies; however, specific definitions of these new literacies differ (see Mioduser, Nachmias, and Forkosh-Baruch, 2008). Reading online is significantly different from reading physical text, not only in the demands it places physically on our eyes, but also because of hyperlinking. In fact, reading physical text can be thought of as two-dimensional reading (across and down) whereas online text can be thought of as three-dimensional reading (across, down, and deep through hyperlinks) (Warlick, 2004). Hyperlinking also changes the ways in which writing can be accomplished online. Richardson (2006) calls writing online "connected writing" because of the ability to hyperlink.

Leu, Kinzer, Coiro, and Cammack (2004) studied literacy for many years and then used their knowledge to examine the literacies necessary when using the Internet. Specifically, they define new literacies as the ability to "identify important questions, navigate complex information networks to locate appropriate information, critically evaluate that information, synthesize it to address those questions, and then communicate the answers to others." Clearly, parts of this definition are important literacy skills whether one uses the Internet or not. However, locating information in complex information networks is a skill that has become heightened with the sheer volume of information available on the Internet. Nobel Laureate Herbert Simon (as cited in Bransford, Brown, and Cocking, 2000) perceived this change when he noted that the definition of "knowing" is shifting to the ability to find and understand information. Additionally, Leu et al.'s (2004) definition does not specifically identify the type of media used to communicate the answers to others, the options for which have certainly broadened with technology. As noted previously in this chapter, there is significant need to also focus on the "C" in ICT. Warlick (2004) identifies six ways in which students in the twenty-first century must be able to communicate to be considered literate: text, images, animation, video production, Web publishing, and programming. These six means of communication can all be addressed using distance learning in a K-12 classroom with Web 2.0 tools.

Web 2.0 can be described as a fundamental shift in the Internet tools available and in the ways the tools are used (O'Reilly, 2005). Web 2.0 tools are more collaborative and have a shorter learning curve than original Internet tools, essentially lowering the threshold for participation. In fact, combining solid research-based literacy approaches with Web 2.0 tools has been shown to create authentic and organic learning opportunities for students (Vasinda, McLeod, and Morrison, 2007). The distance learning K-12 classroom could make use of many Web 2.0 tools such as blogs, wikis, podcasts, and digital storytelling, all of which would increase literacy skills, both traditionally defined and new literacies. Thus, the authors deem Web 2.0 tools as a powerful addition to any distance learning classroom.

Concluding Remarks

Clearly, distance learning applications hold much potential for K-12 learning communities. In areas such as context, commitment, collaboration, and curriculum integration, global classrooms can advance important pedagogical principles, which could ultimately lead to widespread educational reform. These online communities are not without problems, however. Maintaining the safety of students while online, regularly accessing technology, and creating classroom learning environments in which technology is seamlessly integrated are all issues that must be addressed in order to realize the full potential. Indeed, the payoff for successful online global classrooms include honoring the young minds that learn and process information differently, developing new digital literacies while maintaining the old analog literacies and creating collaborative spaces for students to construct meaning themselves; all of which lead to engaged learning by the students and teachers!

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7.3

VIRTUAL SCHOOLS: REDEFINING "A PLACE CALLED SCHOOL"

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Introduction: Virtual Schools as Defining Initiative

Educational technologists have speculated for years on how new electronic technologies might revolutionize teaching and learning practices in one of the most traditional of society's institutions: the presecondary school. Despite the rapid pace of technological developments in the last few decades and the sweeping changes they have made possible in enterprises ranging from auto repair to medical research, K-12 education has proven substantially resistant to these innovations. Until the mid-1990s, the most common observation about technology in education was that it was relatively scarce. Countless studies have been done on why teachers have not integrated new technologies into teaching/learning methods and what can be done to alter this state of affairs (Cuban, Kirkpatrick, and Peck, 2001; Norris, Sullivan, Poirot, and Soloway, 2003).

The digital era of the Information Age, which began when the first Internet browser went live circa 1994, also signaled a remarkable and comparatively rapid change in school's adoption and use of technology. By 2004, over 90% of all U.S. schools had Internet connections in classrooms (Setzer, Lewis, and Greene, 2005), and 77% of schools reported that at least half of their teachers used the Internet for instruction (Education Week, 2005). But rather than long-anticipated reforms in classroom teaching methods, Web-based communications instead leveraged a radically different approach to course delivery: virtual schooling. In its 2005 report, the National Center for Education Statistics found that 36% of American public school districts had students participating in virtual courses as of 2003 for a total of over 325,000 enrolled (Setzer, Lewis, and Greene, 2005). Based on reported virtual school annual enrolment growth of 50–100% (Watson, 2005, p. 11) and the number of new

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state-supported virtual schools each year, subsequent estimates put that figure much higher and predict that the number of virtual school students will explode over the next few years (Wood, 2005).

In just a decade, technology has gone from a tangential role in education to redefining what it means to be "in school." This chapter explores the rapid trajectory of the virtual school movement from its origins in the mid-1990s to the current and projected issues and policy challenges it faces as an education change agent and a harbinger of school reform.

Background on Virtual Schooling

A Brief History of the Virtual School Movement

Why has this movement grown so quickly? As Zucker and Kozma (2003) note, "In 1996… few people were predicting the great speed with which virtual schooling for secondary students would catch on … It is rare for education systems to change so rapidly …" (p. xiii). Certainly the vision that drove the first virtual schools was that of more affordable and equitable access to high-quality educational opportunities for students who traditionally lack such opportunities: rural, underserved, and at-risk populations. However, today's virtual school student is just as likely to be one who prefers the self-pacing and flexibility of "anytime learning" as one who lacks local access to courses needed for graduation (Wood, 2005). Davis and Roblyer (2005) explain it as a timely solution to a widely perceived need:

"The demand for virtual schools is driven at least in part by fundamental changes in our society and the students who inhabit it. As ubiquitous communications and immediate access to information have become more common, learners recognize that learning can be an anytime–anywhere experience. They want educational opportunities that reflect these characteristics. The disconnection between many current educational methods and those possible in an information-connected environment is becoming increasingly obvious. A new kind of student requires a new kind of schooling" (2005, p. 399).

This may help explain why virtual schooling, an educational environment in which K-12 courses and other learning activities are offered mostly or completely through distance technologies, has become one of the fastest growing trends in education. What began as an experiment in educational equity has become a preferred form of instruction for a growing number of students.

Although many descriptions of virtual school history tend to begin with the Concord Consortium School (Fall, 1996, now VHS, Inc.) and the Florida Virtual School (Fall, 1997), the first school was actually Utah's Electronic High School, which began offering courses in Fall, 1994 (Watson and Ryan, 2006). As Table 1 illustrates, only a handful of states followed suit after the initial programs in Utah, Massachusetts, and Florida until the year 2000, at which time seven additional statewide virtual schools were established. As of Watson and Ryan's 2007 update report, there are 30 states with major state-led programs or initiatives, including those states with programs in development. More statewide schools are being proposed each year, and there are literally dozens of smaller virtual school programs scattered throughout the U.S. and abroad.

Table 1 History of virtual school establishment

Year	U.S. statewide virtual schools established	Sample of other large virtual programs established
1994	Utah's Electronic High School	
1996	Concord Consortium's Virtual High School (now VHS, Inc.) Hawaii's Electronic School	Virtual High School (Canada) http://www.virtualhighschool.com/
1997	Florida Virtual School	
1998	Clark County School District Virtual High School	Babbage Net School http://www.babbagenetschool.com
1999	University of California College Prep Online	K12, Inc. http://www.k12.com/about
2000	Alabama Online High School Arkansas Virtual School Kentucky Virtual School Louisiana Virtual School Michigan Virtual High School West Virginia Virtual School Wisconsin Virtual School	Electronic Classroom of Tomorrow (ECOT, Ohio) http://www.ecotohio.org/whatisecot.html
2002	Colorado Online Academy Idaho Digital Learning Academy Illinois Virtual High School Mississippi Inline Learning Institute	Connections Academy http://www.connectionsacademy.com/about
2003	Virginia Virtual Advanced Placement School	Virtual Greenbush (Kansas) http://www.virtualgreenbush.org/default.htm
2004	Iowa Learning Online North Dakota Division of Independent Study	
2005	Georgia Virtual School	
2006	e4TN Initiative (Tennessee) North Carolina Virtual School InSight School of Washington South Dakota Virtual School	Alabama ACCESS Distance Learning Program http://accessdl.state.al.us

Several recent landmark events signaled the emerging importance of virtual schooling for U.S. educational organizations and their constituents. In 2004, Iowa State University and a consortium of teacher education programs received federal funding to develop a program to prepare virtual school teachers (Davis and Roblyer, 2005). This program is intended as a model for others seeking to prepare teachers who are skilled in navigating the relatively unfamiliar waters of online learning.

In April 2006, the Michigan state legislature approved a proposal to require every student to take part in some form of online instruction before they graduate (Carnevale, 2006; Michigan first to mandate online learning, 2006). The first requirement of its kind, it is viewed as a way of assuring that students are prepared for life in work in an increasingly technological society. In July 2006, the state of Washington announced a new virtual school (see Table 1) that could grant diplomas. Although a few of the other virtual schools (e.g., Utah's Electronic High School) have limited diploma-granting authority, this is the first virtual school that was constituted to offer all courses needed for graduation (see http://www.go2ischool.net/).

What Makes it Virtual? Defining Characteristics

Although virtual schooling is helping to redefine education, an authoritative and consistently used definition of "virtual schooling" is difficult to find in current literature. Reflecting on the common definitions of "distance learning," virtual schooling is characterized by "The acquisition of knowledge and skills through mediated information and instruction, encompassing all technologies and other forms of learning at a distance" (Roblyer, 2006, p. 219). The National Forum on Education Statistics (NFES, 2006) defines virtual education as " … instruction during which students and teachers are separated by time and/or location and interact via computers and/or telecommunications technologies. Virtual education ranges from straightforward coursework presented online for students to view at their own pace, to interactive, real-time instruction between teachers and students over an electronic medium unconstrained by geographic or temporal boundaries" (p. 1). A "virtual school," also frequently referred to as a "cyber school," is an educational organization in which " … K-12 courses and activities are offered mostly or completely through distance technologies" (Harms, Niederhauser, Davis, Roblyer, and Gilbert, 2006).

While Clark's definition of virtual schools, "educational organizations that offer K-12 courses through Internet- or Web-based methods," (2001, p. 1), is quoted often, virtual schooling actually may take place through a variety of technologies that include: "Internet courses using synchronous (i.e., simultaneous or "real-time") computer-based instruction, two-way interactive video, one-way prerecorded video, and other technologies" (Setzer, Lewis, and Greene, 2005, p. 9). Thus, the NFES definition is more comprehensive.

In addition to a technology-based means of connecting learners with instructional materials, virtual schooling may also be described in terms of curricular models (Roblyer, 2003). These include:

– *Interactive asynchronous courses*. Most virtual courses offer and require high interactivity between the student and the instructor and among students in the class. This interaction is often facilitated with a course management system (CMS) developed by a proprietary group (e.g., Blackboard). In this model, the school subscribes to the service and places the CMS software on its own server. Designers and/or instructors develop their courses using CMS options, which include features such as: locations for instructors to post readings and assignments; bulletin boards or conferencing areas where students may post copies of their work, make comments on a discussion topic, or leave critiques of each other's postings; an e-mail system for class members; and a chat room for class members. With CMSs, most learning activities are primarily asynchronous; that is, students need not be online at the same time as the instructor. They may access materials and do work at any time, though the course design may specify deadlines for assignments.

- *"Live" interactive, synchronous learning*. Other schools (e.g., the Alabama Online High School) offer courses via a type of interactive videoconferencing (IVC) or use a hybrid of CMS and IVC. These have a sending site in which a teacher lectures and demonstrates content in front of a live classroom to one or more receiving sites. As videoconferencing becomes more available over the Internet (i.e., video over IP), more courses are likely to take advantage of it to support synchronous learning experiences for courses that seem to lend themselves to this approach.
- *Cyber tutorials*. Less often, virtual courses are self-led, online tutorials in which students read information, visit Internet sites related to the content, and do exercises and tests, which they submit online or by e-mail. These kinds of courses are especially helpful to older and more self-motivated learners. Often, they are preparatory courses for entrance exams. Although they offer little interaction with instructors, they allow easy access to prestructured course materials.

Virtual School Administrative Models in the U.S. and Abroad

Virtual schooling is made possible through a number of organizational structures. Though the source of the instruction and the school configuration vary considerably across these models, the one constant is the need for a credit-granting authority that is sanctioned by the state or, in the case of schools outside the U.S., by the country's education agency designated with credit-granting authority. Schools may offer courses to those outside the district, state, or country where the school operates and has its fiscal home, but the student's district, state, or country determines if the course will count toward a high school diploma or completion certificate.

For statewide virtual schools in the U.S., Watson, Winograd, and Kalmon (2004) identified five different types of administrative structures:

- *Statewide supplemental programs*. These offer courses to students enrolled in a traditional school or a cyber school for students who reside anywhere in the state.
- *District-level supplemental programs*. These offer courses to students who reside within a district and are enrolled in a traditional school there.
- *Single-district cyber schools*. Run as stand-alone schools by individual school districts, these are often housed within one of the district's physical (i.e., "brick and mortar") schools.
- *Multidistrict cyber schools*. These are operated by, or chartered within, individual school districts, but they enroll students from several or many school districts throughout a state.
- *Cyber charter schools*. Chartered as state-authorized schools within a single district, these often function as multidistrict cyber schools and are sometimes operated by commercial vendors.

However, in both the U.S. and other countries (e.g., Australia, Canada, England), there are schools that operate across state or country borders. They often form partnerships with various educational credit-granting agencies so that the courses students take with them may be more easily used for credit toward a diploma. As Setzer, Lewis, and Greene (2005) note, students may take virtual courses from a number of entities, including: an online charter school in the district, other schools who offer virtual courses in the district, a district-run entity, another local school district or school, education service agencies (e.g., New York's Board of Cooperative Educational Services or BOCES), a state virtual school (e.g., the Florida Virtual High School) in their own state or another state, districts or schools in other states, a postsecondary institution such as a university, or an independent (i.e., for profit) vendor. These may be categorized according to who offers the courses as:

- *Brick-and-mortar school or district entities*. Schools and districts with physical buildings that offer both traditional and virtual courses or combinations of these
- *Virtual school entities*. Completely online entities such as VHS, Inc. (formerly the Concord Consortium virtual school, http://www.govhs.org) and the Virtual High School in Ontario, Canada (http://www.virtualhighschool.com/), which have no physical facilities and offer courses that are completely virtual
- *Higher education entities*. Universities that either operate a virtual school under their auspices or allow high school students to take university courses for high school or dual credit
- *For-profit organizations*. Companies such as Apex Learning, which provide many virtual courses to schools and districts on a fee basis
- *Virtual course brokering organizations*. Organizations such as Kansas' Virtual Greenbush, which locate courses at the request of students and may also offer other virtual courses themselves

Another way of thinking of virtual course administrative models is from the students' perspective and has perhaps the most far-reaching implications for redefining schools. Depending on the policies of credit-granting organizations, students increasingly have a choice over where they take courses toward their degree. Two models that characterize the nature of these choices are the school coordination model and the school replacement model.

- *School coordination model*. In this model, students take virtual courses because they cannot take them at a school in which they are enrolled. In many cases, they need advanced or specialized (e.g., foreign language) courses for which the school has no teachers and for which there is too little demand to hire teachers. Other students may be prevented from attending their regular school due to scheduling problems, physical impairments, or disciplinary sanctions. In these situations, the students coordinate their choices with the school, and the virtual courses provide helpful supplements to the school's curriculum.
- *School replacement model*. Schools are seeing increasing numbers of students who could take courses at a local school but choose to take them instead from a virtual one. These include both home-schooled students and those seeking an accelerated path to graduation, as well as a variety of those whose choice is more difficult to classify. The latter often find that virtual schooling offers them a safer or more comfortable environment, or they prefer the relative anonymity

of online “attendance.” Since schools lose funding when students use the school replacement model, it is primarily these students who present the most challenges to traditional credit-granting organizations. As increasing numbers of virtual schools emerge as degree-granting entities, this challenge to traditional school attendance will present a variety of issues to both schools and students.

Current Virtual School Issues

Though one of the most successful and growing phenomena in distance education and, indeed, in education itself, virtual schooling is also highly controversial. Both dispute and litigation surround the topics of funding, credit awarding, certification, and even whether or not the whole idea of learning without teacher and student being in the same room is socially desirable or morally acceptable (Roblyer, 2004). These problems are typical of an innovation that offers both significant benefits along with such sweeping changes, but progress is being made on identifying and resolving issues in four categories: program characteristics and accreditation; student access and equity issues; teacher training and certification; and governance and funding.

Program Issues: Required Characteristics and Accreditation

Characteristics of Effective Programs

One VS aspect on which all agree is that students do not succeed equally well in all programs. Dropout and failure rates for virtual programs are reported to be as much as 60–70% in some locations (Loupe, 2001). As with distance courses in higher education, students tend to fail or drop out of virtual courses at a much higher rate than in face-to-face ones. These often-reported dropout figures have confirmed the misgivings of some observers, who feel that, despite the successes of thousands of students, virtual teaching seldom results in real learning.

However, some virtual programs have very low course dropout and failure rates and better passing rates on key criterion tests such as Advanced Placement exams (Smith, Clark, and Blomeyer, 2005) than those of traditional school programs. While some programs struggle to keep students in class, others continually work to find enough teachers to meet the burgeoning demand for their courses. Roblyer (2006) found that successful virtual schools have five characteristics in common, including:

1. *Preparing students for success*. Schools provide student self-checklists of qualities that make for successful online learning and/or precourse orientations to acquaint them with their new learning environments.
2. *Preparing teachers for success*. Virtual programs provide extensive training for teachers, tailored to their own classroom platform and methods. They often offer ongoing professional development in virtual methods.
3. *Interactive, flexible course designs*. The most successful virtual programs require high interaction between teachers and students and among students.

They are also flexible on course scheduling and completion, allowing students to sign up for courses many times and allowing them to complete coursework on a variety of different schedules.

4. *Monitoring and supporting teachers*. The best programs have strategies for monitoring teachers' virtual work and communications with students, giving them continual feedback on their performance. They also support teachers with help from facilitators.
5. *Monitoring and supporting students*. Finally, successful programs are "customer-oriented," and make student success the focal point of all activities.

Further study is needed to identify the factors that contribute to school and student success. Hartley and Bendixen (2001) emphasize the need to study individual differences and student performance in new learning environments. They found that, since self-regulatory skills and epistemological beliefs could drive success or failure in Web-based environments, students who are likely to have problems in these areas could be excluded from the benefits and opportunities of our most potentially powerful learning resources. As Roblyer (2006) notes, "it is essential that we not only identify students who are likely to have problems with online learning, but also find ways to prepare them better to use successfully the relatively novel, often-unstructured formats of online formats" (p. 36).

Program Accreditation

As the number of schools and programs continue to increase in the U.S. and around the world, students' online options have increased dramatically. But as options have increased, so has the need to establish the credentials of the school offering credit. Students who wish to take online courses are often in a *caveat emptor* position. If the school is not one of the longstanding ones or is not affiliated with an established institution or state organization, the student must confirm that it offers a legitimate, accredited program. This is not always an easy task. Students must find out who accredits the virtual program and whether the accrediting agency itself is legitimate. In light of the emergence of online "diploma mills," this promises to become an even greater challenge in the future.

Student Issues: Access, Equity, and Student Success

When the first virtual schools sought startup funding in the mid-1990s, they often cited the potential for increased access to high quality education for all students, regardless of their location or the quality of local resources. Some ten years later, it is still not clear that this promise has been fulfilled. Most studies that report demographic data indicate that the vast majority of students taking courses in some virtual schools are Caucasian (Roblyer and Marshall, 2002–2003; Roblyer, Marshall, and Mills, 2007; Roblyer, Davis, Mills, Marshall, and Pape, in press). Also, Roblyer, et al. (2007) found that students who are most successful tend to be those who have higher Grade Point Averages (GPAs) to begin with, high levels of organization and achievement beliefs, are risk-takers, believe that they are responsible for their own learning, have better-than-average technology skills, and have access to a computer at home and/or an assigned period for virtual learning at school.

Zucker and Kozma (2003) warn that, if VS success is based on home computer access, this may be a factor that limits the benefits to families with higher incomes. They also note that even students who have access to computers may be inherently disadvantaged by limited technology skills or fear of technology. Virtual courses, like most other distance learning activities, are usually primarily text-based, which can present difficulties for students with lower levels of literacy or students who are non-native speakers of the language of instruction.

Teacher Issues: Training and Certification

Virtual school experiences of the last decade have shown that, while virtual teachers must possess the same skills as any good teacher, they also need additional qualities and experiences. Wood (2005) says that, "(there is a) persistent opinion that people who have never taught in this medium can jump in and teach a class … A good classroom teacher is not necessarily a good online teacher" (p. 36). Roblyer and McKenzie (2000) found that many of the same factors that make for a successful online instructor are the same as those for any successful instructor: good communication and classroom organization skills. However, Cyrs (1997) identified several areas of unique competence for distance instructors, all of which require experience with distance learning environments:

- Course planning and organization that capitalize on distance learning strengths and minimize constraints
- Verbal and nonverbal presentation skills specific to distance learning situations
- Collaborative work with others to produce effective courses
- Ability to use questioning strategies
- Ability to involve and coordinate student activities among several sites

Easton's (2003) study of skills required by distance learning instructors supports the observations of both Cyrs (1997) and Roblyer and McKenzie (2000). She found that many communication skills required of the online instructor are similar to those needed for effective classroom teaching. However, she also pointed out that the online instructor's role requires a paradigm shift in perceptions of instructional time and space, virtual management techniques, and ways of engaging students through virtual communications.

Schools and other educational organizations are beginning to confront the need to certify the effectiveness of teachers for virtual environments. Davis and Roblyer (2005) describe a preservice program to prepare teachers and other educational personnel for work in virtual environments. The Southern Regional Education Board (SREB, 2003) provides a set of guidelines for evaluating the quality of online teachers. Their criteria include: addressing state requirements; curriculum, instruction and student assessment criteria; management criteria; and evaluation requirements.

Policy Issues: Governance and Funding

Perhaps the most contentious of the issues surrounding virtual schools relates to who should be allowed to administer them and how they should be funded. The number of litigations brought by the U.S. local and state agencies against virtual school confirms that many established education organizations find these innovative programs very threatening to their funding base (Funding controversies hammer virtual schools, 2003; Goodloe, 2006; Guerard, 2002; Quinn, 2004). These lawsuits revolve around two central issues:

1. Will virtual school funding decrease funding for traditional schools? Most virtual schools are funded by special appropriations. However, the Florida Virtual School lobbied for and received state approval for a per-pupil funding model that is based solely on successful completions. This funding model is unique in the U.S. at the time of this writing. At the same time, school districts in Ohio, Oregon, Pennsylvania, and Wisconsin have brought lawsuits charging that virtual schools constitute a threat to the quality of local education by draining funds from brick and mortar schools to pay for virtual ones (Morson, 2006).
2. Will funding for virtual schools be used to support home schooling? Many policy makers worry that funds set aside for virtual school students could actually pay for home schooling (Bolten, 2003), thus channeling the state's funding for public education into support for private education. Lawsuits are often brought by organizations outside schools or district (Teachers union sues over virtual school, 2004) because of fears over the impact that public funding for private education could have on funding for teachers.

The trend in these lawsuits at this time seems to be in favor of virtual schools. But until education organizations establish funding fair and reasonable guidelines that do not unfairly penalize the support system for traditional schools, this will continue to be an ongoing area of contention.

Research on Virtual School Implementation and Impact

As Rice (2006) observed, "a paucity of research exists when examining high school students enrolled in virtual schools" (p. 430). This lack of definitive evidence is understandable in light of the comparatively recent appearance of this movement, though there is a wealth of studies comparing postsecondary distance courses with those in traditional formats. The latter consistently reflect a "no significant differences" finding, since the impact of a given course depends primarily on factors other than the delivery system (i.e., instructor effectiveness, course design). Rice summarizes the limited findings we do have about the impact of virtual schools in terms of learner characteristics and attitudes and qualities of effective courses. These and other findings provide early indications of the impact of VS on characteristics of successful students, models of teaching and learning models, and what it takes to make a virtual school effective.

Virtual School Impact in Education: Changing Characteristics of Successful Students

Although students may choose virtual environments, research confirms that they do not always succeed in them. Those who do usually: are highly motivated to achieve, believe it is important to be organized and self-directed, are not afraid of taking risks when it is not clear how to proceed (as is often the case in virtual courses), and have good technology skills and access (Roblyer, Marshall, and Mills, 2007). Technology access and skills seem an especially important factor. Early evidence indicates that the most successful students have home computer access and/or a class period set aside for their virtual course. They also are already proficient in using the Internet and tool software such as word processing.

Not surprisingly, successful virtual students also usually tend to be high achievers in traditional courses (i.e., have high grade point averages) (Mills, 2003; Roblyer, Marshall, and Mills, 2007), but students' abilities in face-to-face classes do not always seem to transfer to online environments. An additional set of skills and attitudes seems to be required. These early findings indicate that if all students are to have the benefits of virtual schooling available to them, many may need additional preparation for working productively in online environments. As virtual schooling plays an increasingly large role in their total education options, students will need to make the transition from "learner" to "Information Age learner," and some will need help with this transition. Since distance learning is also growing in popularity in business and industry training, the ability to learn well in virtual classrooms is becoming a "basic skill" of the future.

Virtual School Impact in Education: Changing Models of Teaching and Learning

Rice (2006) found that students consistently report a similar set of reasons for enrolling in virtual courses. Either they want the convenience and scheduling flexibility that virtual learning offers, or they need an alternative to attending their local school. If the latter, they may need a course not available locally, or they may not be able to attend in person for some reason (e.g., disciplinary status, credit recovery). The research in this area indicates a growing trend toward student choice. Now that many students have an alternative to local school attendance, it seems likely that this will drive a trend toward all schools increasing their virtual offerings. As Roblyer (2006) notes, "In light of their growing popularity … online options seem destined to become a service all schools must offer in order to be competitive in the educational marketplace" (p. 36).

Though many students seem to value the freedom of choice they perceive in online learning, distance learning research indicates that the most effective VS models may prove to be hybrids (Oblender, 2002) that merge the "best of both worlds." In this way, students can profit from synchronous, face-to-face exchanges with "live" teachers, while benefiting from the relative flexible formats of online lessons. As technology capabilities improve, "face-to-face" may come to mean either meetings in person or those held through videoconferencing.

Virtual School Implementation: Characteristics of Effective Virtual Learning Environments

This area has the fewest studies of any virtual school topic, and most extant studies are small, qualitative, and rely on self-reported student attitudes, rather than achievement data or other quantitative outcomes. Thus, findings in this area – and, indeed, in all virtual schooling research – should be viewed as preliminary. Rice (2006) reports on studies of what she terms "learner supports" (p. 435). The most effective learning environments appear to be those that have the following characteristics, all of which, though tentative, are logical in light of past research in distance learning and other environments:

- *Are highly interactive*. Students report the highest satisfaction with learning environments in which teachers communicate frequently with students and in which student-to-student communication is also valued and encouraged.
- *Require student-centered learning*. Though it is clearly a generalization, the most effective courses are based on a constructivist model and encourage students to be active, independent learners.
- *Have highly qualified teachers*. Students seem to do best when teachers are highly qualified and experienced in their subject matter.

Challenges for the Future of Virtual Schools

Recommendations for Needed Virtual School Research and Evaluation

Much of what we have learned from postsecondary distance learning can help in the design and implementation of presecondary virtual schools. However, it seems likely that the age level of this population presents unique challenges that must be taken into account in future studies. School students differ from college/university students in both motivation- and maturity levels they bring to learning, and this will have implications for the kinds of virtual course design and facilitation needed to promote success.

Roblyer (2005) recommends that educational technology research proceed along four lines: establishing relative advantage, improving implementation strategies, monitoring impact on societal goals, monitoring impact on common uses to shape desired directions. Example research topics to guide future development and practice for virtual schooling in each of these lines include:

1. *Establishing relative advantage*. Everett Rogers (2003) said that people are more likely to adopt an innovation if they see the advantage of the new strategy relative to what they currently use. With virtual schools, proposed advantages seem to be primarily in the potential for increased access to courses not available locally. However, Smith, Clark, and Blomeyer (2005) note that students in virtual advanced placement (AP) courses pass AP tests at a higher rate than students in traditional courses. We need further study to explore this finding and to determine why it might be so. One approach to this research would be to control

factors related to self-selection into virtual courses, such as higher socio-economic levels and grade point averages, since it may be that students who elect to learn online have characteristics that contribute to higher test scores. If online environments do actually offer unique advantages for certain types of learning, this finding can be used to exploit virtual schooling benefits for other areas.

2. *Improving implementation strategies*. Since virtual schooling is an innovation already in common use, this is the area in most urgent need of findings to guide practice. Further study is needed on student variables (e.g., determining how to identify at-risk learners and how best to prepare them for successful online learning), teacher variables (e.g., strategies used by effective virtual teachers and how best to prepare teachers for online environments), design variables (e.g., characteristics of effective, highly interactive design environments), and implementation variables (e.g., support and facilitation strategies that work best for various kinds of online learners, local and state policies and procedures needed to promote virtual learning and prevent systemic abuses). A recent negative report on Colorado virtual schooling practices and failures (Rouse and Brown, 2006; State of Colorado, 2006) emphasizes the need for this kind of research oversight.
3. *Monitoring impact on societal goals*. Virtual schooling is often cited as a means of insuring equitable access to quality education for underserved students. In light of initial findings that indicate virtual school populations often lack minority participation (Roblyer, Marshall, and Mills, 2007), we need studies to help us determine if virtual courses do, indeed, promote equity or if they are primarily the province of those who are already advantaged.
4. *Monitoring impact on common uses to shape desired directions*. The most common concerns about virtual schooling are that it will have negative impacts on the socialization of young people and that it will lead to widespread plagiarism and other unethical (or even dangerous) educational practices. Further study is needed to explore whether or not these fears have any basis in actual practice.

Decisions About the Future Role of Virtual Schools in Education

As Watson (2005), Watson and Ryan (2006), the NFES (2006), and others have noted, the future of virtual schooling must be shaped by policies developed by states and other credit-granting entities, yet at the time of Watson and Ryan's 2006 report, 26 states had such defined policies. Twelve states had online programs but no significant state-level polices. Only about 50% of states had either (a) a statewide virtual program that had policies and practices in place, or (b) state-level policies that govern all online programs across the state. Policies to shape the future of virtual schooling are needed in each of the following areas (Watson, 2005, pp. 13–14):

– *Funding*. Most funding for virtual students is tied to state full time equivalent (FTE) funding, and this funding is usually not differentiated from that for traditional students. Watson notes that, "… applying traditional student counting methods to online programs can be problematic, but only a few states recognize this in policy" (p. 13).

- *Curriculum*. All states require that virtual schools meet state content standards, but these standards do not address quality issues specific to the online environment. Attention to quality issues could be the single most important policy measure to implement, since it has such pervasive implications for program success.
- *Teacher qualifications and evaluations*. While states require that virtual teachers must meet state certification standards, only Alabama, Georgia, Kansas, and South Dakota required professional development specific to virtual teaching (Watson and Ryan, 2006). Another issue is placing restrictions on the number of students one teacher may teach.
- *Accountability for student achievement*. While all states have required students' assessments, few address the challenges of getting virtual students to take tests given by physical schools.
- *Quality assurance issues*. Required reporting, accreditation, and student time requirements for virtual schools vary considerably from state to state. As the number of schools that operate across state borders increases, the challenges of accreditation and other quality assurance measures will also increase.
- *Equity and access*. Although all states have nondiscrimination laws, few have addressed the digital divide issues that virtual schools can create.
- *Enabling policies*. Finally, most policies that govern schools have their roots in traditional face-to-face learning environments and are designed to ensure quality and prohibit harmful practices. These policies often do not allow for teaching and assessment done at a distance. Thoughtful policies are needed that both allow and promote the use of effective virtual schooling practices.

NFES (2006) emphasizes the importance of collecting data in ways that can help policy makers ascertain the status of virtual school programs and identify how to improve them. "To evaluate whether virtual education is effectively and efficiently serving (desired) functions, decision-makers must have access to high quality data … (Yet) many well developed data systems that generate high quality data for traditional educational endeavors are, as yet, unable to accomplish the same for virtual education … data collectors must carefully consider how to improve existing data systems—what type of information is to be maintained about virtual education, how data elements are to be defined, how existing standards may need to be modified, and when data are to be collected" (p. 4).

Implications of Virtual Schools: A Global Perspective

Since virtual schooling is an international movement, as well as a U.S. one, it has the potential to change teaching and learning models on a worldwide scale. There are indications that this transformation is already beginning to take place. In his review of virtual schools in Europe, Russell (2006) observed that, "School education today is part of a global system where there is the power to communicate instantaneously across national borders … One implication of this change is that nation-states, educational authorities and individuals are faced with the momentum of globalisation. There are strong forces operating that encourage students to use global online networks from their homes, to attend school less frequently than in earlier times, or even not to attend a conventional school at all … Virtual schools represent a new educational paradigm, in which the shift from experiential learning with classrooms and teachers is eventually subsumed by its mediated online counterpart."

Though it is difficult to obtain definitive information about virtual schools in other countries due to what Russell characterizes as "linguistic fragmentation (and) restricted entry to school sites," virtual school sites are emerging on the Word Wide Web in several countries (see http://www.worldwidelearn.com/outside-us/home.php). These include:

– *Australia*. See the Virtual School for the Gifted at http://www.vsg.edu.au/and the Learning Place VSS Community at http://www.learningplace.com.au/default_suborg.asp?orgid=64andsuborgid=365
– *Canada*. See the VirtualHighSchool.com (http://www.virtualhighschool.com/), the Alberta Distance Learning Centre (http://www.adlc.ca/home/), and Chinook College (http://www.chinooklearningservices.com/), among others
– *Finland*. See http://www.edu.fi/english/pageLast.asp?path=500,572,5365
– *United Kingdom*. See InterHigh at: http://www.interhigh.co.uk/

As Russell (2006) notes, " … because of social, cultural and historical differences, the characteristics of future virtual schools in Europe may differ from those that are currently operating in other parts of the world." A clearer view of these differences may emerge as the virtual schooling movement matures.

Conclusion

In the space of a decade, virtual schooling has become one of the most unexpected success stories in the history of educational technology. However, the rapid trajectory of its adoption in the U.S. and elsewhere also makes it one of the most challenging to study and assess. Though government organizations (e.g., the National Center for Educational Statistics) and others have endeavored to study and describe current practices and future needs, virtual schooling takes so many technological and administrative forms and is changing so rapidly that it is nearly impossible to capture an accurate picture of it, let alone to shape and create policies to guide it. For many school leaders, who are already struggling to keep pace with the demands of technological change, virtual schooling is a confusing, even frightening concept.

One concept that will soon become clear to all educators is that learning will never be the same as a result of the "anytime, anyplace" learning opportunities that virtual schooling presents. Like so many of the technology-driven changes occurring throughout our society, virtual schooling has the capacity to redefine traditional institutions in ways that challenge long-held truths and time-honored practices. Yet this level of change has not met with universal approval, as the litigation and protests surrounding virtual schools confirm. Many critical issues related to funding, access, student and teacher preparation, course design standards, and school accreditation to assure quality remain to be decided.

Most importantly, the vision that gave virtual schooling its early momentum – equitable access to educational opportunities – must be continued and nurtured. If virtual schooling is to fulfill its early promise as an Information Age agent of school reform and improvement, its defining challenge will be to assure that its virtual doors are open to all students.

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7.4

DISTANCE LEARNING – ENRICHMENT: A PACIFIC PERSPECTIVE

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Introduction

Background Terminology and Concepts

This chapter will demonstrate the role of Distance Learning – Enrichment (DL-E) as classroom technology integration activities for informal, short-term rather than for teaching formal, extended courses. The goal for DL-E is to make all educators aware of this resource that can enrich their teaching as a complement to their traditional, face-to-face classroom environment. DL-E terminology closely mirrors that for distance learning/education since distance learning technologies are the same, and it's only the application and duration that differ. Most of the examples presented in this chapter relate to elementary and secondary education, which often involved collaboration with postsecondary educators, researchers, or community resources. However, the techniques are appropriate for any educator, community group, or governmental agency for providing interactive experiences with individuals or groups anywhere in the world.

Various studies have sought to evaluate effectiveness of distance education taught compared to face-to-face instruction. Cavanaugh (2001) found that distance education was more effective when it was used with smaller sized groups, shorter duration, and to supplement or support traditional classroom instruction instead of using it for the primary mode of instruction (see also Blomeyer, 2002; Smith, Clark, and Blomeyer, 2005).

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Giving support to the concept of DL-E was Blomeyer's suggestion (Blomeyer, 2002):

In final analysis, online learning or e-learning isn't about digital technologies any more than classroom teaching is about blackboards. E-learning should be about creating and deploying technology systems that enable constructive human interaction and support the improvement of *all* teaching and learning (p. 19).

DL-E is based on the concept of Computer-Based Educational Telecommunication (CBET) (Southworth, 1982; Edwards, 1984). Traditional distance learning involved utilization of expensive satellite, telephone, and television technologies. This often meant use of special telecommunications labs or complicated software/hardware logistics incompatible with the classroom setting.

In these times of rapidly developing telecommunications resources, greater use of alternative systems based on free Internet and inexpensive multimedia CBET systems is possible. Early DL-E involved inexpensive (voice only) speakerphones. Later, a videophone (e.g., Lumaphone) was discovered that allowed for the addition of still, black and white pictures to be exchanged using Slow Scan Television (SSTV). Videoconferencing technologies now come in color with full-motion pictures.

Most significantly, these new systems promote classroom-based programming with computers connected to the Internet using ordinary Webcams and inexpensive communication software. DL-E has been used for many years in the Hawaii and the Pacific than anywhere else in the world as a mode for providing extension experiences for students more isolated from major population centers. Results have been reported mostly in conference presentations rather than journals. Now that the resources are becoming available to educators globally, greater recognition of the ability for enriching classroom experiences through DL-E applications point toward more extensive application of the techniques in the future.

Basic to DL-E has been the Electronic Field Trip (EFT). The basic EFT model uses both *asynchronous* and *synchronous* modes of communication. Students initially post their introductions and questions asynchronously followed by a synchronous teleconference with a guest presenter and ending with follow-up asynchronous posting of thanks or additional questions/discussion. In cases where time zone difference or coordination of a synchronous session is impossible or impractical, using totally asynchronous communication and posted discussion is preferable.

EFT is now used for a variety of modes of CBET experiences. In this chapter, the term is used when personal interaction with a guest or mentor by asynchronous and/or synchronous modes is used. The term Virtual Field Trip (VFT) is increasingly used but here is seen as the growing use of Web-based, prerecorded asynchronous experiences such as tours of museums, geographical features, or other modes such as *podcasts*. VFTs give a time-independent option to educators and will allow for DL-E to be applied at any time. However, they lack the personal, two-way communication with an EFT mentor or guest and are more like a traditional recorded videotape or CD/DVD presentation.

The isolation of Hawaii was the stimulus to find ways to connect students with the world beyond their shores. In the late 60s and 70s various communication resources became available to accomplish that objective. An important element in use of Electronic Field Trips has been the concept of using available technology. In the early years, inter-island Hawaii EFTs were rarely held because of high long-distance telephone

PEACESAT (Pan Pacific Education and Communications Experiments by Satellite) provided free, public use for communication between Hawaii and islands in the Pacific such as American Samoa, Guam, Raratonga, and New Zealand (Kingan, Flanigan, Knezek, & Southworth, 1990).
The Electronic Information Exchange System (EIES) from the new Jersey Institute of technology begun in 1975 (Hiltz & Turoff, 1978; Dator, 1980; Glauberman, 1980). EIES was used internationally and provided opportunities for a wide-range of collaborative ventures as the base for asynchronous conferencing topics and coordination of DL-E collaborative ventures.
In 1977 the University of Hawaii (UH) established a system-wide Computer-Based Education Pilot Project to investigate alternative approaches to using computers in education. UH educators were able to review and test alternative modes of computer-based education including early DL-E experiments using PLATO (later known as NovaNET).

Fig. 1 Initiatives to support DL-E in the 1970s

costs with free Internet links not yet a reality. Initiatives were taken to limit costs for EFTs (see Figure 1).

In the 1970s, multimedia CBET became a focus for further development of DL-E. While high costs of using satellite and phone services precluded or limited isolated places like Hawaii in the past, CBET with low-cost Internet connectivity made both traditional distance learning/education as well as DL-E programming economically feasible and independent of location. Perhaps, most valuable has been the ability to hold videoconferencing using free or inexpensive teleconferencing software and basic Webcams (Southworth, 1982; Southworth, Andreson, Ho, Hvorecky, Morton-Marr, and Narita, 2006).

DL-E Applications in the 1970s

An early use of DL-E involved the start of the American Field Service International Scholarship Program (AFSIS) in Hawaii and its international exchange of high school students. A series of programs was developed that featured travel and living experiences of AFS exchange students in Hawaii, New Zealand, and other locations. The multimedia program involved local viewing of duplicated 35 mm slide sets with narration and discussion carried live by PEACESAT (Southworth, 1977). Recent applications involve synchronous and asynchronous DL-E for text, chat, audio, and video teleconferencing (Southworth et al., 2008).

One of the more creative ventures to link artists in the Pacific during the 1970s was called POP Rap (Potters of the Pacific Rap Sessions). POP Rap was an experimental communications program based on use of PEACESAT and distributed media. Video communications was accomplished by posted duplicate sets of slides sent to each participating PEACESAT station. One such program featured renowned Japanese potter Mutsuo Yanagihara speaking from Honolulu to potters listening and watching slides in Hilo, Kahului, and Fairbanks in Alaska. Yanagihara subsequently visited Fairbanks, Oahu, Kauai, Maui, and Hilo to give live workshops.

The PLATO (= talkomatic) = text chat system that allowed simultaneous typewritten communication in several geographic locations. In 1978, the system was used by art students from the University of Hawaii. The objective was "to develop the use of the PLATO system as a means by which artists can communicate directly with other artists." A series of eight sessions involved participants in Honolulu, Maui, Kauai, Los Angeles, and Illinois for a total of 750 min. The cost of the session was estimated at $123 compared to a cost of $1549 had it been via telephone (Brenner et al., 1978).

A unique communications experiment in the late 1970s linked deaf students in Hawaii's School for the Deaf and Blind with students attending Gallaudet College in Washington, D.C. While students could not hear spoken communication they used the PLATO text chat mode to type written messages for discussion between Hawaii and Washington (Southworth, Dugdale, Mackall, and Richardson, 1980).

New Developments in the 1980s and 1990s

Technological developments in the 1980s and 1990s provided more possibilities to realize DL-E activities. Important developments were the use of Scan Television. Slow Scan Television (SSTV) is sometimes called "freeze frame" TV (Andrade, 1981; Swift, 1983). These devices allowed an ordinary telephone line to transmit slow scanned video images from one site to another, Multi-Mode Node Communications (MMN), which involved the integration of incompatible electronic systems and the possibilities for live teleconferences. It was also in this period that the term Electronic Field Trip was first used.

Some illustrations of the use of these new technologies for DL-E activities are presented below:

– In the early 1980s, SSTV equipment was made available for a special training and certification program on moon rocks by NASA for 50 educators from Hawaii, the US mainland, and parts of Asia and the Pacific Islands. Those participating in the distance learning training program were given certification as if they had taken part in a regular training program on the mainland (Malamalama, Fall 1982).
– The PEACESAT "Computers in Education" series involved getting computer message postings from other parts of the world. Elementary and secondary school teachers from American Samoa were able to issue questions via audio PEACESAT sessions with their requests posted in Honolulu on EIES and PLATO group notes topics dealing with educational use of computers. Answers provided by the computer were read over PEACESAT network to others not able to connect to a computer network. Discussion from the PEACESAT sessions was summarized and posted back on the computer network for all to read (Southworth, Flanigan, and Knezek, 1981). This technique is still in use today for such things as linking persons on one audio system (e.g., speakerphone) with a separate audio system (e.g., computer-based audio conference).
– Another example was in a project organized by secondary marine science teachers (Southworth and Klemm, 1985). Students took part in water quality

monitoring of fresh water sites (US mainland and Hawaii) and salt water sites (Samoa and New Zealand). After exchanging data via EIES and PLATO, a live PEACESAT teleconference was held at the East–West Center where students discussed and compared the results.

– The use of the term EFT began with secondary school beginning chemistry classes collaborating with the UH Medical School. The field of medical technology was appropriate to provide the chemistry students an example of a career that used chemistry. Various modes of computer-asynchronous and telecommunications-synchronous modes were used. Students interact with medical technology educators via computer e-mail or bulletin board forum before a live teleconference for questions and answers (QandA) followed by e-mailed/bulletin board discussion and thank you notes. Students found the use of EFTs an interesting way to bring relevance to classroom instruction. (http://etec.hawaii.edu/etecvideos/videos/medtech/)
– In 1985, the TELEclass (Telecommunications Enriches Language Experiences) Project used the EFT model to support foreign language learning in Hawaii public schools (Wollstein, 1986; Southworth, 1988a, b; Southworth and Ishimaru, 1987; Southworth, Velikhov, Copen, and Morton, 1990). Students were able to communicate through computer and video telephone-based systems for written and spoken language practice. The sense of reality in talking and seeing synchronously native speakers in the target countries proved a meaningful experience for those learning languages (Southworth, Petrov, and Goto, 1991; Southworth and Hvorecky, 1996; Southworth and van Broekhuizen, 1997).

DL-E Projects in the Twenty-First Century

Through technological developments, e.g., Web 2.0 technologies, in the Twenty-First century it became easier and cheaper to provide the necessary infrastructure for organizing DL-E activities. More attention therefore was paid to the organization of effective communication and collaboration. The following two examples show how DL-E activities could be effectively organized. The projects also show that increasingly DL-E is alternated with face-to-face meetings.

StAmPnet: Launching the Twenty-First Century with Student Ambassadors

The "Student Ambassador Program" (StAmPnet) of the University of Hawaii College of Tropical Agriculture and Human Resources (CTAHR) adapted the Electronic Field Trip model by developing a four-phase program of synchronous and asynchronous techniques. These have been used initially to link college students and faculty with students in Hawaii's secondary schools:

– The first step involved the high school students posting introductions and researching CTAHR Websites.

– The second step featured CTAHR students visiting local schools to present the various college/career options their college offered using a Power Point presentation.
– The third step enabled a CTAHR faculty member or researcher to present through an Electronic Field Trip aspects of a particular department or research project.
– The final step involved the students completing the assignment by posting information they learned, additional questions and thanks to those who made presentations.

Secondary school students benefited by gaining information about college, career, and life choices. For more details see:
http://www.ctahr.hawaii.edu/ctahr2001/CTAHRInAction/Oct_02/FASTTrack.asp

STARnet NCLB Project

Starting in 2005, No Child Left Behind (NCLB) funding provided curricular and DL-E programming support at five Big Island middle schools. This project followed the StAmPNet DL-E model and included:

1. Each participating teacher needing a Webcam was provided one for use in classroom Distance Learning – Enrichment Programming.
2. Demonstrations on use of the Webcams and associated programs (i.e., Nicenet, iVisit, and Talking Communities) were provided at the first meeting of the course in November.
3. Follow-up training and workshops were held periodically at local schools.
4. Assistance provided face-to-face as well as electronically to help teachers implement the DL-E model.
5. Students established Nicenet sign-ons and, where possible, taught parents to join Nicenet to monitor project activities as part of the PSCS (Parent–School Communication System).
6. Each school had at least one experience using DL-E for interaction with Koa Ell, science/cultural specialist associated with the Institute for Astronomy.
7. Each school designated a local "Teach-nology" contact person who was experienced with coordinating the technology resources and services at each school to help the STARnet teachers with DL-E technology needs.
8. Presentation of STARnet program curricula and DL-E at 2006 e-School Conference and GEAR UP Showcase of Promising Practices Conference in February 2006.
9. Application of DL-E techniques for project meetings and other projects such as international collaborative exchanges and professional development provided by Phi Delta Kappa meetings.
10. Exploration of using NovaNET lessons to enrich curricular activities.

This program provided formal training during the 2005–2006 school year with the following year being evaluated (Southworth et al., 2007) in terms of whether sustainability was attained by participating teachers.

Fostering Cultural Awareness

In the late 1990s, the expertise in the Hawaii region in the use of DL-E activities for education expanded to other nations, such as Japan. The potential of DL-E to contribute to cultural awareness and understanding emerged. The Japan–Hawaii DL-E partnership is a good example.

In 1995, a disastrous earthquake seriously damaged and destroyed much of Kobe, Japan. This event was featured as a DL-E topic "What's Kobe?" in 1999 when students of the Hyogo University of Teacher Education interacted with Hawaii students. Hyogo, being near Kobe, had students and faculty who experienced the disaster and shared this event. Dr. Narita posted, "*My graduate student, Hideaki Naohara, was one of the few survivors of the earthquake. He was driving in the morning of January 17, 1995. He was on a highway heading toward his school. All of sudden 6:00am, his car was tilted and he got trapped in his car. The highway was broke. The earthquake was devastating*." The Hawaii students could view Websites that showed graphic details of the quake. In response, students commented as in this case, "*We learned a lot about Japan, especially on the Kobe Earthquake in January of 1995. Even though it was over four years ago, we saw that people still remember what happened that very day that made history, killing thousands of people and injuring more. Some of the things we learned included: there were over five thousand casualties; one hundred thousand buildings were destroyed; one student driving could not control his car and he saw two people die. He also took pictures…Going on the websites and looking at the pictures was also very very good because we could see the damage visually and clearly (versus on the television set, where the picture lasted on the screen for only a few seconds) while also having a narrator who was there to tell us what all the pictures were about. Once again, I think this was great and I would like to thank you again*."

A series of collaborative ventures have continued between Hawaii and Hyogo with the most recent being a natural disaster project in 2006–2007. The Pacific-Rim countries have endured a variety of natural disasters, most notably in the recent past, typhoons, earthquakes, and tsunamis. Schools in Hawaii and Japan have addressed natural disasters in their curricula in a variety of ways with varying degrees of success. The Face Natural Disaster Project was created for students at the Hyogo University of Teacher Education's Middle Laboratory School to collaborate with students in Hawaii on the topic of natural disaster preparation and readiness. The goal of the project was to allow students to use DL-E to conduct research, collaborate with other students, and to develop a product addressing the importance of building community awareness for facing natural disasters.

The project was announced from Japan to members attending a September 2006 PDK Hawaii Chapter meeting using iVisit and Talking Communities. Through the membership, word about the project was shared among educators in Hawaii. Those interested were directed to the project Website, http://wisc.ceser.hyogo-u.ac.jp/curtispho/natural_disaster/. Information about the project requirements and travel award to a minicolloquium in Japan were obtained from the Website. Students were also linked to a project blog, http://facend.blogspot.com/that was designed to facilitate collaboration between students in Hawaii and Japan as well as other interested educators worldwide. Entries to the blog increased exponentially after a large earthquake shook Hawaii on October 15, 2006. Students from the Big Island of Hawaii were located closest to the earthquake's epicenter so it was not surprising that they had the most to share on the blog. Messages were also received from Iran, Japan, and Slovakia.

Two students whose projects were selected out of 44 entries attended the minicolloquium in Japan in February 2007. They joined several Japanese students in sharing their natural disaster projects. The presentations were shown live to Hawaii using iVisit.

Techniques for Classroom Technology Integration Using DL-E

The advancement of technology over time has provided geographically isolated students with increased access to knowledge and experiences otherwise not available to them locally. With more access to instructional resources, teachers have the responsibility of selecting and implementing appropriate and meaningful learning experiences. The following is a list of techniques and strategies for integrating technology in the classroom, gleaned over 30 years of experience in using DL-E.

Resources

- When planning DL-E activities, one needs to review available resources and decide whether to use synchronous or asynchronous techniques. This relates to whether the experience will involve a "virtual" experience with all resources posted or recorded and/or "live" presentations by a guest presenter.
- With "virtual" Electronic Field Trip experiences, one has more freedom in terms of time and connectivity as Websites or other recorded information can be accessed generally at any time.…though something like a live Webcam (e.g., on a volcano, city, or tourist site) may be dark during night time in its location…unless artificial light is sufficient.
- What technologies are available and what are to be used? Is it necessary to go to a telecommunications or computer lab or can the activities be done in the classroom and/or at home? Will the services of a technology coordinator or trained students be needed and thus scheduled?
- Various systems are available for asynchronous posting of information including email or Web-based communication sites or blogs; podcasting is a new form of posting recorded audiovisual programs that can simulate live presentations.
- Various systems are available for synchronous teleconferencing from simple speakerphones or elaborate videoconferencing systems. See what is available in your environment…but be sure the remote participant(s) also have access to the system of choice.

- Cell phone technology is becoming more and more pervasive as well as multimedia. This should make DL-E applications possible at any place and at any time.
- Always hold at least a brief technology testing before the actual event. This will determine if systems work properly or whether adjustments are needed.

Classroom Preparation

- Determine whether to individualize the topic or make it a class activity. When individualized, students can use email or an electronic bulletin board to post their introductions, ask questions, and provide feedback reports/thanks/suggestions.
- When done as a class activity, there is less preparation and details focus on the projection of an event to the class. This saves time but lacks student involvement in writing, questioning, and other communication and technology skills.

Scheduling

- If a remote guest presenter is involved for the first time, there needs to be communication with that person to discuss the modes and schedule for the activity. Will there be asynchronous student posting of introductions, reviewing background material, posting of questions and thank you messages? Will there only be a synchronous teleconference at a mutually agreed upon time?
- If separated by several time zones, use of GMT (Greenwich Mean Time) standardizes times for all locations and avoids the need to "translate" and take into effect whether Daylight Time Savings is or is not a factor.
- Set up a detailed schedule so that all participants know the limitations of time (e.g., what school period start/stop time is required; does attendance or announcement need to be completed before start of program) to avoid confusion and rushing to complete in the available time period.

Curriculum Integration

- Consider where the activity "fits" best in the curriculum or whether it is time independent.
- Some activities are set up around holidays or other fixed events (e.g., Earth Day in April) so that planning and participation could accommodate the activity.
- Review your text or curricular program to see if it has suggestions for virtual or live Electronic Field Trips.
- If students will be given credit for participating in a DL-E event, work out a rubric for assessment. This could be the number of points for posting of questions/introductions, participating in the live event as a student moderator or asking a specific question, and posting of thanks or a report of something learned from the experience. Consider the importance of proper grammar and spelling in postings.

Table 1 Distance learning enrichment rating scale

	SD	D	U	A	SA
1. Context (vs. content) of course	1	2	3	4	5
2. Motivation for further learning	1	2	3	4	5
3. Global context awareness	1	2	3	4	5
4. Accommodating alternative learning modalities	1	2	3	4	5
5. Involvement/ownership of learning	1	2	3	4	5
6. Group collaboration/social interactions	1	2	3	4	5
7. Incidental learning (beyond standards/course objectives)	1	2	3	4	5
8. Preparation to be a productive member of society	1	2	3	4	5
9. Others, please specify:					

Instructions: How well do you think the enrichment activities presented in these sessions would contribute to the following aspects of a K-12 or university/industry course: 1 = SD = Strongly Disagree. 5 = SA = Strongly Agree

– Consider opportunities to report/share your successful DL-E projects through school professional development workshops, newsletters, journals, or educational or technology conferences.

Assessment of Added Value of DL-E

One question that often arises with these types of activities is: How does one justify its use? Much work remains to be done in the area but progress has begun. Southworth, Knezek, Christensen, and Hvorecky (2004) triangulated findings from the Distance Learning Enrichment Scale shown in Table 1, participant ratings from the Rubric for Assessing Interactive Qualities of Distance Learning Courses (Roblyer and Ekhaml, 2000), and responses by participants to open-ended statements asking for likes, dislikes, and suggestions for improvements. Findings confirmed that reasonably reliable and valid (relevant, meaningful) assessments of activities are possible. Additional research is needed to establish the generalizability of these and related findings. However, great benefits can be derived from analysis of even simple evaluation forms that ask for good points, bad points, suggestions for improvement, and an overall rating on a 1 = very poor to 5 = superb scale.

Concluding Remarks

Classroom technology integration at all levels of education makes possible an increasing spectrum of technology applications for the classroom. Professional development for teachers in effective uses of these new technologies is vital for pre- and in-service teachers. Distance Learning – Enrichment provides an opportunity for introducing exciting enhancement opportunities for teaching and learning. The goal of Distance

Learning – Enrichment is typically for the student to get something extra out of a course – some value-added aspect(s) beyond the minimum requirements – while the goal of typical online instruction may be to serve as the only viable means to deliver the bare essentials of the content itself. Thus, if one's goal is to efficiently deliver primary information, then DL-E may not be preferred. However, if one accepts the philosophy that enrichment activities are those that could not or would not normally be carried out in a classroom, then the goal of DL-E can be said to be to broaden horizons and expand participants' views of the world.

The concept of the global classroom is truly becoming a reality for students not only in isolated locations such as the Pacific region but anywhere in the world as increasing communication technologies and networking spans our earth and the solar system. Greater recognition is needed not only by teachers but also by administrators, parents, and politicians about the potential of significant enrichment in the classroom. DL-E can truly develop a real-world global classroom environment for students as they prepare for their responsibilities in dealing with a growing list of challenging needs to preserve the global environment for future generations (Southworth, Knezek, Flanigan, and Hapai, 2003.

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7.5

TECHNOLOGY AND OPEN LEARNING: THE POTENTIAL OF OPEN EDUCATION RESOURCES FOR K-12 EDUCATION

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Introduction

> "Surely our aim must be to combine connectivity with learning resources so as to create a global intellectual commons accessible to the whole of humankind?" (Daniel, West, D'Antoni, and Uvalic-Trumbic, 2006, p. 23)

The growth of distance education methods of delivery was a key feature of education in the twentieth century and continues still. Three primary reasons for this trend can be identified. First, the need has grown to provide access to students who would – either because of work commitments, geographical distance, or poor quality or inadequate prior learning experiences – be denied access to traditional, full-time contact education. Second, it has been necessary to expand access to education to significantly larger numbers of learners. Third, there has been a need to shift patterns of expenditure to achieve economies of scale by amortizing identified costs over time and large student numbers (SAIDE, 2002, 2004). In African contexts, these drivers are often underpinned by the need to transform education systems that have been ravaged by colonial histories and political instability.

In the K-12 sector, many countries around the world, when faced with problems of learner access to the conventional schooling systems, have implemented some or other form of Open School as a response to these problems. However, such approaches have tended to operate outside of the mainstream education system, thus leaving it unchanged rather than spearheading the transformation needed to create dynamic and responsive systems educating learners who are able to critically engage with a

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continuously changing environment. Very often, establishment of Open Schools has also been motivated by intrinsic weaknesses in the mainstream, "contact" schooling system, which policy makers have seen requiring years of structural change before large-scale improvements will become noticeable. Thus, Open Schools provide a handy, reasonably quick institutional solution to problems of educational delivery, which can operate largely outside of the mainstream schooling system.

Against this backdrop, the key question when considering the potential of Information and Communication Technology (ICT) in K-12 education is how ICT can function as a catalyst to transform education systems. How can we use ICT to shift greater levels of control back to the level of the school and to learners? Experience working in various contexts has shown that schools, teachers and learners are becoming increasingly disempowered agents in the strengthening bureaucracies of centrally planned education systems, and the negative effects of this are seen starkly in African schools. In many instances, in Africa and other parts of the world, national curricula do not teach what learners need to know before they leave school (Levy and Murname, 2006; NEPAD, e-Africa Commission, 2006; see also Anderson, 2008; Voogt, 2008).

While ICT potentially presents opportunities to change many of these negative dynamics in education systems, the dominant approach is currently to layer ICT use as an additional problem on top of these inefficient and disempowering systems (NEPAD, e-Africa Commission, 2006). Thus, ICT projects often serve to further alienate and marginalize those at the bottom of the system, while they increase inefficiencies by creating new costs without increasing productivity across the system in any noticeable ways. It is common to talk about constructivist learning pedagogies and learner-centred education and to include these terms in education policies, but these philosophies are seldom reflected in the way the overall schooling system operates (NEPAD, e-Africa Commission, 2006).

This context raises questions about the role that distance education and technology can play in solving educational problems in developing countries. In this chapter we consider the concept of distance education in relation to open schooling, and then move on to define the concept of open learning. All too often, distance education and open learning are assumed to be the same thing, as evidenced in terms such as "open and distance learning". We argue that the concept of distance education and open learning are not necessarily the same and conflating the two has negative consequences for education systems. Instead, we argue that increasing openness should be the criterion of success to which education systems and planners strive irrespective of the mode(s) of delivery employed. We consider how technology can be used to support open learning, with a particular focus on the role that open education resources (OERs) might play in improving quality and reach of education. The chapter ends with a brief example of an OER project supporting K-12 education in South Africa.

Distance Education and Open Schooling

Distance Education describes a set of teaching and learning strategies (or education methods) that can be used to overcome spatial and temporal separation between educators and learners. Further, since economies of scale can be achieved through the enrolment of larger numbers of learners than is possible in a face-to-face context, distance education is often presented as a cost-effective solution to the challenges of increasing access to education (SAIDE, 2002, 2004).

An Open School is an educational institution operating in the spheres of primary and/or secondary education, providing courses and programmes predominantly through use of distance education methods. Most schools of this nature have been established for some time. The Correspondence School in New Zealand, for example, was established in 1922, while the Open School in India is over 20 years old. Reasons for establishing such schools have tended to revolve around accessibility to traditional schooling. In these two examples, part of the motivation to establish the school was to provide access to students in remote farming communities (New Zealand) and access to large numbers of students whom the mainstream schooling system could not absorb (India).

Over the last four decades, a growing number of countries within Southern Africa have experimented with a broad range of different kinds of open and distance learning models, in an effort to solve the twin problems of the low access and low efficiency of conventional secondary schooling. Some of the early efforts, such as in Malawi, actually pioneered national alternative secondary school systems which have since been adopted by government and integrated into the conventional secondary sector. The old Malawi College of Distance Education study centres have now been incorporated into the mainstream secondary sector and strengthened to form Day Community Secondary Schools. In other countries, such as Zambia and Zimbabwe, the models have either failed to work at scale and hence cost effectively, or they were inadequately supported and so were unable to deliver the required quality and have hence declined. The phenomenon of increasing number of out of school youth has prompted states like Botswana and Namibia to develop other models, which has given rise to "new Open Schools" like Botswana College of Distance and Open Learning (BOCODOL) (Tau, 2005; see also http://www.moe.gov.bw/bocodol/index.html) and the Namibian College for Open Learning (NAMCOL) (Mensah, 2005; see also http://www.namcol.com.na/). These organizations have effectively built on the lessons of the past to offer high quality education nationally and at scale (IRFOL, 2004). Both BOCODOL and NAMCOL now enrol well over 25,000 students at secondary school levels, and as a consequence enjoy increasing public support and legitimacy.

Thus, Open Schools have become increasingly common in African countries and serve important functions of expanding access to, and sometimes, improving quality of education. Yet, in most countries, mainstream education systems remain intact and educational outcomes for learners remain poor. Current understandings and categorizations of education as either "distance" or "face-to-face" perpetuate this situation. The concept of "modes of delivery", often employed in educational planning and policy making, is based on an historical distinction in education systems between "distance" and "contact" education. This distinction has been very useful for many years, particularly as it allowed for the establishment of innovative responses to education problems – such as Open Universities and Open Schools – that could be set up and run without waiting for changes in mainstream education systems.

This flexibility was important to the success of many distance education institutions around the world, but has also had the unfortunate consequence of establishing two distinct education systems, which have historically operated in parallel and created long-term policy problems. This problem has been compounded recently, as there has been an explosion of education delivery options, around which it has become increasingly difficult to establish meaningful policy and regulatory frameworks.

Neat categorizations of "distance" and "contact" education are increasingly containing too divergent a range of educational practices to remain relevant. This has become particularly problematic in the area of distance education with the increasing use of ICTs (Butcher, 2003). For example, distributed lecturing systems using video-conferencing equipment and systems using instructionally designed study guides and decentralized tutorial support find themselves located within the same category, although they bear almost no resemblance in terms of pedagogical approach, technologies used, and their financial implications. This is not to suggest that one is intrinsically better than the other. It simply points to the inadequacy of planning approaches that assume that the planning requirements of both will be adequately met by a single framework called "distance education".

Awareness is now growing that elements of distance education have almost always existed in face-to-face programmes, while educators involved in good quality distance education increasingly recognize the importance of different types of face-to-face education as structured elements of their programmes. This trend has rendered rigid distinctions between the two modes of delivery meaningless.

An appropriate solution to this problem is the conceptual introduction of a planning continuum of education provision (Butcher, 2007). This continuum has, as two imaginary poles, provision only at a distance and provision that is solely face-to-face. The reality is that all education provision exists somewhere on this continuum, but cannot be placed strictly at either pole. Educators often end up equating particular methods of education with good quality education, even when these methods are being poorly implemented. The notion of this continuum is free of such premature and unnecessary judgments about quality.

This conceptual shift is vital in changing the structure of education systems around the world. In particular, it allows for greater flexibility and opens possibilities of collaboration, both of which are vital to improvements in educational quality and cost-effectiveness of education provision, issues of particular relevance to policy-makers. It allows education providers to plan, implement and review each education intervention on its own merits, rather than being forced into simplistic, dichotomous categories (such as "distance education" or "contact education"), which set arbitrary and unhelpful constraints. This flexibility should form the cornerstone of all education planning processes. Education systems always serve a diversity of people with a wide range of educational needs. There is no single teaching and learning model that will equally meet these diverse needs equally well.

This stance fits well with the concept of *open learning* as an underlying philosophy to guide educational provision. Not only does a move to open learning as a defining feature of education systems overcome the problem of artificial distinctions described above, it also creates opportunities for exploring how technology can be used to change how mainstream education systems function.

Open Learning

Open learning is based on the principle of flexibility in order to increase access to education and often forms part of broader equity efforts in society. This approach allows learners much more freedom to determine what, how and when they want to learn, than the traditional approaches to education. The aim is to provide learning opportunities to a diverse range of learners both originating from, and learning in, different contexts. Within open learning approaches, there is common reference to learner-centred approaches, as well as resource-based and autonomous learning. This means that the learner is central, "learning to learn" is in itself a goal, and the learner develops critical thinking skills and the ability to learn independently. This philosophy becomes increasingly important in the context of lifelong learning and the need for people to be equipped to function in the knowledge society.

Thus, open learning describes a concept that is complex and yet invigorating educationally. Herein, however, lies a great danger, namely that the term "open learning" can be used by educationists and politicians as an "inspirational" title, which allows for the perpetuation of outdated modes of educational practice under the guise of something new and exciting. If the term is not simply to be used as a smokescreen for such a phenomenon, it is vital to understand the full implications of making use of the concept. This problem is compounded by the growing use of the term internationally – as well as the emergence of hybrid terms such as open and distance learning – which is leading to further divergence in the definitions of the term.

Much of what has been written about open learning has led to the formation of certain misconceptions about it, which are reinforced by several uses of the term in practice. Clearing up these misconceptions is essential in attempting to define the concept. In particular, it is common to assume that open learning and distance education are synonymous (Butcher, 2003).

The term "distance education" describes a collection of methods for the provision of structured learning. Its object is to avoid the necessity for learners to discover the curriculum by attending classes frequently and for very long periods in order to listen to it being spoken about. This does not mean that there is no face-to-face contact, but that most communication between learners and educators is not face-to-face. Instead, it makes use of different media as necessary. Distance education, therefore, provides techniques of educational design and provision that – under certain circumstances – can bring better chances of educational success to vastly more people at greatly reduced costs (Butcher, 2003; SAIDE, 2004). Nevertheless, the provision of distance education does not automatically equate with openness in education. As Rumble (1989, p. 31) points out, for example:

> "the technological basis of distance education may…lead to a closed system if undue emphasis is placed on 'programmed' media such as texts, broadcasts,

audio- and video-cassettes, computer-based instruction, etc, where the content is pre-determined and communication is one way (from the teacher to the student)".

Globally, a vast amount of distance education provision is closed in many respects. Consequently, although distance education is a collection of educational practices that has demonstrated great potential for increasing openness in learning, the terms should not be confused.

In addition to confusing the terms open learning and distance education, there has been a further tendency to regard open learning as something that can find final expression through individual projects, initiatives, institutions or other educational systems. This is expressed quite clearly in the names of several organizations, for example, the Open Learning Agency in Canada, the Open Learning Institute of Hong Kong (now also renamed as an Open University) or the Open University in the United Kingdom. The idea is also contained in opinions such as the following: "A sensible use of educational technology theories and technological devices can provide a truly open system" (Bosworth, 1991, p. 8). This notion is, however, misleading, as Rumble (1989, p. 33) makes clear:

> "There is, I believe, an attempt to highjack [*sic*] the descriptive adjective 'open' and apply it to learning systems to form a compound noun 'open-learning-systems', which is then used in sentences such as 'the [institution's name] is an open learning system'. Such sentences are then used to define the particular system in a way which is attractive politically, given the political and financial advantages which may accrue from claiming status as an open learning-system. In practice the systems so described may be anything but open".

There is a great danger in labelling individual initiatives in this way, because it implies the creation of a separate "open learning" system alongside conventional education and training, running parallel to it through various "open learning projects". Such a tendency robs open learning of its strengths as a concept. This is because it suggests that open learning is a perceptible method of educational provision that is to be offered alongside conventional education.

Rather, then, open learning should be understood as an approach to education, the principles of which can continually inform all educational practices with the aim of improving them. This is most easily expressed in a simple grammatical switch, from understanding "open" not as an adjective – which then describes a particular kind of learning – but rather as a verb, creating an impetus for action. Thus, the strength of the concept lies in its capacity to lead to action focused on systematically opening learning. This it is able to do because open learning brings together key educational principles, all of which focus in one form or another on opening learning. These principles do not amount to a coherent doctrine or philosophy; indeed, often they exist in tension with one another. This tension is important, because it can help educational planners to understand where closure in their educational systems is required and where it is unhelpful. Thus, the principles of open learning provide a set of benchmarks against which all aspects of any educational system (international, national, provincial or institutional) can be measured.

Open learning as an approach to education seeks to remove all unnecessary barriers to learning, while aiming to provide learners with a reasonable chance of success in an education and training system centred on their specific needs and located in multiple arenas of learning. To explain this further, it is necessary to outline those educational principles that can be clustered around the concept of open learning.

Learner-Centredness

This notion is a primary prerequisite of openness. The principle of learner-centredness, in essence, acknowledges that the learner should be the focus of the educational process and should be regarded as an active participant in an interactive process. Education should not be viewed as a transmission procedure, where there is a one-way flow of information from the source of knowledge (whether it be an educator or an educational course made up of one or more media) to a passive learner (Bransford, Brown, and Cocking, 2000). Rather, education should encourage independent and critical thinking and develop problem-solving capabilities (Levy and Murname, 2006). This is facilitated by regarding the learner as an active participant in the educational process, and can be further enhanced by offering learners choices, possibilities and contesting viewpoints within that process. Finally, learner-centred education should also build on learners' own experiences, using these as the starting point and basis for any learning process (Laurillard, 1993).

Lifelong Learning

The concept of lifelong learning is also central to openness. It argues that learning should continue throughout life, rather than being limited to childhood, and should be of direct relevance to the needs and life experience of learners. As Bosworth (1991, p. 76) points out, "educationalists, in particular, should always remember that a great deal is learned from material that is not specifically designated as 'learning' or 'training'". Thus, for example, watching, hearing or reading an advertisement is as much a learning experience (teaching the learner to buy a product) as is attending a lecture or working through a training course. It is vital, in attempting to open learning opportunities, to re-conceptualize what constitutes a "learning experience". The concept of lifelong learning is not, however, merely a philosophical concept about human rights, but a national necessity for economic survival. It is becoming clearly understood globally that commitment to lifelong learning is an economic necessity (Anderson, 2008; Laurillard, 1993).

Flexibility in Learning

The concept of open learning entails increasing the flexibility of learning provision to cater for the diverse needs and contexts of learners (Bransford, Brown, and Cocking, 2000). This includes allowing learners flexibility in determining what, how and when they want to learn (SAIDE, 2002; Rumble, 1989). This implies that learners will increasingly take control of and responsibility for their own learning.

Removal of Unnecessary Barriers to Access

Central to the process of opening learning is the principle of removing all unnecessary barriers to access to educational opportunities. Barriers that learners might face would include geographical isolation, discrimination on the basis of race, gender, home language or language of learning, age or physical disability, the inability to take time off work for a course, lack of "appropriate" qualifications, and lack of funds required to enrol in particular courses and pay for the necessary resources (SAIDE, 2002; IRFOL, 2004).

Recognition of Prior Learning Experiences and Current Competencies

As mentioned above, one of the key barriers to access to courses in many educational institutions is the lack of "appropriate" qualifications. Hence, related to the principle of opening access to learning opportunities is the need for recognition of relevant prior learning experiences of learners and of the current competencies that they possess. Such experiences and competencies should also be accredited appropriately where applicable (SAIDE, 2002). In a schooling context, this principle implies that the pre-existing knowledge of learners is considered and integrated into the classroom environment (Bransford, Brown, and Cocking, 2000).

Learner Support

The process of opening educational opportunities cannot be effective unless educational providers ensure that it is accompanied by adequate support to learners (SAIDE, 2002). This involves the provision of a range of services such as advice, relevant information and counselling throughout the learning process. Several types of support should be made available to learners: support of all kinds offered by educators on a regular basis both through face-to-face contact and other forms of communication (including telephones, the post and computer links); the encouragement of interaction between learners in both group and one-to-one basis; the provision of any necessary learner support in educational courses; and by providing access to the necessary facilities, including a space in which learning activities and interaction between learners can take place, as well as access to computers, laboratories and other resources which might be a necessary requirement within the learning process (see also IRFOL, 2004, where quality of learner support is noted as a factor affecting educational effectiveness and sustainability).

Expectations of Success

Holt and Bonnici (quoted in Bosworth, 1991, p. 2) note that "open learning is not just about opening up access alone, it is also about providing people with a fair chance of success". This necessitates offering learners the opportunity to complete learning programmes successfully, but also ensuring that the qualifications they earn will ultimately have value in the occupational marketplace. Linked to this, therefore, is the notion that, ultimately, it is essential that the education offered should be of the highest possible quality. This ensures that educational providers can meet expectations of success created by opening learning opportunities.

Cost-Effectiveness

Another critical principle of open learning, which draws together and expresses many of the tensions inherent in combining these principles, is the principle of cost-effectiveness. Cost-effectiveness is used here as a term distinct from cost-efficiency. The latter is about "cheapness" of educational provision – usually expressed in terms of per-student costs – while the former represents striking the optimal balance between cost, student numbers and educational quality, a balance that will be entirely different for different educational contexts (SAIDE, 2004). In many ways, the concept of cost-effectiveness represents the balancing act that constitutes open learning. There is no magical formula that leads to cost-effective education; rather, cost-effectiveness needs to be measured on an ongoing basis in relation to changing contextual requirements.

Open learning, in many instances supported by distance education methodologies and advances in technology, can potentially support many of the worlds' poor to access educational opportunities from which they are currently excluded. In many instances, those educational opportunities that do exist are of poor quality, often due to lack of resources – human, financial and educational. Bringing education to this marginalized group will require drastic cost cuts as well as local adaptability. A focus on the role that technology might play in fostering more open education systems is thus of critical importance.

Technology and Open Learning

Technology has a role to play in the realization of many, if not all, of the principles of open learning. In particular, technology (when used correctly) supports increased flexibility in education provision and learner-centred approaches. For example, Momanyi, Norby, and Strand (2006, p. 159) note the following in a review of technology use in education:

> "Norton and Gonzales (1998) noted that using technology could change the way teachers teach. They further observed that technology supported more student-centred approaches to instruction so that students conducted their own inquiries

> and engaged in collaborative activities while the teacher assumed the role of facilitator. Peck and Dorricott (1994) have similar views about student learning. They suggested that since students learn and develop at different rates, technology could help individualise instruction and, through an integrated system, students could move at an appropriate pace in a nonthreatening environment".

Key in learner-centred approaches is an emphasis on problem-solving and the development of critical thinking skills. When used to specifically further this ideal (ICTs can also be used to support traditional teacher-centred methodologies), ICTs become tools for supporting learners' decision-making, creativity, higher order thinking and knowledge construction (Haddad and Draxler, 2002). Thus in the context of open learning,

> "what is important about computer use is not being able to word process, or view a multimedia presentation, but the ability to interact with the computer in the manipulation and creation of knowledge through the rapid manipulation of various symbol systems. The value is not in more efficient representation but in improving the capability to generate thought" (Hokanson and Hooper 2000, p. 547).

Flexible learning is about providing learners with choices about when, where and how they learn. The wide range of technologies and applications available to support education provide a variety of means of delivering education. Examples of different ways in which education could be provided to learners would include human interaction (either at a distance or face-to-face), practical work, interactive television classes, drama in education, educational broadcasting, computer-based training and a range of media materials (including printed materials, videos and audio cassettes). Implicit in all of this is that learners will be given greater freedom to choose where they wish to learn, whether it be at home, in a classroom or learning centre, or at the workplace.

Further, technology also has the potential to increase access to educational opportunities. There are at least two different elements to consider in the context of technology removing barriers to access. The first is the use of technology to provide access to educational programmes, not available in their immediate environment often through the provision of online courses as is becoming common in Open Schools (Haddad and Draxler, 2002). The second is the use of technology to provide access to quality educational resources, the lack of which are a barrier to open learning.

Given these potential benefits of technology for education, much attention in the past ten years has been dedicated to improving access to technology – seen in the importance attributed to ICT penetration rates, learner: computer ratios, etc – while far less attention, until more recently, has been directed at the development of educational content or resources of high quality and contextual relevance. Macleod (2005) argues that:

> "Currently there is discrepancy between the potential of educational multimedia and the reality of its content which its widespread use. For example the majority

of online content currently emanates from the US, is text based, and written in English. Not only does this exclude those in developing countries with low basic literacy levels but it is also of questionable cultural relevance".

It is not denied that access to technology remains deserving of attention and investment, particularly in developing countries. However, technology access alone is likely to have minimal educational impact without appropriate learning materials and resources (e.g., see Hepp, Hinostroza, Laval, and Rehbein, 2004).

In 2002, Cushman (p. 1) noted that:

> "With a virtual world closing in on 10 million web sites and some 500 million users, it may seem odd to speak of shortages or slowness. Despite such expansion, the WWW remains something of a disappointment to educators. Those hoping for transformation of the educational process have yet to see it. And a significant corpus of digital content – preferably available free or at least at low-cost – is still mostly a dream. More and better digital *content sharing* would be a means to serve these ends".

Open Education Resources (OER)

Present debates in the distance education and educational technology arenas often centre on the issue of learning objects and more recently on open education resources (OERs) and the potential of these developments to support education (Johnstone, 2005). It is argued in this chapter that, when used appropriately, OERs also have much potential to advance open learning possibilities.

Learning Objects

Curriculum design and development is – in many ways – the most important investment in the quality of educational programmes, as it provides the basis for everything that takes place in a teaching and learning environment. Unfortunately, though, most curriculum design and development tends to be undertaken in an ad hoc and often individualistic way (Cushman, 2002; Butcher, 2007). Thus, it is plagued by three problems. First, lack of systematic investments in curriculum design and development prevent implementation of strategies for containing the ongoing costs of this work (or – worse – result in such investments being halted). Second, because curriculum design and development is not approached systematically, it becomes harder to understand and is often implemented very inefficiently. Third, because the process resides predominantly with individuals, large investments are often quickly lost when an individual leaves an institution or become unhealthily tied up with that individual, creating significant potential management problems.

In an attempt to overcome these problems, growing attention has focused recently on the concept of creating "learning objects" in an effort to attempt to systematize the codification and storage of this critical intellectual property (see also McKenney, Nieveen, and Strijker, 2008). Much of this work began as a result of developments in e-learning, but the concept has grown rapidly to have relevance in much wider array of educational settings.

There has been much confusion about how to define a learning object, and Sosteric and Hesemeier (2002, p. 1) note that:

> "For some, 'learning objects' are the 'next big thing' in distance education promising smart learning environments, fantastic economics of scale, and the power to tap into existing educational markets. While learning objects may be revolutionary in the long term, in the short term, definitional problems and conceptual confusion undermine our ability to understand and critically evaluate the emerging field".

Many definitions, particularly the earlier definitions, of learning objects draw heavily on the object-oriented design of computer science theory. Object-oriented design focuses on the creation of components – objects – that can be reused in different contexts (Wiley, 2000). While one of the characteristics of learning objects is reusability, this property alone does not define a learning object and definitions focusing too strongly on reusability have received much criticism. (e.g., see Sosteric and Hesemeier, 2002; Wiley, 2000; Nurmi and Jaakkola, 2005). Cushman (2002, p. 7) states that:

> "…object-oriented digital pedagogy can also imply both a positive and normative stance about learning. Not everyone agrees that all (or even most) forms of knowledge can be decomposed into independent, context-insensitive chunks; and not everyone who thinks it is possible sees it as desirable".

Further, it has been argued that adopting an object-oriented design definition of learning objects implies reductionist views of teaching and learning. Nurmi and Jaakkola (2005, p. 3) note that:

> "The typical LO approach stresses learning content and its effective delivery to the learner instead of supporting knowledge construction, and neglects the essential nature of learning processes and learner's personal knowledge construction. Thus the prevailing LO approach takes a teaching perspective whereas according to the constructivist ideas the focus should be based on a learning perspective".

These authors argue further that the content of learning objects should be seen only as information or raw material from which knowledge can be constructed when used within an educational context. Similarly, Sosteric and Hesemeier (2002) note that learning objects do not become useful as learning tools until they have a specific context attached to them with pedagogical intent. Wiley (2005) highlights the importance of instruction design theory informing learning object development if learning is to be facilitated, rather than an overly technical approach, such as is common when object-oriented development is taken as the starting point. He notes:

> "If learning objects ever live up to their press and provide the foundation for an adaptive, generative, scalable learning architecture, teaching and learning as we know them are certain to be revolutionized. However, this revolution will never occur unless more voices speak out regarding the explicitly instructional use of learning objects – the automated or by-hand spatial or temporal juxtaposition of learning objects intended to facilitate learning. These voices must penetrate the din of metadata, data interchange protocol, tool/agent communication and other technical standards conversations. While instructional design theory may not be as 'sexy' as bleeding-edge technology, there must be concentrated effort made to understand the instructional issues inherent in the learning objects notion. The potential of learning objects as an instructional technology is great, but will never be realized without a balanced effort in technology and instructional design".

Several learning object definitions have also been criticized for being so wide and all encompassing so as not to be helpful. Calls are made for simplified, more focused and more practical definitions (Sosteric and Hesemeier, 2002; Nurmi and Jaakkola, 2005). For the purposes of this chapter, the following definition provides a useful and succinct starting point:

> "A learning object…is an object or set of resources that can be used for facilitating intended learning outcomes, and can be extracted and reused in other learning environments" (Mills, 2002, p. 1).

From the discussion above, we see that initial conceptualizations of learning objects tended to be very weak, as they tended to assume that education was a process free of context, and thus that it would be a simple matter to re-deploy individual objects to new learning contexts and reuse them. They also contained an underlying assumption that all learning objects would be quite similar, thus assuming that standardization would be key to interoperability of learning objects. However, as the field has grown, it has become clear that learning objects come in many shapes and sizes, and that what will work well for one educational context may well be highly inappropriate for another. Thus, codifying curriculum information through learning objects has proven to be more complex than initially anticipated. Nevertheless, the process has focused attention on the importance of investing in high quality educational content development, as one key part of knowledge management in education.

Irrespective of the definition of learning objects ascribed to, one of the key reasons that interest has grown in learning objects is because of their promise of "reusability" and hence the promise of costs savings, efficiency and potential quality enhancement where learning objects are well designed. If a learning object is designed well, stored in an appropriate database, and catalogued accurately, then there is significant potential that this investment might find use beyond its original audience and educational context.

Open Educational Resources

Building on this early work, a more recent development taking place in the field of learning object development has been a move towards creating "open" educational resources. This move has been stimulated by a growing movement to make information more freely accessible as a reusable resource. The concept was recently defined as follows during an online discussion hosted by UNESCO:

> "Open Educational Resources are defined as 'technology-enabled, open provision of educational resources for consultation, use and adaptation by a community of users for non-commercial purposes.' They are typically made freely available over the Web or the Internet. Their principle use is by teachers and educational institutions to support course development, but they can also be used directly by students. Open Educational Resources include learning objects such as lecture material, references and readings, simulations, experiments and demonstrations, as well as syllabuses, curricula, and teachers' guides" (http://opencontent.org/blog/archives/247).

A similar definition has been provided by the Organization for Economic Cooperation and Development (OECD) Centre for Educational Research and Innovation (CERI) (Hylen, 2005).

Open educational content development is premised on the idea that the principles of the open source and free software movements can be productively applied to content (Downes, 2001; Daniel and West, 2006; Daniel, West, D'Antoni, and Uvalic-Trumbric, 2006). Most open educational content projects release the products of work completed using a Creative Commons license, which allows authors to retain certain rights while granting other rights to users (particularly the right to make copies of content produced). Additional information on Creative Commons licenses can be found at the following site: http://creativecommons.org/about/licenses/index_html. In this way, the open educational content movement poses a serious threat to many vested interests in educational content development, whose livelihood is based on protecting copyright. This was succinctly summed up by Downes (2001, p. 31) as follows:

> "There is very much a tension, between those who create the knowledge, and who jealously guard their monopoly over its propagation and distribution, and those who must consume that knowledge to get a job, to build a life, to partake fully in society".

The OER movement is still in its embryonic stages, but is starting to provide a compelling case for different economic models of educational content development. This is particularly relevant for developing countries where access to quality learning materials is often poor. For example, Beshears (2005) has provided a well-argued economic case for creative commons textbooks. Zalta (2005) presented "a new funding model for sustainable open access to scholarly and educational content". However, economic viability and sustainability of OERs has been and continues to be questioned (Unwin, 2006; Nurmi and Jaakkola, 2005). Unwin (2006, p. 1) asks:

> "How can good quality OER be funded sustainably? Can we always rely on government funding, enlightened civil society donations, or the 'spare time' of well-intentioned developers who can earn sufficient income from other sources to subsidize their free and open resource development? High quality multimedia games and learning resources are expensive to produce. Will OER ever have sufficient funding to ensure continuing excellence of product?"

Downes (2006) reviews nine current funding models of OER and concludes that OERs can indeed be sustainable, but need to be seen as:

> "part of a larger picture, one that includes volunteers and incentives, community and partnerships, co-production and sharing, distributed management and control" (Downes, 2006, p. 14).

This conclusion is based on an understanding of sustainability that is more than just financial. Downes (2006, citing Walker 2005) argues that:

> "By sustainability we must mean " 'has long term viability for all concerned' – meets provider objectives for scale, quality, production cost, margins and returns on investment". This is significant: for after all, if the *consumer* of the resource obtains the resource for free, then the provision of the resource must be sustainable (whatever that means) from a *provider* perspective, no matter what the benefit to the consumer".

Assuming, along with the various authors cited above, that sustainable models can be maintained, the concept of OERs holds particular value in resource-poor developing contexts, with African education systems poised to benefit significantly if it is applied appropriately. For example, well-developed and maintained portals have the potential to provide access to wealth of educational content. Key to successful implementation, however, are the following:

1. *Development of OERs needs to be closely aligned to institutional accreditation, recognition and reward processes from the outset*. A major problem with initial development of OERs is that institutional delivery partners had not been identified and their commitment to use the OERs secured during project design. This means that content is developed without any clear sense of who will use it and how. Much OER development has tended to be supply- rather than demand-driven (Cushman, 2002). For this reason, it is critical that institutional partners who are committed to using completed OERs in their programmes are part of all OER development projects. A related challenge is the need to ensure appropriate recognition and reward of researchers and educators who support the development of OERs (Geser, 2007).

(a) *OER investments need to be significant enough and sufficiently well planned to ensure high quality products*. A key challenge with OERs is to ensure that the resulting products are educationally effective and of a high standard (Atkins, Brown, and Hammond, 2007). Unfortunately, a high percentage of currently available OERs are of quite poor quality, particularly in terms of their underlying educational design. Part of the problem in this regard is also that materials are often not produced by people who understand the context in which their use is intended or that the involvement of institutional partners is expected to be funded by the institution.

(b) *Investment in OERs should be used as an opportunity to develop capacity to produce high quality programmes and materials*. Linked to the above set of issues is the reality that many OER projects intended to benefit Africa are driven from the developed world. Similarly, Geser (2007) notes that many current OER repositories regard teachers and learners as consumers rather than co-creators of educational resources. This has two obvious consequences. First, it means that materials are developed by people who do not have insight into the context and challenges of educational delivery. Second, it perpetuates the problem of Africans being conceived of as consumers of products created in the developed world (Johnstone, 2005). A key benefit of OER projects is not just the finished product, but also the opportunity that is created to develop capacity in educational materials development and the implications this process has for improving teaching and learning processes (Geser, 2007). Wiley (2005) stated:

> "What is the future of open education? Where is it going? I think there is only one answer: localisation".

If these critical issues are taken into account during development of OERs, then the concept has enormous potential to open and improve the quality of education in Africa and other developing regions, and to drive a process of establishing African educators as producers of high quality knowledge products rather than consumers of products produced elsewhere. In the context of K-12 education specifically, Hepburn (2004, p. 8) concludes:

"As educators learn about open source development models and re-consider some long held assumptions about how educational resources are produced, they can leverage open source processes to take control of meeting educational needs. In addition to producing substitutes for commercial resources, educators are likely to begin producing resources that are new and innovative. Education can quickly move towards the ideal of a commons and, perhaps more importantly, embrace the ideal of fostering a true innovative commons".

OERs and Open Learning

We defined open learning as a principle-driven approach to education which seeks to remove all unnecessary barriers to learning, while aiming to provide learners with a reasonable chance of success in an education and training system centred on their specific needs and located in multiple arenas of learning, distance and face-to-face. When used in contextually embedded education processes, OERs become a valuable tool in the achievement of open learning principles. This is not to say that OERs always support open learning, indeed the danger of such simplistic assumptions has been emphasized in the preceding sections. Rather, the OER movement is one pillar on which open learning can be built and becomes a useful means of conceptualizing the relationship between technology and open learning.

The sharing of investment costs and reusability of OERs have a great potential to support the open learning principles of flexibility and removal of barriers to access. The sharing of learning objects and their re-deployment, with relevant localization, across educational contexts can become a key element in the provision of more flexible education options. The concepts of learning objects and OERs can both support learner-centred education where learners have access to a wealth of relevant educational content from which to select and can contribute to the creation and development of resources. Finally, cost-effectiveness (as opposed to cost-efficiency) is a key driver of both the OER and open learning paradigms, hence OERs have much potential to support cost-effective open learning.

OERs in Action: A Practical Example from the K-12 Sector

While many OER efforts have targeted tertiary education, the following example has been selected to demonstrate the potential of OERs in the K-12 sector. The authors have been involved in the development of this resource in South Africa. As noted above, the development of OERs is still in its infancy and hence much further investment and development in this area is required for the many potential benefits to open learning to be realized. None the less, the example presented below demonstrates the value that technology can contribute to supporting and furthering the development of open learning.

South African National Educational Portal: Thutong (www.thutong.org.za)

A project of the South African Department of Education, Thutong is the national education portal and aims to be the starting point for South African schooling communities seeking educational information. Thutong was officially launched on 24th January 2005. The portal exists to provide access to a wide range of curriculum and support material. It provides access to a vast and ever-increasing range of quality curriculum and learner support materials, as well as educator professional development resources, administration and management resources and tools, education policy documents, and general news and information related to the latest developments in South African education. The content is highly relevant to the lives and learning contexts of South African learners, educators, education managers/administrators and parents, and has been strictly quality assured by experts in the education field. Over time – and with users' active participation and input – the portal resources will continue to expand and become even more representative of users' interests and needs.

The Thutong portal represents a first sustained opportunity to pull together the online educational experience for South African educational communities. The portal is a not-for-profit project. Its extensive resources are made available free to its registered users, with particular priority given to the needs of those from previously disadvantaged schools and rural areas who often have limited access to learning resources. At the time of writing, a total of 27,791 registered users were benefiting from the resources provided. By requiring portal users to register, the Thutong portal is assured of delivering users a customized portal experience, tailored to suit user-defined needs and preferences. Of these users, 60% are teachers, 13% are learners and 13% are parents. The remaining users are community members, researchers, school administrators, school managers, and employees of the Department of Education. Registered users represent all nine provinces of South Africa. Teachers and learners represent all grades of the K-12 system, with the greatest proportion being in or teaching grades six to twelve.

At present, Thutong provides access to 21,183 education-related resources searchable by keyword, topic or by learning outcome. As far as possible, resources in all South African languages are made available. Users are able to contribute to the portal by adding resources and by taking part in various discussion lists. The development of Thutong is an ongoing process and includes expanding the resources available, enhancing functionality, and research to better understand issues of user requirements and portal usability.

Conclusion

While there have been many attempts to introduce distance education to schools, most notably the establishment of Open Schools, these approaches have been limited because they tend not to challenge the problematic mainstream systems which necessitated the introduction of these new models. In this chapter it was argued that the concept of open learning is central in understanding how mainstream education systems might be challenged and transformed. The role of technology in supporting open learning, rather than traditional distance education only, was considered, with particular attention paid to the emerging field of learning objects and open education resources, which hold much potential for supporting open learning in both developing and developed country education systems. This potential not withstanding, many challenges remain and time will tell whether open education resources will live up to their promise. Future research and action needs to document and test out different sustainability models for OERs and most importantly should focus on understanding how OERs are used in practice, particularly in developing countries, with a view towards using this understanding as a basis for challenging mainstream education systems that do not currently deliver the type and quality of education demanded in the twenty-first century.

In conclusion, it is useful to remember the following:

> "We must view the vast body of open educational resources as 'content infrastructure'…instead of thinking about Open Educational Resources as being the educational opportunity we are trying to share with people (the end of our work), we should think about them as the basic resources necessary for doing our job (a means to the end of our work). A vast collection of Open Educational Resources is, of course, the first milestone in our work, not the end of our work" (Wiley, 2005, cited by Albright, 2005, p. 4).

and

> "As reflective practitioners we never allow our work to become a matter of routine. We remain alive to new issues, new theories, new knowledge, new technologies, new controversies that touch upon our field. We expect to go on learning and developing new approaches of our own as long as we practice" (Rowntree, 1992, p. 2).

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7.6

ONLINE PROFESSIONAL DEVELOPMENT FOR TEACHERS

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Introduction

The world is facing an acute and growing shortage of teachers. Besides, many teachers work in overcrowded classrooms where frontal teaching and rote learning makes it difficult to motivate children to learn in school, thus new teaching methods and strategies are needed to change teacher practices. Technology can create virtual learning environments, which on the one hand provides motivating learning situations as well as allows to quickly reach remote areas in need and provide a flexible training environment for all participants (UNESCO – Teacher Education Web site, n.d.).

Online education originated from Distance Education as technology penetrated deeper into the method of delivery and communication. Distance Education refers to the delivery of education to students who are not physically at the training institution itself. Delivery of learning materials are provided through printed or electronic media or e-learning/online-learning technology and communication between teachers and students can be managed through technology that allows asynchronous or synchronous communication. In case any amount of on-site presence is required, then the learning mode is rather described as *blended* learning, and in case more of the subjects and objects of learning are connected through technology, then the learning mode is described to be facilitated through *virtual learning environment*. In terms of prefix use, one can trace the path of development and be able to distinguish between *D-learning* (Distance Education), *E-learning* (Technology-Enhanced Learning) and *M-learning* (Mobile Learning) where students do not need to keep location and use mobile or portable technology (Wikipedia – Distance Education Web site, n.d.).

However, *e-learning* is not a synonym of *online learning*. While e-learning requires the fluent use of enhanced technology in itself as it is performed through emerging technologies, delivering knowledge and information through multimedia content and Internet resources, it is not necessarily performed online, but can well be utilized in

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a face-to-face classroom situation as well. The essence of online learning – in addition – is in its collaborative nature, that simulates face-to-face classroom activities by providing virtual learning environment (e.g. Moodle, BSCW, Blackboard, WebCT), collaborative teaching/learning environments to share and communicate online (by using e-mail, mailing lists, chats, forums or videoconferences), use virtual laboratories to perform experiments and facilitate assessment by application of automatic assessment tools, portfolios and Web-logs.

It is evident from the above, how technology plays a deterministic role in the mode of education in exactly the same way as technology penetrates the everyday lives of business and leisure activities. Even though the call of time has urged technology to make an immediate penetration into business, a delayed impact on the leisure market is observed, and a far more retarded emergence within education can be experienced. Technology, as it is, seems to be an unproved obstacle for schools rather than an enhanced facilitator for learning. Therefore, teacher education of our present days has to exert distinct efforts to show and prove good practices and integrate Information and Communication Technologies (ICT) into the everyday teaching processes. The main problem might originate from the fact that the majority of teachers practising today have learned the teaching profession through books and in face-to-face, frontal teaching situations and have little chance within their own learning experiences in using technology to provide self-proof. Technology progresses rapidly, hence Initial Teacher Training (ITE) cannot prove to be enough, but Continuous Professional Development (CPD) has to deal with new emerging technology, context and methods, in which the use of ICT must have an outstanding role. Therefore, this chapter deals not only with online professional development of teachers in general, but specifically concentrates on the issue of using ICT tools and e-learning materials on the road as it both facilitates the learning process of teachers as well as provides resources for enhanced learning in schools.

Besides official training programmes, the case of providing online curriculum materials is highly important. Research in the UK claims that the nature of ICT is fundamentally antipathetic to the culture of the school and highlights the dissatisfaction towards the educational system, which is leading increasing numbers of parents in the USA and the UK to remove their children from school and educate them at home, using the services of Internet-based providers of educational materials (Somekh, 2004). Of course one can only understand the problems fully by examining the pedagogy related to ICT usage – this chapter cannot deal with this rather extensive and very important issue – but one should be guided on with the evidence that new affordances provided by virtual learning environments require teachers to undertake more complex pedagogical reasoning than before in their planning and teaching (Webb and Cox, 2004). There is also evidence that online projects make great impact on teachers and thus act as professional development side-effect, especially in relation to the use of new technologies (Turcsányi-Szabó, 2006a; also see under *Special Projects at ELTE University* in this chapter). The assertion claims that classroom activities are the catalyst for professional growth as classroom behaviours are determined directly by teacher beliefs on which the experiences can make impact after reflections on evaluations of success of new practices (Fisher, 2003). Moreover, classroom observations suggest that technology integration is governed by six key elements (relevance, recognition, resources, reflection, readiness and risk), which changes pedagogic practices and allows teachers to take ownership of their professional development (Rodrigues, 2006). Whereas, the design of virtual learning environments and activities also require the implementation of an integrated approach to pedagogy and technology which recognizes how these activities, communities and environments represent, transform and encourage a virtual extension of a face-to-face classroom (Richards, 2006).

This chapter first examines Initial Teacher Education (ITE) and Continuous Professional Development (CPD) within Europe and beyond, discusses virtual and distance learning possibilities offered for teachers and highlights case studies from all over the world. Then it elaborates on trends of knowledge delivery and revisits lessons learned in Teacher Education (TE) within the region of Asia and the Pacific. Finally, the issues are specifically examined within the example of Hungary.

Teacher Training in Europe and Beyond

The governments of all European countries share the awareness that teachers' professional development in ICT for education is a key factor in school innovation. However, they have adopted different approaches to the question, ranging from very *decentralized* and *autonomous initiatives* to very *structured systems* (Midoro, 2005).

Basic Skills in the Use of ICT Within ITE

An increasing number of students already acquire ICT skills before entering higher education, which has been mastered either at school (primary or secondary) or autonomously, independent of their education path. Thus, in some institutions, basic ICT skills are already considered as a prerequisite in higher education. But, since the situation is often quite heterogeneous, most institutions also offer (mandatory or optional) courses for developing basic ICT skills on different levels. In some countries like Iceland and the UK, institutions offer their ICT courses online, so that trainees acquire a certain implicit knowledge concerning both the used technology (CMC systems, virtual learning environments, etc.) and the processes of online communication and collaboration. Unfortunately, this does not mean that future teachers are also able to use ICT effectively in the classroom. Thus, institutions in Europe are following two main kinds of approaches in order to develop the specific competencies needed: to use new technologies for supporting learning processes within specific subject areas, and to master methods and tools for designing and using virtual learning environments (Midoro, 2005).

Approaches of Continuing Professional Development (CPD)

In some countries, teachers' professional development is a natural continuation of ITE and in other countries, there seems to be no continuity between ITE and CPD.

For example, in Belgium, Germany and Sweden, public or certified private bodies autonomously propose courses in ICT for education addressed to in-service teachers, while in Greece, CPD is completely organized and managed at a national level by a single central body. In some approaches, centralized and decentralized aspects are merged together and this can occur with different levels of intensity (Midoro, 2005). Often, courses are delivered blended, allowing face-to-face lessons as well as online lessons with collaborative activities (see also National Reports of Italy, Norway, Finland, Iceland, Greece, Portugal, Germany and Spain (@Teacher - National Reports Web site)).

In many countries, qualities of teachers are more often measured through competencies within their professional functionality (Resta, 2002; Midoro, 2005), which of course depends on local principles and strategies employed in planning as well as the surrounding community (Majumdar, 2005).

Virtual and Distance Learning for Teachers

Evidence shows that distance education in its various forms can work and if well designed can be educationally legitimate. It has been applied to the education of teachers and has been shown to be effective on a number of measures, for example, the number of students enrolled, outcome, cost, etc. (Perraton, Creed, and Robinson, 2002).

How to Build Virtual and Distance Learning for Teachers

In terms of cost per student, distance education programmes have often shown advantages over conventional programmes (Perraton, Creed, and Robinson, 2002). UNESCO is very actively publishing experiences in TE all over the world and provides guidelines especially for developing countries to gain knowledge on building effective institutions (UNESCO – Teacher Education Web site, n.d.). Regional and country overviews, projects, online resources, and more valuable information can also be accessed for use. (UNESCO Bangkok – ICT in Education Web site, n.d.)

Models for Online Professional Development

Based on Tinker's taxonomy, four models of online professional development can be identified (Haddad and Draxler, 2002): the *course supplement model*, complements traditional face-to-face teacher training; the *online lecture model*, uses primarily one-way delivery of high-quality content and some orientation from instructor; the *online correspondence model*, uses fewer resources, but offers increased personal contact; and the *online collaborative model*, emphasizes on collaboration activities among participants through high technology and expert facilitation.

Besides normal universities, all sorts of formal and informal form of education exist, which often require high levels of online presence.

Types of Institutions

Open Universities: A substantial portion of open university students are seeking regular university degrees, and another significant portion are engaged in lifelong learning, advancing their knowledge and skills for occupational, family and personal purposes (Haddad and Draxler, 2002). *Examples:* The Open University Web site (http://www.open.ac.uk/), China TV University Web site (http://www.crtvu.edu.cn), Indira Gandhi National Open University Web site (http://www.ignou.org/index.htm).

Virtual Universities: Incorporates a variety of institutions that may be classified as mega universities, open universities, and dual-mode universities, and whose primary programmes are at a distance, as well as those that may be referred to commonly as virtual universities (Haddad and Draxler, 2002). *Examples:* Peru's Higher Technological Institute Web site (http://www.tecsup.edu.pe) and African Virtual University Web site (http://www.avu.org).

Community tele-centres: In developing countries on every continent, public ICT access centres are springing up and bringing information from around the world to communities, generally referred to as tele-centres. They vary in the clientele they serve and the services they provide. All models are useful. But so far, the version designed specifically to achieve education and development goals – including affordable access and training for students, teachers, non-governmental organizations (NGOs) and other social development agents – is the most likely one to ensure access for targeted, low-income populations (Haddad and Draxler, 2002). Their publication mentions examples from Benin, Ghana, Asunción and Bulgaria.

Thus, learning can take place in various types of formal and informal institutions of learning, where the essential element can be viewed as the access to motivating learning materials that allow flexible use in a lifelong learning scheme. The design of such learning materials is crucial, as flexibility also means the use of the same learning elements in different contexts. This will be dealt with in the next section.

Trends in Knowledge Delivery

Trends in Content Development – Learning Objects and Repositories

There is a need for standardized systems that can catalogue, store and retrieve content in ways that enable users to access and organize it for their particular purposes as well as sharing it institutionally, nationally and internationally. There is a great deal of effort being expended around the world on the development of such systems – ones that will standardize the development of resources Learning Objects (LOs), catalogue them (metadata) and store them in repositories (Glen and Farrel, 2003; see also McKenney, Nieveen, and Strijker, 2008). *Examples:* The eduSource project Web site (www.edusource.ca/english/what_eng.html) and Merlot Web site (www.merlot.org/Home.po).

The use of LOs in education – especially elementary and secondary education – is still in a starting stage and thus a lot of lessons still need to be learned in order to make them have an innovative impact on the learning process. McCormick and Li (2006) evaluated the use of European LOs. Their findings indicated that teachers were generally unhappy about the fit of LOs to the curriculum, though they are able to superimpose their own pedagogy on any LO and found their granularity and interoperability characteristic to be the most significant in their usefulness. LOs themselves do not guarantee high-quality learning performance and meaningful learning activities, but they require carefully designed learning environments and instructional arrangements (Nurmi and Jaakkola, 2006a). The teachers' role in organizing, structuring and guiding the whole process is crucial, whereas the design of LOs have to take into consideration a pedagogical context which is less task-centred, but more idea-centred (Ilomaki, Lakkala, and Paavola, 2006). In fact, the promises of LOs can only be fulfilled when they are used according to the principles of contemporary learning theories – viz. engaging students in active knowledge construction and meaning making (Nurmi and Jaakkola, 2006b). Thus, frameworks for knowledge management and appropriate environments need to be put in place to activate LOs to their full potential and allow emergence of online communities of users.

Trends in Portal Development

Butcher (as cited in Glen and Farrel, 2003) describes three types of portals currently available, emphasising that, in many instances, these services are merged in a single portal: Networking Portals, provides access to various individuals to tools and facilities; Organizational Portals, constructed by organizations whose core business is to deliver educational materials; Resource-based Portals, provides access to various educational resources online.

To create successful online communities, strong social and intellectual benefits that cannot easily be accomplished in face-to-face communication must be realized – and innovative technology must be a part of that overall package. Collaboration with, or sharing of, resources can be helped by facilitating sharing and communication in communities governed by common work and purposes. Building communities of practice has become a major theme of educators' professional development research and practice since it enables teachers to promote collaboration, increase idea creation, solve problems in time- and cost-efficient manners, and, therefore, foster social capital. *Example:* TeacherBridge project Web site (http://teacherbridge.cs.vt.edu/).

When the learning task itself is the learner's task, when the situation is under the learner's control and when the activities of learning are personalized by that learner, participants are motivated and educational outcomes are greatly enhanced. This approach allows teachers to get started on projects as quickly as possible, a behaviour which minimalist theory explicitly encourages: people can easily learn by doing with concrete examples, not by being told how to do things (Kim, Isenhour, Carroll, Rosson, and Dunlap, 2003). *Examples:* AskERIC Web site (http://askeric.org/About/), Knowledge Finder Web site (http://colfinder.org/public) and UNESCO Community of Practice in Curriculum Development Web site (http://www.ibe.unesco.org/COPs.htm).

It is not only professional development that such portals can support, but also the target areas of public education with all other sorts of emerging informal learning modes.

Trends in Learning Modes

Open Schools: The models that have evolved in the primary and secondary education sectors as a result of the use of distance education methodologies often use the label *Open School* (Glen and Farrel, 2003). *Examples:* Open School BC Web site (http://online.openschool.bc.ca/).

School Nets: A portal managed by local or international stakeholders, providing learning materials and activities for both institutions and individuals on a broad level (Glen and Farrel, 2003). *Examples:* SchoolNet Canada Web site (www.schoolnet.ca), European SchoolNet Web site (www.eun.org or www.eschoolnet.org), SchoolNet South Africa Web site (www.school.za), SchoolNet Africa Web site (www.schoolnetafrica.net) and World Links for Development Web site (www.worldbank.org/worldlinks).

The question remains: how well can these trends and experiences be utilized on a larger scale, bloom within different cultures and language areas, serve varieties of country policies and be adaptable in underdeveloped regions as well, where the greatest need for teaching and learning is required. It is worth examining the factors that lead to effective implementations.

Lessons Learned in Asia and The Pacific Region

Curriculum and Content Development

A synthesis of lessons learned provides the basis for the development of tools and blueprints to guide policy and programme improvements for the appropriate use of resource to support the integration of ICT in education, based on the experiences of Indonesia, Malaysia, Philippines, Singapore, South Korea and Thailand, with respect to curriculum, pedagogy and content development in the integration of ICT in education (UNESCO, 2004a).

School Networking

The decision to establish a SchoolNet must take into account wide-ranging considerations, as can be seen from experiences of Indonesia, Malaysia, Philippines, Singapore and Thailand, with respect to SchoolNet-related infrastructure and connectivity (UNESCO, 2004b). Further country overviews can highlight different aspects in relation to (I)TE programmes in Asia and the Pacific at UNESCO Bangkok – Regions and Country Overviews Web site (http://www.unescobkk.org/index.php?id=783).

Private enterprises also provide support and very successful initiatives that spread rapidly all over the world. A very good example is Intel, which offers free professional development to K-12 educators, focused on enhancing education with technology and student-centred learning approaches (Intel Teach to the Future project Web site - http://www97.intel.com/education/teach/).

There are of course many different success stories. The International Federation for Information Processing (IFIP), among others, holds a Technical Committee of ICT in Education that operates a Web page where the different country profiles contain basic documents for planning at national level, national educational networks, and the best educational projects that are running in the country at present (IFIP TC 3 Country Profiles Web site - http://www.ifip-tc3.net/rubrique.php3?id_rubrique=18).

The Case of Hungary

Teacher Training

In Hungary, concerning ITE, one has to consider that Informatics is a compulsory subject from elementary fifth grade onwards since 1998 (Turcsányi-Szabó and Ambruszter, 2001). Thus specialized Informatics teachers are trained throughout the country to deliver the subject on a high level, both at elementary and at secondary schools. There were four universities in Hungary that were involved in the training of secondary school informatics teachers and five colleges that were involved in training elementary school teachers so far, which are now in the process of change due to the Bologna process.

Concerning CPD, all teachers in Hungary have to undergo 120 lesson hours of in-service training once every seven years. Thus, courses offered all over the country, in Universities, Teacher Training Colleges and Institutes for Professional Development, concentrate on new competencies to be mastered according to the requirements of present time.

Infrastructure

In 1994, the Hungarian Ministry of Education initiated a nation-wide project financing Internet facilities for all schools, training and content for school work facilitating connection to institutes bearing public collections and its access as well to Hungarian nationals outside the country (Turcsányi-Szabó and Ambruszter, 2001). The project financed the following topics:

- The establishment and operation of 64-Kb communication lines for schools allowing unrestricted Internet access.
- To equip all schools (all secondary schools till 1st September 1998, all elementary schools till 2002) with Internet-ready multimedia lab.
- To develop content for educational materials accessible via Internet that would help school work: supplementary course materials, assignments for individual

work, multimedia and Internet introductory kit, monthly newsletter, musical resource kit, and recently accessible research materials.
- To facilitate bi-directional data exchange via co-ordinated data-bases that could be accessed nation-wide.

The ministry also financed the establishment of reference centres and training centres for teachers, where courses would be held in the following levels:

- Basic Internet use: for all teachers that are not specialized in informatics.
- Educational Informatician: a high degree for non-informatics specialists.
- School ICT advisor: for those bearing a middle degree in computer science.

Distance Education

Considerable efforts have been made in Hungary since the early 1990s to establish a distance education system for taking advantage of the increasing ICT use. As a promoter of the development, the National Council for Distance Education (set up in 1991, NCDE Web site - http://www.ntt.hu) coordinated large Tempus and PHARE projects aiming at the modernization of the so-called traditional evening and correspondence education. Training of experts and trainers, establishment of Regional Training Centres and their network based on higher education institutions, and setting up of a National Methodological Centre were the main results of this activity (Tóth, 2002).

Present Situation

At present, all higher educational institutions are connected through broadband fibre optic cable and broadband (ADSL) Internet access is provided to all (5,500) primary and secondary schools. Until 2006, in the National Development Plan, the Human Resource Operative Programme is responsible for building lifelong learning skills and pedagogical methodology reform in primary and secondary education using a competence-based approach (Horváth, 2004).

Concerning teachers of all subject areas, the Ministry of Education initiated in-service teacher training and incentives for purchasing computing instruments: Till the spring of 2004, ICT training for 10,000 teachers; 2004–2006, ICT training for 30,000 teachers for competence-based education combined with incentives for purchasing computing products through tax allowance policies (Magyar, 2004).

Sulinet Digital Knowledge Base and Portal

The content development strategy of Hungarian SchoolNet (Sulinet) can be determined according to two target areas (Főző and Pap, 2004; Abonyi-Tóth, 2006):

- The Sulinet Web page – The goal is to operate a well-functioning educational portal, which attends 50,000 visitors a day.
- Development of digital educational auxiliary materials, which are usable in the field of public education as open source.

The Sulinet Digital Knowledge Base (SDT Web site - http://sdt.sulinet.hu/), edited and managed by Sulinet, aims to establish a complete electronic database covering all the cultural domains of primary and secondary education specified in the Hungarian National Curriculum. The available database offers lesson plans, methodological support, subject matters and basic learning blocks for teachers and students to use in the everyday teaching/learning process. The use of SDT is free of charge for all individuals and educational institutions within Hungary and those beyond the borders. It aims to serve not only public education, but also ITE and CPD.

The different elements of the Knowledge Base (pictures, texts, sound- and video files) are designed as re-usable LOs and are placed into a Learning Content Management System (LCMS) designed to suit local requirements. More than 200,000 reusable LOs are placed within the LCMS. Different users are entitled to go through different paths depending on their preferences, levels and purpose. Enhanced search facilities provide direct access to required topics, and use of bookmarks ease the process of collecting entry points to revisit. Materials can be accessed thematically; through designed paths; searched titles, keywords and other specified tags; established connections via an internal concept graph, which also serves as visualization tool for knowledge integration.

The internal storage of data and publishing complies with international standards (SCORM, IMS, LOM, Dublin Core) to attain re-use and portability of content. The structure of the system also makes it possible to publish the materials in other interfaces like mobile phones or palmtops. Functionality allows not just browsing and download of materials, but also editing new materials or adapting existing content to suit specific needs. The system is also equipped with messaging, forum, and activity area to facilitate project work and collaboration.

Besides, Sulinet portal (Sulinet Web site - http://www.sulinet.hu/tart/kat/Re) publishes auxiliary educational materials and subject matter blocks too as well as methodological information. The portal consists of four sub-portals (e-Learning, School, Pedagogy, Systems administrator) with 28 sections altogether. School bodies can find all sorts of information they need and can easily exchange with others on topics and experiences. In addition, Sulinet also launched a 30-h ICT-based modular in-service teacher training programme consisting of ten modules that can be attended all over the country (Sulinet Express Web site - http://www.oki.hu/printerFriendly.php?tipus=cikkandkod=link-Sulinet-Express).

Thus, the Hungarian approach embedded within Sulinet provides a unique environment with equal access for all citizens and Hungarian nationals around the world, to be part of the learning community, allowing participants to take active role in further perfection of the established knowledge base as members of a community of practice in the educational arena of the twenty-first century.

Teacher Training at ELTE University

Eötvös Loránd University (ELTE University Web site - http://www.elte.hu/en/) was the first to introduce computers into the teacher training programmes. Students with several types of majors attended introductory computer and programming courses and learnt about their applications in subject areas. ELTE University is the biggest university in Hungary that, apart from other subject areas, produces the largest amount of teachers in the field of informatics and prepares all teachers for the use of ICT in education. Its educational policy, which was very highly programming oriented, has shifted more towards the use of ICT in subject areas rather than the heavy emphasis on the learning of the technology and computer science itself.

EPICT – The European Pedagogical ICT Licence is a comprehensive, flexible and efficient in-service training course introducing a European quality standard for the continued professional development of teachers in the pedagogical integration of information, media and communication technologies (ICT) in education, controlled internationally by the EPICT Group (EPICT Group Web site - http://www.epict.eu/about_epict/index.html). The Hungarian representative is the Centre for Multimedia and Educational technology (MULTIPED Web site - http://edutech.elte.hu/kozpont/english/index.html) based at the Faculty of Sciences at ELTE University, serving teacher training faculties of the university with courses on Educational Technology and ICT in Education.

Special Projects at ELTE University

The emphasis of Informatics is so high in the country that three years ago the Faculty of Informatics was established within ELTE University, which considers – among others – the training of informatics experts and teachers, continuing their pioneer activities of integrating ICT into TE in a more effective setup. Besides the official courses in teacher training, there are special projects that help infusion of innovation within public education initiated within TE. An example is the practice of ELTE University TeaM lab (TeaM Lab Web site - http://teamlabor.inf.elte.hu/), which offers courses for higher graders as undergraduate non-compulsory electives, mainly within the Informatics teacher training programme and secondly for programmer and programme designer mathematicians with relation to developing e-learning materials and running projects in public education (Turcsányi-Szabó, 2006a).

All courses require project work that outlines a definitive part of an actual project to be launched and the sequence of courses contribute to the building, launching, running and evaluating processes within project activities. Projects are launched directly into public education often in association with the national computer society (John von Neumann Computer Society, Public Education SIG - http://njszt-kozokt.inf.elte.hu/) and results are reported twice a year at the conferences for Informatics Teachers (INFO conferences Web site - http://www.infoera.hu/), where discussions with practising teachers can produce important conclusions for the future.

One such project type is the TeaM Challenge Game series (TeaM Challenge Game series Web site - http://matchsz.inf.elte.hu/kihivas/), launched every year since 2002 (Turcsányi-Szabó, Bedo, and Pluhar, 2006). TeaM lab initiates projects not only for formal public education, but also for tele-centres in underdeveloped regions as capacity-building initiative, during which a model for mentoring has been developed (Turcsányi-Szabó, 2003), which is since then successfully utilized within the Hungarian tele-centre community (Telehouse association - http://www.telehaz.hu/).

Another such continuous project is the development of subject-oriented micro-worlds for elementary education and special education. In fact, e-learning material for teachers has been developed in 1996 within NETLogo project on how to use, configure and design such micro-worlds using Comenius Logo as authoring tool (Turcsányi-Szabó, 2000). This material was later extended and adapted to suit elementary education as well and was used for many years at ELTE university ITE in blended courses and opened for the public (visited by both in-service teachers and students), mentored online by future teachers themselves (Turcsányi-Szabó, 2004). At present, ITE uses the localized version of Imagine authoring tool and an e-learning material developed by TeaM lab, which has been adapted as LOs for Sulinet SDT "Digital literacy" course (Turcsányi-Szabó, 2006b) and can be accessed freely by public education for use in class work too. The English language version of this material is also available through Logotron Ltd. (Turcsányi-Szabó, 2006c) and is distributed in English language cultures.

Thus, it can be said that TeaM lab not only takes part intensively in face-to-face and online ITE, but also develops the necessary e-learning materials that are suitable for both training purposes and direct use in class work. Thus, formal and informal CPD also profits through direct use of materials in schools and at homes for which online mentoring is provided.

Conclusion

ITE and CPD vary in forms, resources, methods and delivery along the different countries in Europe and beyond, but case studies suggest that ICT use is a benchmark for success and the effectiveness of all initiatives depend on the fluent use of enhanced technology, availability of adequate and suitable LOs, the setup of suitable virtual learning environments, and initiation of innovative projects that allow an integrated approach to pedagogy and technology as a virtual extension of formal and informal learning in general. Research on the actual effectiveness of these tools and resources is in an early stage and the concrete parameters of success are yet to be proved.

However, it is well visible that lessons are worth learning from other cultures and regions as there is always something new and innovative to examine, try out and if proven, to adapt to local needs. The overview of the picture is quite wide on an international scale and all countries should find their own profile, depending on capabilities to utilize the right tools and methodology that would really enable them to make changes with the needed impact. It might well be different from country to country, as the add-on values of local communities can be highlighted only if appropriate basic requirements are met on which a well-designed structure of schooling is built on, which can be flexibly adopted according to needs.

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Section 8

IT AND THE DIGITAL DIVIDE

8

IT AND THE DIGITAL DIVIDE

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Around the world, the move toward digital equity still faces significant challenges at the regional, national, and local levels. There is, however, growing recognition at all levels of the critical role IT must play in preparing a new generation of students with the knowledge and skills needed to be successful in a knowledge-based global society. There is also acknowledgement that a failure to increase educational access and use of IT will result in the educational, social, and economic exclusion of groups. Instead of arguing that IT widens the gap between sexes, economic groups, ethnic groups, and countries, the contributing authors consider IT as a potential agent for social inclusion. Therefore, they devote much attention to the issues, challenges, and strategies involved in moving toward digital equity and the ways in which teachers and teacher educators can pay attention to issues of equity when using IT in education.

The introductory chapter situates IT access and use within the context of twenty-first century life and work, and identifies five access-and-use issues and the related challenges and strategies based on what research says about the digital divide. The chapter points to the new digital literacy demands placed on education systems, while also underscoring the challenges and need for basic literacy that allows individuals to access information and use IT to create value for their communities.

Chapters 8.2 and 8.3 look at individual differences. Chapter 8.2, by Looker, presents an overview of initiatives that address gender-based digital divide issues and the research needed in this area. It discusses the differences between the developing and developed world in gender digital divide issues and dynamics. For instance, cultural issues with respect to appropriate gender behavior and attitudes are particularly salient in the developing world. The concern is to ensure that girls and women are not further marginalized by IT. In the developed world, the gender divide in physical access is diminishing. The focus is on the types and extent of use by men and women, and the research literature focuses mainly on the ways that women are disadvantaged

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relative to men. Chapter 8.3, cowritten by Treviranus and Roberts, demonstrates how assistive technologies may address the needs of disabled students, for instance, the visually handicapped, and highlights the ways in which interoperable learning applications can benefit inclusive education. They argue that properly designed learning applications (e.g., learning objects, learner management systems, and learning object repositories) allow educational resources, and their delivery, to be customized for students with disabilities. To this end, developers must apply specifications and standards to match individual preferences.

In Chapter 8.4, Pittman, McLaughlin, and Bracey-Sutton discuss the critical factors to a successful approach to digital equity. Cases are provided to illustrate the strategies that have proven effective in helping close the digital divide in different contexts. Chapter 8.5, written by Roy, Chen, Cherian, and Tuiono, addresses the role of technology as a means of providing culturally responsive education and as a tool for preserving the cultures of indigenous peoples. They discuss how technology can be a double-edged sword, one that can either hasten the erosion and loss of culture, or empower indigenous peoples and other groups to create their own culturally relevant content to enhance the education of their children. The cultural and the geographic divide that exists between the Northern and Southern Hemispheres is also addressed, with a special focus on First Nations/Aboriginal people.

Finally, Chapter 8.6, written by Gibson, provides a leadership approach to the question of how teachers and teacher educators can collaborate in "doing and living equity" at the same time as focusing upon the local achievement of relevant learning goals.

These chapters, taken together, are intended to help foster an understanding of the role of IT as an agent for social inclusion. For social inclusion to occur, cultural leaders, policymakers, educational innovators, and the private sector must establish partnerships to help communities build capacity in IT access and foster its use in education and other sectors. The authors discuss the barriers that impede progress toward digital equity and identify strategies that may help overcome the barriers.

8.1

ISSUES AND CHALLENGES RELATED TO DIGITAL EQUITY

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Introduction

Digital equity is a source of concern for those who understand the power and role of the Internet and digital technologies in the emerging knowledge-based society (Castells, 2001; Compaine, 2001; Norris, 2001; Organisation for Economic Co-operation and Development (OECD), 2001; Selwyn, 2004; Tolbert et al., 2003; United Nations Development Program (UNDP), 2001). However, many people across the globe do not have access to the Internet and related technologies resulting in a new form of digital exclusion often thought of as a "digital divide." The global concern is reflected in the following statement by the World Summit on the Information Society (WSIS) of the United Nations Educational Scientific and Cultural Organization (UNESCO) in Tunisia in 2005: "*We underline* the importance of removing barriers to bridging the digital divide, particularly those that hinder the full achievement of the economic, social and cultural development of countries and the welfare of their people, in particular, in developing countries" (WSIS, 2005, p. 1, article 10).

The term digital divide refers to "situations in which there is a marked gap in access to or use of ICT devices" (Campbell, 2001, p. 1). Gorski (2005) indicates that a digital divide exists when group's access to digital technologies and resources differs along one or more dimensions of social, economic, cultural, or national identity. Individuals are subject to social exclusion depending on age, gender, differing abilities, income, education and skills, location, language, and culture (Sen, 1999). For Warschauer (2004), "digital solutions" do not come without consideration of the complex factors, resources, and interventions required for supporting social inclusion. In 2002, he suggested to replace the notion of the digital divide by the alternate concept of technology for social inclusion:

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> Meaningful access to ICT encompasses far more than merely providing computers and Internet connections. Rather, access to ICT is embedded in a complex array of factors encompassing physical, digital, human, and social resources and relationships. Content and language, literacy and education, and community and institutional structures must all be taken into account if meaningful access to new technologies is to be provided (p. 2).

As noted by Warschauer (2002) and Sciadas (2003), there are many variations and levels of access, and they suggested that those concerned should be thinking of a gradation instead of a divide between those who can use IT to access, adapt, and create knowledge and those who cannot. However, we chose to keep the term digital divide in the title of this section as it continues to focus scholars', citizens', and policy makers' attention on this critical social issue and its challenges (e.g., the Tunis Summit, WSIS, 2005). This introductory chapter provides a conceptual framework for understanding the major dimensions of digital equity and the issues and challenges related to each dimension. These issues and challenges are discussed in detail within each of the five chapters of the section.

Conceptual Framework

Digital equity (Solomon, 2002) is a social justice goal. Digital equity for social inclusion, or universal access (Alampay, 2006), is the impetus behind informed advocacy toward IT access and use. Moreover, the digital divide helps widen an even more alarming divide – the knowledge divide.In industrialized nations, the economic base is shifting from industry to information (Haddad and Draxler, 2002). Knowledge societies (Anderson, 2008; Bindé, 2005) are becoming the aspiration of both North and South countries. Institutions and citizens are faced with an exponential growth in basic and applied knowledge: the world knowledge base doubles every 2–3 years, with similar growth trends in information on the Internet. With an increasing flow of information, national economies grow more internationalized. There is a social demand for higher levels of education as technology is reducing the need for many types of unskilled or low-skilled workers (Haddad and Draxler, 2002).

Digital Equity for Social Inclusion

The growing efforts to move toward digital equity are fueled by the prospect that digital exclusion will add to social and economic exclusion of individual learners and citizens and, on the broader scene, whole populations. The main assumption here is that the access and use of the Internet and digital technologies are critical elements for individuals to participate and derive the benefits of a global knowledge society. A requisite for participation, however, is basic literacy. Literacy levels vary greatly across gender, nations, and the world. The fact that almost two-thirds of illiterates are women (Figure 1) limits womens' access to IT. Gender is a digital equity factor, and its manifestations and evolution are studied in scholarly works (Ono and Zavodny,

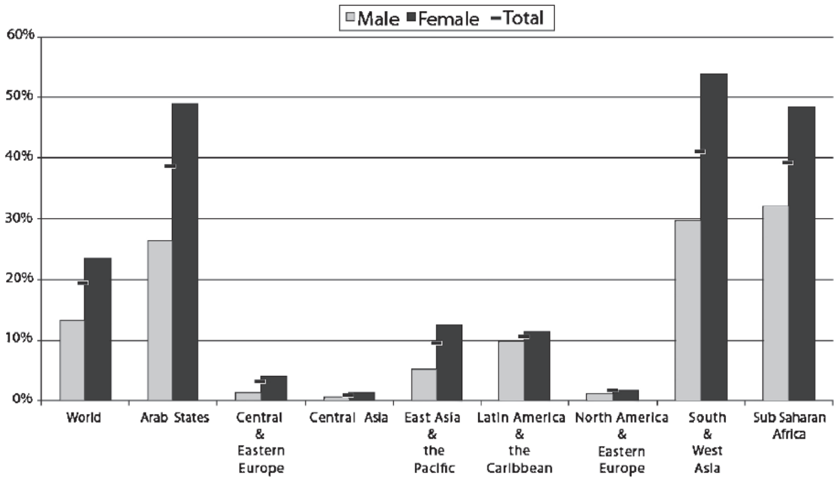

Fig. 1 Adult illiteracy rates by region and gender. UIS, Literacy database, June 2005

2005; Looker and Thiessen, 2003; Kawabata, 2003). Besides gender, another individual difference that impinges upon literacy and access to IT, even in developed countries with a high level of Internet penetration, is visual impairment and other disabilities. The visually impaired individual requires adaptive technology. This section devotes its two chapters to these issues. Looker (2008) discusses challenges and strategies related to womens' access and use of IT, and Treviranus and Roberts (2008) address trends, issues, and strategies in the use of adaptive technology.

Digital Equity in Education

Although the basic literacy or "print divide" remains an important issue in many parts of the world, the digital divide has become a growing concern in education based on the growing recognition of the strong relationship between education and socioeconomic development (economics of education, e.g., Barro, 1991; Cohen and Levinthal, 1989). There are efforts being made throughout the world that attempt to put the potentials of IT in the service of education. The final three chapters of the section address a number of critical issues and strategies related to digital equity in education. Pittman et al. (2008) discuss the value-added dimensions of IT in education. Roy et al. (2008) address issues related to culturally responsive use of IT in education, and Gibson (2008) discusses organizational empowerment issues and strategies in moving toward digital equity. These chapters exemplify individual and/ or collective emancipation (basic skills, twenty-first century skills) through access to information or people, and knowledge creation using IT.

For such emancipation to occur, however, education must understand that digital equity is more than access to computers and connectivity. Digital equity involves the following five dimensions:

– Access to hardware, software and connectivity to the Internet
– Access to meaningful, high quality, culturally relevant content in local languages
– Access to creating, sharing, and exchanging digital content
– Access to educators who know how to use digital tools and resources
– Access to high-quality research on the application of digital technologies to enhance learning

Issues and Challenges

The following section describes the issues and challenges related to each major dimension of digital equity.

Access to Hardware, Software and Connectivity to the Internet

Internet providers are conscious of the value of their goods, and consumers want an affordable price, reliability of service, and speed. However, in the Southern hemisphere there are great numbers of individuals who are disadvantaged. Geographical location matters a great deal when it comes to digital equity. Although the Internet is spreading at a much faster rate than electricity, the latter is still missing in some rural areas of the world. The International Telecommunications Union (ITU, 2003) states that the Internet infrastructure is now in place in all continents. According to Internet World Stats (2007) (http://www.internetworldstats.com), Asia is now the world region that has the highest number of Internet users (Figure 2), but the Internet penetration level is only 11% (Figure 3). North America remains the region with the highest level (69.7%) of Internet penetration whereas Africa has the lowest (4%).

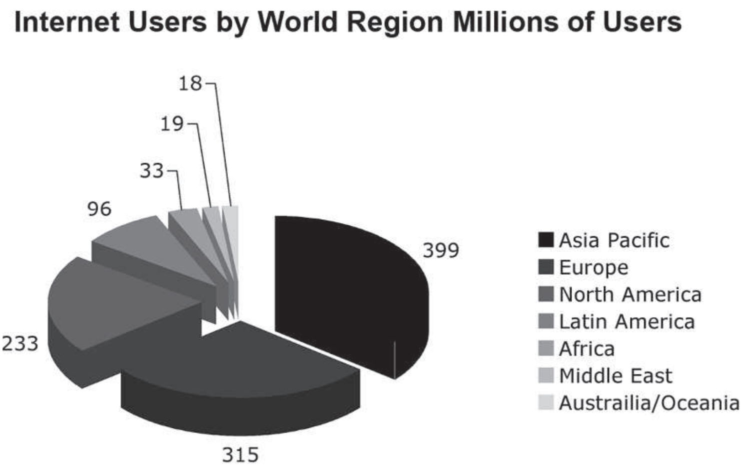

Fig. 2 Internet users by world region (World Internet Usage Statistics News and Population Stats, 2007)

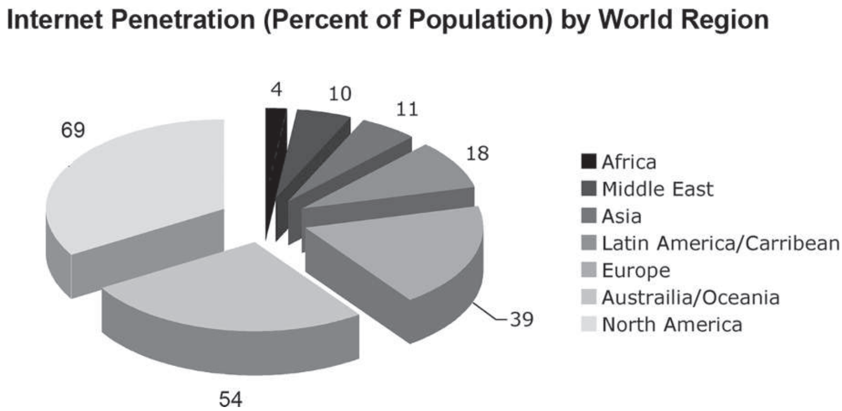

Fig. 3 Internet penetration (Percent of population) by world region (World Internet Usage Statistics News and Population Stats, 2007)

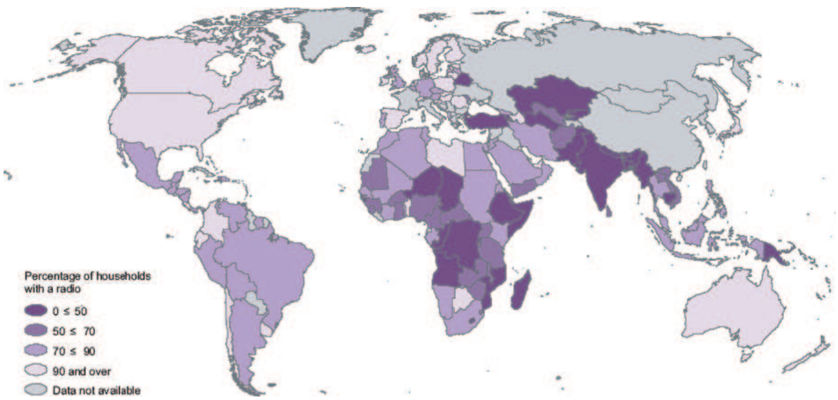

Fig. 4 Percent of households with a radio. UIS from ITU World Telecommunication Indicators Database (2005)

Looking at the worldwide distribution of radios (Figure 4), a rather simple information technology, one cannot help thinking that the digital equity goal is a far-reaching one. Contrary to radio, television, or print, computers are more complex, and this very factor keeps citizens away from using them, including ones who are literate, wealthy, and living in the city.

In primary and secondary schools and classrooms, the cost of computing equipment and connectivity is the first issue that comes to mind. In developed countries, those connected to the Internet require increasing bandwidth for audio and/or video use. Exemplars of new limits reached are as follows:

A suburban school in a wealthy city finds it difficult to keep up with the demand on bandwidth created by the 500 computers used by students during class time. A small student team from a remote rural school can hardly hear students from another school with whom they are doing a learning project because the latter students are part of a large school whose three computer labs take almost all of the available bandwidth.

Developing countries would be facing similar issues except that IT keeps improving. Leapfrog initiatives are expected as hardware costs are coming down (25% per year in increased power and lowered costs), and wireless technologies are growing rapidly in number and range (e.g., WiMAX). The One-laptop-per-child (OLPC) Negroponte's (2005) initiative (http://laptop.org) – also known as the MIT $100 computer – is an attempt to seriously address hardware, software, and connectivity costs.

Challenge

Technology leadership on the part of educational administrators, including school principals or master teachers, is the key challenge at any early stage of IT integration to teaching and learning (Solomon et al., 2003). Educational leaders will face many who are more trustful of traditional technology (blackboard, printed resources) for school learners, and wary of the costs of computers and connectivity. Government officials are looking for return on investment (ROI). "Despite the potential of ICTs to be an engine for social and economic development, there is limited quantifiable proof and little internationally comparable data" (ITU, 2006, p. 30).

Informed Strategy

The societal passage from print to digital information is underway. Educators and policy makers must understand the importance of bridging the digital divide in education as an important element of the national strategy to prepare students with twenty-first century skills needed in global society. While computers keep growing in interactive functionalities, countries can build capacity through dialogue and the development of partnerships between the governmental, educational, and the private sectors.

Access to Meaningful, High Quality, Culturally Relevant Content in Local Languages

The Declaration of Principles adopted at the World Summit on the Information Society (Geneva, 2003, Article 1) declared "[the] common desire and commitment to build a people-centered, inclusive, and development-oriented Information Society, where everyone can create, access, utilize, and share information and knowledge" (WSIS, 2003, p. 1). The impetus behind the Geneva Summit was the growing awareness of the digital divide. IT should be turned into "a digital opportunity for all" according to the Summit's Declaration of Principles and Plan of Action (UNESCO, 2001).

Although the Web offers vast resources that are of value to education and lifelong learning, it must be recognized that the quantity of information available on the surface

Table 1 Size of internet in terabytes (Lyman and Varian, 2003)

Medium	2002 (Tb)
Surface web	167
Deep web	91,850
Email (originals)	440,696
Instant messaging	274
Total	532,897

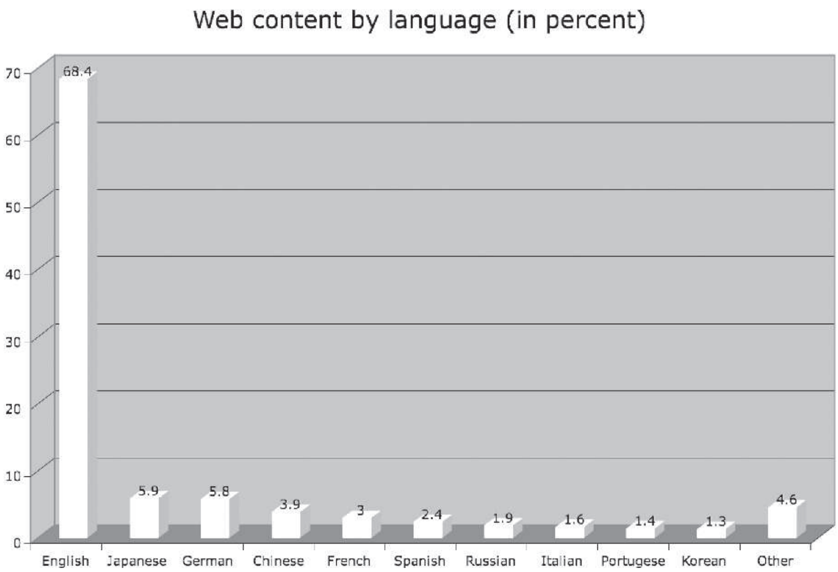

Fig. 5 Percent of Web content by language, 313 billion web pages (September 2004) (Global Reach, 2004 – http://global-reach.biz/globstats/refs.php3)

web (i.e., what is normally considered the Web) represents only a fraction of the resources that are available on the deep web. The deep web represents the part of the Internet that is inaccessible to conventional search engines and, consequently, to most users on the web. As shown in Table 1, the content available in the deep web is over 500 times greater than what is available on the surface web.

When one looks at Web content by language (Figure 5), another major issue stands out, that is the dominance of the English language (68.4%). Although there are vast numbers of Chinese and other Asian users (see Figure 2) on the Web, Web content in Chinese is only 3.9%. English has become the world's lingua franca through globalization.

Challenge

Cultural preservation and development through the creation of digital content in local languages is a major challenge confronting many countries across the globe. Affirmative culturally oriented actions such as declarations and conferences (e.g., *Achieving quality of Access, Ireland, 2004, HEA Conference Proceedings*) are helping to raise the level of global visibility and concern over this trend. There are also a growing number of public/private initiatives, such as SchoolNet Africa (http://www.schoolnetafrica.net), and the eGranary Digital Library (http://www.widernet.org/digitallibrary) that have emerged to develop and/or provide access to high-quality educational content in local languages.

Informed Strategy

The use of open educational resources (e.g., open courseware initiatives (MIT, UNESCO), Creative Commons (some rights reserved), and open source software (Open Office, GIMP, Tux Paint, Nvu) for individual and community empowerment is the employed strategy. For instance, Native Americans have engaged in digital repatriation of sacred or important artifacts that reside in national or regional museums. Indigenous communities are now able to use technology to develop educational resources and materials that reflect the language, culture, history, and resident knowledge of indigenous communities to help support culturally responsive teaching and learning in schools serving native children (Resta et al., 2004).

Access to Educators Who Know How to Use Digital Tools and Resources

The relevance of IT to teaching and learning has been argued from the perspective of twenty-first century skills. Stewart (2000) stressed that geographical, generational, cultural, and pedagogical issues and challenges combine to expand school learners' participation in the determination of both individual and collective life chances.

When education systems plan to innovate through the use of digital tools and resources for teaching and learning, they face the issue of teacher development. They can rely on a small minority of innovative teacher educators and teachers (see Rogers' notion of early adopters, 1995; Cuban, 2001) willing to take risks. Innovation in teaching refers to new modes of delivery (e.g., learning object repositories), including online courses (see http://opentraining.unesco-ci.org), or new approaches to learning (e.g., Bransford et al., 1999). Teachers who are transforming their primary or secondary classrooms into hybrid (or blended) learning environments by combining onsite and online learning activities (Kozma and McGhee, 2003) are examples of early adopters and innovators in the use of IT in teaching and learning. To expand beyond this group, however, poses significant challenges and the need for leadership and administrative, collegial, and pedagogical support.

Challenge

IT partnerships that include universities, schools and sometimes governmental agencies are instrumental for capacity building in the use of digital tools and resources: see, for instance, Lating's (2006) study on hybrid e-learning for rural secondary schools in Uganda or Allaire et al.'s (2006) study on Quebec's (Canada) remote networked schools. Partners face coordination and collaboration challenges. For instance, in Allaire et al.'s study, the Ministry of Education, three universities, 13 school districts and over 50 schools were involved. Even the most capable and interested teachers kept having access problems to basic equipment and connectivity (e.g., delayed arrival of sufficient bandwidth, upgraded firewalls and antivirus software reducing computer processing power, reconfiguration of computers on a routine basis or on the arrival of new personnel, and competing choices regarding desktop videoconferencing systems), the cumulative effect of which posed significant challenges to engaging in collaborative planning among teachers and implementation with students from different schools. Moreover, most teachers had previously been operating in a system that valued teacher-proof curricula (objective testing aligned with discrete behavioral objectives). Although an educational reform effort was underway, one giving more deliberative power to teachers regarding classroom activity, finding time to engage school learners in online collaborative inquiry remained a serious challenge for most teachers. A minority of teachers who adopted the online tools to support their own collaborative planning and school learners' inquiries served as exemplars of the use of digital tools and resources to transform the classroom activity in helping to foster deeper student understanding of real problems (Bereiter, 2002).

Informed Strategy

Those who adopt a new technology tend to apply the tool in accordance with previous practices (Cuban, 2001; Perelman, 1992; Seidel and Perez, 1994). Rather than recognizing the immense potential for doing things differently, teachers often use technology in accordance with old instructional practices, doing the same thing as before, but a little more quickly, a little more frequently, or a little better. In many instances, the teachers are not able to realize the full potential of information and communication technologies to enhance the teaching–learning process because of lack of comfort and competency in using the new tools for learning. Thus, to achieve digital equity requires more than the provision of access to computers and connectivity in the classroom. It requires the provision of high quality and sustained professional development to teachers. This may be accomplished in a number of ways such as providing online learning and professional development resources for teachers and building online communities of practice (see also Turcsányi-Szabó (2008) and Looi et al. (2008) in this handbook. Another strategy would be to network teacher education institutions for online learning purposes (see the Teacher Education Goes Into Virtual Schooling project (TEGIVS) involving teacher educators from Iowa State University and Florida State University, http://www.public.iastate.edu/~vschool/TEGIVS/homepage.html).

Access to High-Quality Research on the Application of Digital Technologies to Enhance Learning

High-quality research is often considered to include quantitative studies involving large numbers of participants, pre-post testing associated with short-term experimentation. There is also an emerging trend toward ethnographic studies involving in-depth observation and/or analysis of a small number of subjects. The former provides descriptive low-end information on what is being applied on a large-scale basis whereas the latter provides higher-end but small-scale information growing out of detailed observations or interviews with limited generalizability. Both types of research have value provided they are done according to the highest standards of rigor for both types of research.

Challenge

Innovation requires both the use of well-established research approaches as well as the development of new research strategies to understand better the complex environments and interactions in learning with the new digital technologies. Design experiments (Brown, 1992; Collins, 1992) and design research (Bell, 2004) were especially conceived to these ends. These methodologies are collaborative (university-based researchers and classroom-based teachers); they take context into account, and reinvest in the next iteration lessons learned as well as questions arising from the preceding iteration. Research is needed in the following areas: (1) types of access to computers and Internet, (2) classroom activity with online tools and resources, (3) learning outcomes as innovative practices are put into place, and (4) community progress being made as teachers and learners are adopting digital tools and resources.

Informed Strategy

In places where the digital divide is the most pronounced, there is typically also a lack of access to high-quality research. One strategy for fostering research in these settings is through the creation of networked communities inclusive of experts, competent teachers, beginning and prospective teachers (Czerniewicz and Carr, 2005; Lamon et al., 2008). This may also involve multi-institution collaborations to support innovative and enduring onsite/online experimentation with digital technologies (see Kash and Rycroft, 1999).

Access to Content Creation

The Geneva Declaration of Principles, which was adopted at the World Summit on the Information Society (Geneva, 2003, p. 1), foresaw "an […] Information Society, where everyone can create, access, utilize and share information and knowledge." The rapid growth of digital libraries and repositories is not without issues and challenges related to access to content (see Chapter 2.3), but here the emphasis is on access to content creation opportunities. We understand the above quote from the Geneva Declaration to be an incentive toward the democratization of content creation, one to engage school learners through collaborative ventures and the recognition of students' voices, and ability to learn, create, and disseminate under the guidance of their teachers.

Challenge

This approach (namely, knowledge building, Scardamalia and Bereiter, 2003) has implications for education, culture, and democracy. It requires trust in school learners' capacity to engage in collective inquiry and produce publishable work. It also requires a less normative approach to the digital equity problem, one that takes advantage of local circumstances and expertise to make contributions to one's community and to other networked communities. The Knowledge Society Network (http://ikit.org/ksn.html) provides numerous exemplars of knowledge creation through the use of the same suite of digital tools.

Informed Strategy

The democratization of knowledge must be pursued at both ends, that is, both in access to and for the creation of knowledge. There is a growing number of Web 2.0 applications and user-created content. It is also important for educational systems to recognize that both teachers and students have the right to produce as well as reproduce knowledge. In areas where there is a lack of content in local languages, teachers, teacher educators, elders, and students may use IT tools to create content that reflects their culture and resident knowledge. A global problem is a growing loss of local languages. Although media and technology have largely contributed to the loss of local languages, they may also be used to help preserve them. In the Four Directions Project (http://www.4Directions.org), for example, a number of indigenous communities had very few fluent speakers of the native language. Teams of teachers, students, and elders worked together using digital technologies to develop audio recordings of the elders and to develop associated books and other materials to help students learn their native language.

Conclusion

This introductory chapter provides an overview of the global challenge of the digital divide and the critical conditions that must be addressed to move toward digital equity. The major issues and challenges also appear and are discussed within specific contexts in each of the following chapters. In a rapidly changing, technology-based, and knowledge-based global economy, it is important to understand where we are now and how far we have to go to reach the WSIS goals of a global information society. As daunting as the task may be, the effects of doing little or nothing to move toward digital equity can only result in the greater social and economic exclusion of people and greater instability across the globe.

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8.2

GENDER AND INFORMATION TECHNOLOGY

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Introduction

There is much literature documenting and discussing the nature and extent of a gender-based digital divide. Before identifying some of the measures that have been taken by schools and other educational institutions to counter this divide, it is important to highlight some of the key issues that have been addressed in this literature.

It is clear from the research literature that there are very different issues and dynamics in the developing world as compared to the developed world. Cultural issues with respect to appropriate gender behavior and attitudes are particularly salient in the developing world. Given these differences, the two cultural settings will be discussed separately at times in this overview.

Overall, it is clear that the gender digital divide is seen mainly in terms of the ways that females are disadvantaged relative to males. There is little discussion in the research literature of programs relating specifically to males and IT. I will return to this point later.

Identifying the Issues – The Developed World

The key issue in the developed world is *how* girls and young women use IT, rather than their access to it. While it is true that females are somewhat less likely than males to have home access to a computer (and less access to the internet if they do have a computer), the gender differences in access are not large. What is more, both males and females have access in school. Virtually all schools in developed, industrialized countries have computers that are available to some extent to students. Given this access, the key differences tend to be in attitudes to computers and the Internet and the types and extent of use by males and females. The focus of much of the research

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and many of the intervention programs seems to be to encourage females into careers involving IT. This emphasis reflects concern about the fact that in many countries, female participation in computer science and related courses has declined in recent years. For example, in Canada, only about 25% of those enrolled in Computer Science and Mathematics career programs were women as of the late 1990s and into the twenty-first 21st century (Hancock et al., 2003).

Looking at attitudes, one barrier to the involvement of females in IT seems to be their perceptions of IT. Various researchers have found that females find computer courses uninteresting and difficult, more appropriate for men (Davies et al., 2000), and leading to careers that do not suit their desire to work with people (Timms et al., 2006). Computer careers are seen as paths for "geeky" men (Bolan, 2000; Timms et al., 2006). The relative lack of female role models in IT-related careers exacerbates this perception (Sanders, 2005). Overall, males tend to have more positive attitudes toward computers, especially in the higher grades of secondary schooling (Filsell and Barnes, 2001; Sanders, 2005).

The effect of the more positive attitudes and experiences of males with IT is that girls and women tend to have lower levels of comfort when working with computers (Sanders, 2005). They also tend to have lower self-esteem (Filsell and Barnes, 2001) and less confidence when working with IT (Bolan, 2000). These feelings can, of course, become a self-fulfilling prophecy (Cooper and Weaver, 2003). Thiessen (2006) presents some intriguing results based on a large nationally representative sample of Canadian youth. He finds that girls tend to underrepresent their abilities in mathematics, even when they take the same advanced courses as boys, and even when they get marks that match or exceed their male counterparts. Some of this is due to what could be termed "gender modesty," wherein males overestimate and females underestimate their abilities in "male-dominate" spheres. However, there are also indications that girls (a) differentiate their skills more and (b) downplay their mathematical skills because, in comparison, they excel in language skills. These findings highlight the importance of using measures other than strictly self-reported ones when estimating IT and related skills.

Gender stereotypes of computers as associated with males highlight these differences (Cooper and Weaver, 2003; Sanders, 2005). The *context* in which learning about computers and their uses takes place seems to matter (Cooper and Weaver, 2003). In many coeducational classrooms, males tend to dominate time on the computer and control of the machine (Sanders, 2005, p. 13). This finding has given rise to various "female only" initiatives to counter this bias.

Identifying the Issues – The Developing World

In the developing world, the issues raised above often come into play. In addition, some issues flow from the gendered division of labor and the gendered expectations placed on females and males in particular cultures.

In many developing countries, a key issue is access to schooling for females. As the UNESCO Education for All Initiative (The World Bank, 2006) recognizes, girls and women lag seriously behind boys and men in terms of education. They are less likely to attend school at all (two-thirds of all children who do not attend any school are females; 97% of these children live in developing countries) (Huyer, 2003). Even if they do attend school, girls in developing countries are less likely than boys to complete their education. These patterns often reflect strong cultural traditions against women obtaining education and participating in formal employment (Leahy and Yermish, 2003; The World Bank, 2006).

There are also barriers within the school. When girls in developing countries are in school there are as many if not more barriers to accessing computers, developing computer skills, and aspiring to careers in computer fields as there are in the developed world. In many areas, there is still strict gender segregation of courses. Those catering to males are more likely to involve computer access and the development of IT skills. As is true in the developed world, there are differences in participation in science and technology, with males dominating these courses. Girls and women have much less access to and, therefore, lower rates of use of IT in the developing world. The women who do use IT, particularly the Internet, tend to be an elite educated urban minority (Huyer, 2003, p. 103; Miliszewska et al., 2006, p. 4). Both education and IT access is much more restricted for females in rural and remote areas of these countries (Hafkin and Taggart, 2001).

Finally, there are huge differences, particularly in the developing world, in terms of postschool expectations for males and females. The effect of many of these forces is that "girls and women are poorly placed to benefit from the knowledge economy," particularly in developing countries (Trattner et al., 2000, p. 1). Given this fact, females have more to gain from programs that serve to enhance access to IT (Hawkins, 2002). This gain can be especially important in rural areas, since "The Internet provides a constructive and uplifting escape from geographic community" (Coleman, 2003, p. 100) allowing poor rural as well as more wealthy individuals to access communities of interest "rather than the compulsory tolerance of people you often do not like forced on you by proximity" (Coleman, 2003, p. 100). In this way, IT can have social as well as economic benefits in rural areas.

Interestingly, some researchers (Charles and Bradley, 2005) have found that where females have more choice in their educational decisions, there is more gender bias. Government practices that restrict choice may lead to a more gender-neutral distribution in computer science classes, assuming that the policies and practices emphasize merit (Sanders, 2005, p. 8).

Why is This Important?

Hafkin and Taggart (2001) highlight the importance of (a) IT as a "potent force for transforming social, economic, and political life globally" (p. 3), (b) IT as particularly important to women, and (c) IT as particularly important to women in the developing world. "Most women in developing countries are in the deepest part of the divide, further removed from the information age than the men whose poverty they share" (Hafkin and Taggart, 2001, p. 3). Without access to this technology, there is the danger that women in the developing world will become even further marginalized than they are. "IT may be even more important for women in developing countries than it is for women in the developed world who have access to an abundance of alternatives" (Hafkin and Taggart, 2001, p. 3). Also, given the traditional barriers to educating women and girls, IT may be one method of delivering education in a way that allows them to continue to fulfill their traditional roles (Leahy and Yermish, 2003), particularly through the use of technology-assisted distance education.

Even within the developed world, the gender gap in IT use and expertise is seen as important and problematic. According to some, IT is seen as "so integral to the everyday practices of both teachers and pupils that it is imperative that the school curriculum focuses on offering equal access to boys and to girls" (Opie, 1998, p. 80). At issue is the concern that "Failure to take elective computer courses at the high school level may limit students' career options, both inside and outside the growing IT field" (Crombie et al., 2000, p. 64). More generally, acceptance of gender-biased career choices and development of IT skills entrenches gender stereotyped interests and assumptions by both girls and boys (Sanders, 2005). While most writers focus on the effect of these attitudes for girls, there are important ways in which they may also affect boys, especially if they do not conform to these norms.

Educational Interventions

Female Only Resources

Given the emphasis on the ways females are disadvantaged in coeducational settings (allowing boys to dominate the computers, accepting the image of computers and computer games as "male," questioning their competence with IT), it is perhaps not surprising that one type of intervention has involved the creation of "female only" environments. There are a number of variations on this theme. One is the creation of "girls only" clubs, workshops, or camps, usually within the purview of the school.

In the developing world, the Peace Corps in Ghana has developed a girls' club with computer classes. According to the teacher/facilitator, when boys were not around, the girls asked more questions, helped each other more and "generally seemed to enjoy themselves a bit more" (Harmon, 2001, p. 11). Similarly, SchoolNet Uganda targets girls-only schools (The World Bank, 2006).

Distance education courses (offered via radio, television, or the Internet) that target girls and women have been found to be effective especially in rural areas in the developing world. Indeed, even within the developed world, females often outnumber males in distance education courses at both the secondary and postsecondary level (The World Bank, 2006). According to one study, females seem to "prefer the privacy of virtual education, with no pressure or fear of embarrassment in front of male peers" (The World Bank, 2006, p. 4).

Some schools have created girls-only computer classes to help encourage females to pursue computer science education and possibly careers, and to try to dispel the stereotypical male image of such classes, and to reduce male dominance of access to IT in classes (Opie, 1998). Proponents for this approach argue that "an all female CS [Computer Science] class can be an effective program when administrators and teachers are prepared and committed to support this approach" (Crombie et al., 2000, p. 72). The all-female class is seen as a safe, nonthreatening environment allowing some of the less assertive females to participate more actively. Some take it as far as having same-sex schools for girls to counter a variety of disadvantages they ostensibly face in mixed schools.

While there is some evidence that these programs benefit girls, it is less clear what the effect is on boys. There seems to be some indication that boys prefer and benefit from being in mixed settings (Cooper and Weaver, 2003). Cooper and Weaver (2003) suggest that schools experiment with voluntary single-sex schools and equally voluntary single-sex classrooms as an option for science, technology, and mathematics (p. 151). Having these voluntary options avoids the charge that the civil rights of one group or another are being violated. However, it assumes sufficient resources and a critical mass of students, teachers, and facilities that would allow such separate offerings. Many jurisdictions, especially those in the developing world, do not have these resources. Indeed, they may be struggling to provide basic IT resources to all students. Separation into girls-only classes assumes one has sufficient numbers of girls interested in a subject to make up such a class. Comparing single-sex to mixed-sex classes within a school with voluntary choice of type of course may, as one researcher notes (Sanders, 2005), mask the important factors at work. Therefore, the lower satisfaction of girls in a mixed class may reflect, not the presence of the boys, but the absence of the girl's friends (since many of them may have opted for the girls-only class).

Ideally, one would have an experimental design with random assignment to test the effects of a particular course or program, or indeed any intervention. The reality is that such a design is impractical in most real-world situations, especially in the developing world.

Female Role Models

Since one of the barriers to females' involvement in IT, particularly courses and careers in IT, appears to be the stereotypical image of those fields as male, one solution is to ensure that girls and young women are exposed to positive female role models in the field (Sanders, 2005). This exposure can be especially important in the developing world where there are often strong culturally driven stereotypes about appropriate roles for males and females (The World Bank, 2006).

Having successful women computer scientists come and talk to female students is often part of the programs of the girls' clubs, described earlier (Condon and McGrenere, 2004). This exposure is seen as particularly important in the high school years, in part to counter the traditional dominance of male teachers of mathematics and science as well as the specific field of computer studies (Davies et al., 2000). Finding role models who are close in age to the girls in the program can increase their impact (National Science Foundation, 2002). As the overview of NSF projects notes, in selecting role models, “It is particularly helpful to find stories of perseverance, and personal stories that focus not just on the science and engineering, but on the people who have been involved in the lives of the role models from girls to adults” (NSF, 2002, p. 17).

Pedagogical Interventions

There are ranges of pedagogical interventions that seek to address the social dynamics of the classrooms in which girls and boys learn IT. These approaches often assume that males and females have different ways of learning – in general and about IT in particular. The usefulness of the interventions is, therefore, predicated on the validity of these underlying assumptions. While some approaches try to address the issue by increasing access to computers and IT-related courses, some argue that specific actions need to be taken to ensure that girls have equal access to the resources that are available (Huyer, 2003).

According to some research (Huyer, 2003; Sanders, 2005), girls prefer a more “hands on” approach to learning and an emphasis on its application to everyday life, for example, how technology fits into the larger social context. Providing this social context and discussing the relevance of computers to the world, as well as clarifying the range of careers (not just a lonely geek sitting in an office cubicle), can serve to counter some of the negative stereotypes of computer world.

Related to the issues of learning styles, given the well-documented fact that boys play computer games more than girls (Garson, 2003), one way some schools have tried to involve girls more with computers is by incorporating more “female friendly games into the classroom. For example one game, Phoenix Quest, has more of a story line and involves a lot of social interactions, attributes that are seen to appeal to girls (Davies et al., 2002, p. 13). Girls are also thought to prefer more cooperative play (and cooperative study environments), sharing a game such as The Incredible Machine side-by-side with another girl (Crombie et al., 2000; Sanders, 2005). Boys tend to be more solitary and competitive and focus more on rapid progress through a game, which mean they finish faster, but they do not necessarily learn more (Davies et al., 2002, p. 14). These tendencies are also evident in male and female learning styles with respect to IT more generally (Crombie et al., 2000).

Those in low-income situations (especially girls and women) often do not have the academic background to take IT-oriented courses. One program, CISCO Networking Academic Programs (Huyer, 2003, p. 106), targets these groups (in both the developed and developing world) with specially designed content to take this lack of academic preparation into account.

Teacher (and faculty – see National Science Foundation, 2002) attitudes are identified as an issue for some (The World Bank, 2006; Crombie et al., 2000; Sanders, 2005). The concern is that teachers pay more attention to boys, and assume that they will be better at mathematics and at courses that require use of IT. Changes to these attitudes obviously require a long-term solution in terms of teacher training and teacher sensitivity to gender issues.

What About the Boys?

It is well established that males are much more likely to drop out of school before finishing their high school diploma (de Broucker, 2005; Ross and Gray, 2005; Shaienks et al., 2001). Further, once they have left they are less likely to return (Looker, 2002; Looker and Thiessen, 2007). It is equally well established, as evident in the research cited earlier, that young men are attracted to computers and, when given the opportunity, tend to dominate access to them. Recent evidence (Thiessen and Looker, 2007) also suggests that students who use IT tend (up to a point) to have higher reading scores. They tend to do better in school and stay in school longer (Martin and Halperin, 2006).

If one puts these findings together, it raises the question of whether the tendency toward male attraction to IT cannot be put to some use. This is not to argue that males should be allowed to continue to dominate access to and use of IT. Rather it is to note that IT can be a tool to increase the engagement of young men with schools. Minimally, it points to a serious gap in the research literature on how IT is being used to engage male students, and on possible interventions that can make use of this technology, targeting males in ways that might be different from programs that target females.

Conclusion

On the basis of this brief overview, what can we say about equity in education with respect to gender and IT? First, it is clear that the issues and, therefore, the approaches are very different in the more developed as compared to the less developed parts of the world. This divide is critical to understanding both what needs to be done and what is being done to address issues of gender equity.

In the developed world, the gender divide in physical access is diminishing. Therefore, the focus of research and of interventions tends to be on general attitudes to and use of IT, and on the low levels of participation in technology-related courses and careers by females. This later issue has sparked a number of interventions to try and encourage more young women to prepare for and enter occupations in science and technology. The other thrust is a more general one to ensure equitable access and use of IT in schools.

In the developing world, access to education is an issue for many girls and young women. When they are able to attend school, they face further restrictions in terms of access not only to the technology but also to science and technology oriented courses, which often target men. These gender divisions are often reinforced and exacerbated by cultural belief systems, as well as income differentials, so that the nature and extent of the gender divide often varies by ethnic, racial, and cultural group. It is not uncommon for the gender digital divide to be more pronounced in the more rural areas of developing countries, areas that often encompass a large proportion of the population. Nevertheless, IT can be and has been used to provide distance education to women (and men) who might not otherwise have access to this education.

Given the differences facing females and males in the developing world, many of the intervention programs designed to increase gender equity focus on broader issues. Nevertheless, programs such as gender-specific computer classes and clubs appear to be facilitating access for at least some young women.

In the developed world, there are a wider range of programs and initiatives targeting gender equity (which, in practice, means increasing access and use by females). These include the following: female-only workshops, websites, courses, clubs, and schools. Female role models, especially those in IT-related fields are used to encourage by example. Other initiatives focus on the *way* technology is used and taught in schools, in order to identify more "female friendly approaches.

Workshops, in-service offerings, and training programs have been designed to modify teacher attitudes to IT. One intended outcome of these initiatives is sensitizing teachers to gender equity issues with respect to this technology.

Further Research

Despite the relative wealth of research on the issue of gender equity and IT, some gaps are evident when we review this literature. While there are too many individual initiatives to provide a comprehensive listing, one recurring issue is the lack of systematic evaluations of the programs. Some programs (unfortunately a minority) do try to evaluate outcomes. However, there are problems of selection and attrition bias. Moreover, the resources (and energy) put into a pilot project can rarely be matched when it is more widely introduced, so the same results cannot necessarily be expected. Nevertheless, the more information on what has been shown to work for whom, the more likely effective interventions can be found.

Despite documentation of the importance of teacher attitudes on student access to and use of IT, there is surprisingly little research on teachers. In particular, it would be important to examine how concerns with gender equity fit in their lists of priorities. It is counterproductive to assume simply that it tops the priority list. The better our knowledge of the challenges and barriers facing teachers as they try to incorporate IT into their classrooms, the more likely we are to be able to make recommendations that will be effective.

Finally, it is important not to totally lose sight of how males use IT, despite their apparent advantages. Not all males have ready access to or feel comfortable with IT, yet it is often assumed they do. What is more, there is some evidence that the general male fascination with technology can be used to advantage to keep in school some of the many young men who dropout. Many areas define these dropouts as a critical issue facing today's youth, and it is one that should not be ignored.

In sum, much research has been done and many programs have been devised to reduce inequities based on gender with respect to IT in education. This brief overview has highlighted some of that research and some of those interventions. Nevertheless, it is evident that, particularly in the developing world, we are still far from reaching the goal of gender equity or of fully understanding the nature of the barriers facing females and males in education, and therefore, far from developing a range of programs that effectively counter these barriers.

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8.3

MEETING THE LEARNING NEEDS OF ALL LEARNERS THROUGH IT

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Introduction

For a learner with a sensory, physical or learning disability, information technologies that are designed correctly can remove barriers to education that the learner would normally experience in a traditional classroom. In fact, when considered from a technological perspective, disability is not an identifying characteristic of the learner but rather a failure of the learning environment to meet the learner's needs. Disability is a mismatch between the learner's requirements and the education offered. Inclusion, then, is a learning environment that will transform appropriately to create the optimal education environment for the individual learner.

To a busy educator within a strained educational system, the idea of personalizing the learning environment for every individual may sound at worst, ridiculous and at best, Utopian; however, with the appropriate technical supports, personalization is feasible. The online system when designed correctly has the capacity to transform and customize educational content. This section will describe the processes and technologies that enable inclusive learning through content transformation and individualized education.

Assistive Technologies

Some learners will already use assistive technologies to access a computer. Screen readers, on-screen keyboards, switches, magnifiers and Braille displays are some examples of assistive technologies that may be used by the learner in the online envi-

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ronment. For inclusion, the first task of the online learning environment is to enable technology-assisted access: learners must be able to use any assistive technologies they would normally use to access the online environment. The online system can accomplish this task either through direct access or indirectly through compatibility with assistive technology. A directly accessible environment is one that provides the necessary alternative means of access as part of the standard environment. Certain assistive technologies such as switches, modified keyboards and Braille displays are difficult to replicate in a standard environment, and in these cases, the environment must be designed to work with these alternative access devices. An assistive technology compatible environment will work seamlessly with alternative access devices as well as with alternative access software such as screen readers. This interoperability is achieved by following interoperability specifications and standards that are available for each computer platform (e.g., Windows, MacIntosh, Unix).

Guidelines and Specifications

Good design is at the core of inclusive educational technology. Guidelines and specifications are freely and widely available to developers and authors to enable interoperability and accessibility of educational technologies. While the moral case for good design is clear, the legal imperative and business case have had the most influence on adoption of inclusive design practices. As governments become more responsive to disability rights issues and the general public moves to a variety of access technologies such as cell phones, PDAs or laptops; device independence, interoperability and accessibility principles have become increasingly important. The following guidelines and specifications are important in the provision of equal access to on-line, computer-mediated education

Accessibility Guidelines of the World Wide Web Consortium

The World Wide Web Consortium (W3C) has developed a number of guideline documents through the Web Accessibility Initiative (WAI, http://www.w3.org/WAI/.) to reduce or eliminate barriers to access of web applications and information. These are as follows:

– Web content accessibility guidelines,
– User agent accessibility guidelines (UAAG),
– Authoring tool accessibility guidelines (ATAG).

These guidelines are frequently referenced in standards documents and legislation and are briefly discussed in the following sections.

Web Content Accessibility Guidelines

A good starting point for accessible design of web applications is the Web Content Accessibility Guidelines (WCAG). WCAG 1.0 (Chisolm et al., 1999) is a stable document and is referenced by most existing legal mandates for web accessibility.

WCAG 2.0 (Caldwell et al., 2006) is under development and should also be consulted by individuals who want to understand web accessibility. Although the 14 guidelines address barriers to accessibility in web content, they can be applied to all digital content. The guidelines cover the following areas:

1. Provide equivalent alternatives to auditory and visual content,
2. Do not rely on colour alone,
3. Use markup and style sheets and do so properly,
4. Clarify natural language usage,
5. Create tables that transform gracefully,
6. Ensure that pages featuring new technologies transform gracefully,
7. Ensure user control of time-sensitive content changes,
8. Ensure direct accessibility of embedded user interfaces,
9. Design for device independence,
10. Use interim solutions,
11. Use W3C technologies and guidelines,
12. Provide context and orientation information,
13. Provide clear navigation mechanisms,
14. Ensure that documents are clear and simple.

WCAG also includes useful techniques and documents that demonstrate how to develop accessible multimedia content. Following these guidelines removes barriers to content and user interface transformation, making it possible to personalize Web-delivered learning resources.

User Agent Accessibility Guidelines

UAAG 1.0 (Jacobs et al., 2002) provide information about ways to design user agents (e.g., HTML browsers and other types of software that retrieve and render Web content (see http://www.w3.org/TR/WAI-USERAGENT/glossary.html#def-content) as well as the supporting documentation for these applications) so that they reduce barriers to access of web content for individuals with disabilities. UAAG 1.0 sets out 12 guidelines each with a priority level and related checkpoint information. The guidelines cover the following areas:

1. Support input and output device-independence,
2. Ensure user access to all content,
3. Allow configuration not to render some content that may reduce accessibility,
4. Ensure user control of rendering,
5. Ensure user control of user interface behaviour,
6. Implement interoperable application programming interfaces,
7. Observe operating environment conventions,
8. Implement specifications that benefit accessibility,
9. Provide navigation mechanisms,
10. Orient the user,
11. Allow configuration and customization,
12. Provide accessible user agent documentation and help.

Browsers and media players that conform to these guidelines have more accessible interfaces and are better able to communicate with assistive technologies.

Authoring Tool Accessibility Guidelines

ATAG 1.0 (Treviranus et al., 2000) provide information to web authoring tool developers about how to design tools that will produce accessible web sites as well as how to design authoring tools that have accessible interfaces. The purpose of these guidelines is to make it easier for web developers to produce accessible content even when they are not aware of or motivated to follow accessibility guidelines and to enable individuals with disabilities to participate in the construction of web content. The guidelines cover the following areas:

1. Support accessible authoring practices,
2. Generate standard markup,
3. Support the creation of accessible content,
4. Provide ways of checking and correcting inaccessible content,
5. Integrate accessibility solutions into the overall "look and feel",
6. Promote accessibility in help and documentation,
7. Ensure that the authoring tool is accessible to authors with disabilities.

Authoring tools that comply with the seven guidelines of the ATAG document can support accessible web authoring through prompts, alerts, checking and repair functions, help files and automated tools. Additionally, the authoring tool will be accessible to authors with disabilities. The goal of ATAG is to encourage development of accessible web content that reaches a broader, more diverse audience as well as enable individuals with disabilities to participate fully in web culture as active creators of content.

The WAI guidelines provide guidance in creating accessible Web content, authoring tools and browsers. The guidelines were originally developed when the Web consisted of static HTML pages, and the assumption was that a single configuration of a Web site must be accessible to all users. The needs of learners differ greatly. It is very difficult to optimize learning for all learners using a single resource or user interface. Given the advance of systems that dynamically deliver content, this is no longer necessary. However, to deliver resources that meet the needs of each individual learner, the resource must be labelled with enough information to choose a resource that matches the learner's needs. In an accessible, learner-centric, distributed learning environment, the WAI guidelines must be accompanied by information that helps determine the suitability of a learning resource for each learner and a description of the needs of a learner. These are described in the following sections.

Metadata

Distributed learning and learner-centric education have become increasingly popular as technology has evolved to enable rapid delivery of rich media content and storage and retrieval of large amounts of information has become more efficient. These learning approaches are supported by more formal learning object repositories, computer systems that store and retrieve educational material or learning objects, and less formal collections of learning resources on the Web. As with any library, a system for cataloguing and referencing the information is a necessary component. For digital resources, this catalogue information is called metadata. There are two popular metadata standards: Dublin Core and IEEE LOM. Dublin Core is widely implemented in the library world, while IEEE LOM was specifically created for distributed learning environments. Organizations and learning resource projects have created their own adaptations or variations of these standards (these include ADL/SCORM, ARIADNE, CENISSEdNA, IMS, PROMETEUS, Cancore and others – http://www.cetis.ac.uk). An excellent reference site for educational metadata standards bodies and organization is found on the Center for Educational Technology and Interoperability Standards web site (http://metadata.cetis.ac.uk/references/ed-met_html). The variety of standards is a reflection of the originally proprietary nature of learning object repositories and the variety of educational approaches served by the repositories. Currently, resource sharing is more widely accepted amongst repositories, and the interoperability and standardization of these metadata systems is critical for wide distribution of learning objects. Wide distribution and resource sharing is also key in providing accessible digital resources to learners. Through resource sharing, educators and learners may select from a wider pool of learning objects, and efforts to make previously inaccessible resources accessible need not be duplicated across competing providers.

Standard metadata provides important information about digital resources that can be used to sort and find resources on a desired topic, at the appropriate level, by trusted authors, in the desired language and media. To achieve optimization of learning environments for learners with disabilities, more information is required about the resource but more importantly, there needs to be a standard way of describing learner needs.

Matching the Resource to the Needs of the Learner Through Metadata

Two specifications that extend standard metadata and add to the information used to describe learners, collectively called “AccessForAll”, have been developed within the IMS Global Learning Consortium. These specifications are now becoming international standards. The “AccessForAll” specifications are making their way through the adoption process as ISO/IEC (International Organization for Standardization) international standards for accessible e-learning as ISO 24751 (http://jtc1.sc36.org). The “AccessForAll” specifications/standards provide a common language for describing resources and a common language for specifying learner needs and preferences. Compliant learning applications can use these two descriptions to match resources to learner needs.

Resource Accessibility Metadata

One side of the match is the description of the learning resource. An important addition to the metadata standards is Accessibility Metadata. Accessibility metadata elements provide information about the resource such as the senses needed to process the resource, the ability of content to transform in ways necessary for accessibility and the availability of equivalent resources (Jackl et al., 2004). Accessibility Metadata divides learning resources into two categories: (1) primary resources and (2) equivalent alternatives. Primary resources are the original resource created by the author. The metadata that is collected for these resources is kept to a minimum to reduce the workload on the author. Information collected includes the following:

1. A statement about the flexibility of the presentation and control of the resource. This information is in the output of common accessibility validators (systems that check web code for potential accessibility issues based on WAI guidelines and create accessibility report files in Evaluation and Repair Language or EARL and the Resource Description Framework or RDF statements) and, in a well-designed authoring tool, will be automatically attached to the resource.
2. A statement about the mode of access that indicates whether vision, hearing, text literacy or touch is required to use the resource.
3. A URL for any known equivalent alternatives such as a caption file for a video resource.

Equivalent or alternative resources replace or supplement primary resources to address an accessibility issue that a learner may have with the primary resource. Equivalent or alternative resources communicate the same learning objective or lesson as the primary resource, but do so in another modality that is accessible to the learner. For example, a supplementary alternative would be captions of audio or descriptions of visual elements of a video. An alternative resource may be a graphical representation of a concept that is text-based in the original. For example, a map of time zones could replace a tabular representation of the same information. This alternative would suit learners who benefit from visual content.

Through accessibility metadata, resources that are accessible or can be made accessible are easily identified and utilized by educators, learners or the learning management system they employ.

Learner Needs and Preferences

A learner using a learning management system to access electronic resources may provide identifying information to the system, which helps the system provide the correct courses or resources for that learner. This learner information package (LIP) has been extended for accessibility in a specification known as Accessibility Learner Information Package (ACCLIP) (Norton and Treviranus, 2003). Through ACCLIP, the learner can express preferences for how the resource should be displayed, how the resource should be controlled and what form of content should be delivered. These preferences can be applied to both the standard system and available assistive technologies.

Learners can specify their access preferences through a "preferences wizard" that guides them through the three preference groups. Learners respond to a number of preference questions by selecting provided options. For example, under content, learners can express a preference for text alternatives to images; under display, learners can express preferred text and background colours and, under control, learners can select alternative navigation preferences such as keyboard navigation. The ACCLIP that is created can be read by any AccessForAll compliant systems such as a Learning Management System (LMS), a personal Web portal, a digital repository or a multiuser workstation in a library, a computer lab or an Internet café. These preferences may then be stored on a network computer or made portable via storage on a smart card, USB key, disc or other portable memory device. In this way, learners can take their preferences with them from computer to computer or from one LMS to another.

An important approach of the ACCLIP specification is that it is not disability-centric. Instead of assuming preferences based on stated disability, the ACCLIP specification assumes that any learner will have different access preferences depending on any number of factors: their location, bandwidth, access device and subject of study to name a few. AccessForAll is about individualization and customization for the learner in a way that benefits all learners. This approach is especially relevant given the convergence of information technologies. Any of the access preferences stated above could equally benefit an individual with low vision or an individual using a cell phone browser.

ACCLIP is the corresponding specification or match to Accessibility Metadata: a learner is able to specify accessibility preferences like text alternatives to image content, and the appropriate resource that meets these preferences can be identified by the corresponding accessibility metadata.

Transformation

We have defined inclusive learning technology as a learning environment that will transform appropriately to create the optimal education environment for the individual learner. Transformation of content based on user preferences is a powerful mechanism for inclusion and presents exciting possibilities for a system of education that effectively meets the needs of learners as individuals rather than "typical learners" only. Given implementation of the metadata specifications that have been discussed in the previous sections, transformation as a way to create accessible content is carried out by the system in a way that is transparent to the learner. Once a learner has specified preferences, content appears according to these specifications every time the learner uses the system. This transformation process is explained in the following section.

First, the learner creates a personal profile that includes information relative to the ACCLIP element. For example, does the learner prefer images, text, condensed presentation, captions, dictionaries and/or large font? Once these specifications are made, then the system will present the content to the learner's specifications whenever possible by matching the ACCLIP to the accessibility metadata of the content and/or by using styling mechanisms such as cascading style sheets (CSS) to adjust the presentation of the resource. In some cases, the system will find accessible versions of the content or even alternative but equivalent content.

For example, a geography lesson on the six time zones of Canada might show a map of the country with colour-coded regions and vertical lines indicating each of the time zones. For a learner who has difficulty with graphical learning, an alternative might be text representation that states the provinces in each zone and the difference of the time from Greenwich Mean Time. The only barrier now is learning objects that will not transform due to poorly designed code or lack of accessibility metadata or due to lack of equivalents.

Reusable Learning Resources

A key component of an inclusive educational system is the reusable learning object (RLO). The RLO is a learning resource that may be repurposed or used in a variety of contexts (Wiley, 2000). The following is an example (Treviranus and Roberts, 2005) of a learning object that is reused and repurposed.

Ryan, a tutor with Frontier College, an adult literacy programme, works with a learner Jim who would like to learn to use on-line banking, since the trek to the bank is difficult during the winter. Jim needs assistance in learning to use the interface, reading and comprehending the information on the screens, paying the bills that he receives regularly and keeping track of his balances. Ryan uses the on-line learning design structure to specify the overall learning plan and the individual objectives. These he then populates with the actual screens that Jim will encounter at each step, his own clarifications of components of the screen, step-by-step instructions on how to accomplish each task, ways to recognize and correct errors and instructions on how to verify that he has been successful. This completed assembly object or lesson is checked into the repository.

When Jim views the lesson, the service delivers the assembly object according to Jim's previously expressed learner preferences. His preferences specify where, when and how clarifications, instructions, help and self-evaluations will be displayed and how feedback will be given. Because Jim has a learning disability, all text will be read to him when he points to it using his head pointer. Because he has difficulty in pointing accurately, all active areas of the screen such as buttons or input fields will be enlarged.

Mary is working with a learner, Fernando, who uses the same bank but has a different set of bills to pay. She checks out the lesson and replaces the learning content pertaining to the unwanted bills with information about bills relevant to Fernando. Because Fernando is learning English and is more conversant in Spanish, Mary adds a Spanish translation of the clarifications and instructions, help and feedback. Mary also remembers a very simple-to-use accessible calculator that she has previously seen in a linked repository. She searches for it and adds a link to it. She then checks this new version of the lesson or assembly object into the repository. When Fernando accesses the lesson, he reads and listens to both the English and Spanish text.

Judith is a trainer with the bank referenced in the lesson. She has just created an educational video about on-line banking. She includes verbatim captions of the video and then links the indexed segments of the video to the appropriate points in the learning plan. When Jim next views the lesson, he can choose to reinforce what he is learning with the instructional video.

Alfred is a tutor working with a class who need to access the on-line banking service of another bank. He views the lesson and decides that he likes the structure of the learning plan and many of the generic explanations, but he must replace the screen shots and detailed instructions. After making these changes, he checks the new version of the lesson or assembly object into the repository.

In this way, the original learning object is modified, enhanced and utilized by a variety of educators who save valuable time and resources through the reuse and repurposing of the learning object.

Moreover, a RLO may have layers for increased or decreased complexity. Imagine three different students viewing the same math package on an online system. One student grasps the concept quickly and shows mastery, another shows average skill while the third exhibits some difficulty with the concept. A RLO would enable each

Math Word Problem That is Changed Based on Skill Level

1. Concept: Pythagorean theorem

Skills: algebra

Complexity: simple

A cat has climbed up a tree and cannot find the way back down. You have a ladder that is 6-ft long. The ladder just reaches the cat when the base is placed 3 ft from the tree. How high did the cat climb?

2. Concept: Pythagorean theorem

Skills: algebra, measurement, problem-solving

Complexity: moderate

A cat has climbed up a tree and cannot find the way back down. You have enough wood to make a ladder with four rungs 1 ft apart. The bottom of the first rung is 1 ft from the bottom and the bottom of the last rung is 1 ft from the top. The ladder just reaches the cat when the base is placed 3 ft from the tree. How high did the cat climb?

3. Concept: Pythagorean theorem

Skills: algebra, measurement, problem-solving, visualization

Complexity: difficult

A cat has climbed up a tree and cannot find the way back down. You have one 2 × 4 that is 16-ft long, and carpentry supplies. You make a ladder 1-ft wide with four evenly spaced rungs. There is no wood left over. The ladder just reaches the cat when the base is placed 3 ft from the tree. How high did the cat climb?

Sentence Components Used to Compile Sample Questions:

The Problem:

(1,2,3) *A cat has climbed up a tree and cannot find the way back down.*

Given Variables:

1. *You have a ladder that is 6-ft long.*

(1,2,3) *The ladder just reaches the cat when the base is placed 3 ft from the tree.*

Solve for Variables:

(2) *You have enough wood to make a ladder with four rungs 1 ft apart. The bottom of the first rung is 1 ft from the bottom and the bottom of the last rung is 1 ft from the top.*

(3) *You have one 2 by 4 that is 16-ft long, and carpentry supplies. You make a ladder 1-ft wide with four evenly spaced rungs. There is no wood left over.*

Solve for:

(1,2,3) *How high did the cat climb?*

student to work on math problems that are suited to their learning needs. The student who masters the concept may be challenged with additional concepts while the student experiencing difficulty may receive some additional simplified problems. The following shows how a math problem may be altered based on skill level.

This transformation of the content based on skill level is well within the capacity of educational technology. A system that utilizes content packages and learning objects can dynamically reconstruct the content presented to the learner based on preferences as well as demonstrated skill. The following demonstrates how this layering of complexity is achieved.

The idea is not that the educator creates multiple levels for every math problem they might teach, but rather that within a learning object repository, educators share math problems such that the educator may select multiple math problems that are appropriate to their lesson plan or curriculum requirements. Educators should experience a freeing of their time through learning object repositories allowing them to devote previously unavailable time to creating a greater variety of rich learning resources, thereby making it possible to optimize learning for a greater diversity of learners.

Content-Free Activity Templates

In addition to content-based learning objects, repositories may also house content-free activity templates. These templates harness the interactive capacity of technology-assisted instruction without requiring the educator to have programming expertise.

For example, activities such as debates and web quests have the same structure regardless of content. Templates that adhere to accessibility guidelines regardless of the content that is subsequently added make it possible for educators to create inclusive activities without any knowledge of guidelines or of the programming languages normally required to create an interactive application.

Accessibility in Practice

The Adaptive Technology Resource Centre has to date implemented the concept of customization and preference matching in two projects: The Inclusive Learning Exchange (TILE) (www.inclusivelearning.ca) and TransformAble (http://culturall.atrc.utoronto.ca).

The Inclusive Learning Exchange

TILE developed at the University of Toronto includes an authoring tool that supports educators in developing accessible curriculum that may be shared and re-purposed. Accurate metadata is critical for the success of the repository as well as the success of the goal of inclusion. The TILE authoring tool guides educators through critical metadata entry through plain language dialogues and lifts the burden of complete metadata entry by automating the process wherever possible. In the same way, learner preferences that match ACCLIP metadata are gathered from the learner through a series of “check-box” dialogues. The learner need only enter these preferences once, however, they can be modified at any time. TILE is an example of inclusive learning technology and demonstrates how inclusive learning can be supported through adherence to standards and specifications, sharing of content and provision of accessible interactive activities.

TransformAble

As part of the CulturAll project, the ATRC developed TransformAble, an application that applies the “AccessForAll” international interoperability specifications to allow websites to transform the presentation of online resources so that they are personalized to each individual user’s needs. For example, if a user who is visually impaired logs into a site linked to the TransformAble Web Service, according to the user’s previously stated preferences, the size of the text will be increased, the colours of the background and text will be adjusted to enhance the contrast, and important information will be relocated within the view. TransformAble consists of three parts: (1) StyleAble, (2) PreferAble and (3) SensAble. StyleAble is a component that generates customized style sheets based on a user’s stated preferences, allowing the user to control the overall appearance of the site, including the font size, face, foreground colour, background colour, highlight colour and link appearance. User preferences are created through a tool currently called PreferAble, which can be added to any workspace. SensAble aggregates resources to create a resource that matches a user's stated preferences. In February 2007, TransformAble was integrated with Sakai (http://sakaiproject.org/), a widely used, community source, online collaboration and learning environment.

Challenges

The Utopia of customized learning is technically within our reach, yet there are still significant barriers to overcome. Approaches and attitudes must shift to match the technological advances and to meet the moral imperative of education that is accessible to all learners.

Paradigm Shift

Fundamental principles of "AccessForAll" technologies are that content is sufficiently independent of its presentation and structure, that the presentation and structure can be transformed, that the resource is sufficiently structured so that content in different media can be separated and supplemented or replaced, that the learner can navigate through the content and that the method of controlling interactive components is flexible. For educators and content developers, thinking about the content before the presentation and thinking of content as three layers that include structure, control and presentation represents a paradigm shift in how they conceive of creating educational curriculum. This separation, however, enables transformation of the appearance of the content in ways appropriate to the platform or learner's specifications and also facilitates substitution of alternative but equivalent content.

Open Source/Open Access

Accessible learning object repositories and educational applications can only go part way in insuring an inclusive education if proprietary textbooks and formats are used. Copyright and other intellectual property measures create barriers to equal access and the necessary adaptation of content needed to make it accessible. When textbooks and required readings are open access, these barriers no longer exist. In the same way, interoperability between alternative access systems and computer or web applications is much easier to achieve when the applications are open source. The open source community, its motivations and interactions serve as a model for removing barriers to access that result from protective and proprietary measures.

Conclusions

It is recognized worldwide that access to learning is a right. Educators have long acknowledged that learners learn differently. All learners benefit from flexible learning environments that match their individual learning needs and context. The malleability of digital resources, the flexibility of online learning environments and the ease of pooling, sharing and repurposing learning resources make individually optimized learning an achievable goal. These learning environments accommodate human diversity and benefit all learners.

They accommodate learners with disabilities, learners with alternative linguistic backgrounds, learners with specific cultural preferences, or any learner or learning context that does not fit the hypothetical norm. Important prerequisites for this individual optimization are a critical mass of diverse transformable learning resources and an educational culture open to sharing, which values individual potential and focuses on learning goals rather than presentation.

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8.4

CRITICAL SUCCESS FACTORS IN MOVING TOWARD DIGITAL EQUITY

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Introduction

Understanding critical success factors for the access and use of information technologies to improve learning is crucial to move toward digital equity in education. According to the Educational Reform Network of National Institute for Community Innovations (2003), the goal of *Digital Equity (DE)* is to provide equitable access to learning technology resources and opportunities for all learners. More specifically, achieving digital equity involves the following critical factors: providing educators and learners with access to technology resources, culturally responsive content and high quality content, preparing and upgrading skills of educators to assure they are skilled in using these resources, and providing opportunities for students and educators to create their own content (McLaughlin, 2003).

Before digital equity can evolve, basic access to information technology must flow to or be diffused into educational systems and communities within poorer societies. Besides access to technology, Resta and Laferrière (2008) discuss other dimensions of digital equity that need to be in place for moving toward digital equity. They distinguish the following five dimensions:

– Access to hardware, software and connectivity to the Internet.
– Access to meaningful, high quality, culturally relevant content in local languages.
– Access to creating, sharing, and exchanging digital content.
– Access to educators who know how to use digital tools and resources.

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- Access to high-quality research on the application of digital technologies to enhance learning.

These dimensions are used in this chapter to develop a better understanding of the factors and strategies that are evidenced in a number of exemplary efforts to move toward digital equity in diverse contexts.

Example Cases: Initiatives that Have Made Progress in Moving Toward Digital Equity in Different Global Contexts

In many countries, technology is simply not available. Norris (2000) in *The Worldwide Digital Divide: Information Poverty, the Internet and Development*, places emphasis on the "global dimension and the diffusion of the new technology worldwide from Azerbaijan to Zambia (p. 1)." Although the Internet offers the potential to revolutionize education and the quality of life for developing societies and especially for reducing the familiar North–South divide, that potential has not yet been realized. There is, however, a growing number of governmental, private sector, and nongovernmental initiatives that are focused on helping to bridge the global digital divide, reducing information poverty and the growing inequalities between the information-haves and have-nots (Norris, 2000).

In this section, four examples of educational technology initiatives and partnerships are presented to help identify factors that have contributed to the success of the efforts in moving toward digital equity. At the heart of each story is the human element that demonstrates how learners' performance was enhanced through the application of IT in different contexts around the world. Each case was selected because it is supported by significant attention to evaluation of the initiative including documentation of the challenges faced by each initiative and the strategies that enabled them to overcome the barriers to achieve value-added integration of IT to improve education.

Literacy and Technology: Developing Nations Move Toward Literacy to Lift Learning Through Storybooks

Organizations: Sunshine Online, READ (Rural Education and Development – South Africa), World Conference on Literacy.

In South Africa, a reading program, *Sunshine Online*, was designed to create a positive impact on reading and language skills of primary school children in disadvantaged schools with the help of IT. Staff members from READ, a South African NGO (nongovernmental organization) closely involved in literacy programs were trained to use the program. This ongoing project was created in the African Union as part of the movement toward the use of African languages. The development of the year of African languages was supported in some ways by the World

Bank in dissemination of the information for the year of African Languages. The initiative involved the development and dissemination of a combination of online resources, books, software, and teacher instruction for involved and interactive reading. In instances where there is limited or no connectivity, teachers are able to use the books and software. In instances where teachers have online access, they are able to use online resources as well. The little books produced by the project were translated into 11 South African languages. This initiative responds to a critical need, as Africa is one of the most linguistically diverse continents in the world. According to the United Nations Educational Scientific and Cultural Organization (UNESCO), the project exemplified the statement by the United Nations Secretary General that "The time has come to move beyond broad discussions of the 'digital divide' – the gap in communications technology between rich and poor – to outlining a specific plan to give people access to the technologies they need and the education to use them effectively" (United Nations Secretary General Kofi Annan, November 6, 2005). In using their own languages, people can add content that is meaningful to them, as well as their own literature (Bracey and Culver, 2003).

Evaluation

The focus of evaluation within this initiative was on the impact of the books on student learning. Eight months after the project started, both quantitative and qualitative measures were used to measure the results for pupils in the eight Book Flood schools. The learners were thoroughly assessed with tests of reading, writing, listening comprehension, speaking, and use of English structures, and the results were compared with those of pupils in the control group schools on the same tests. Twelve months later, all groups were again administered a comprehensive set of language tests to establish whether the changes observed in the first year were persistent. Testing was carried out by a team of assessors, recruited mainly from the Ministry of Education and the University of the South Pacific and trained by the researchers. The whole set of research findings can be found in Elley et al. (1996). The hypothesis to be tested, which was that a greatly enriched online reading program would improve the pupils' English language growth, was clearly supported by the evaluation results. Preliminary results of formative evaluation showed unexpectedly that there was little difference between the overall mean scores for the Shared Reading and the Silent Reading groups, on most tests. However, in the summative evaluation, a class-by-class analysis revealed, amongst other things, that the pupils who gained most were those whose teachers followed the Shared Reading program as intended. The data showed that pupils who were exposed to a large supply of high-interest illustrated story books, and given activities that ensured that they actively processed the text, daily, produced an unusually rapid rate of growth (Elley et. al., 1996, p. 1). Available at http://www.literacyonline.org/products/ili/webdocs/ilproc/ilprocwe.htm.

Success Factors

The following features of the initiative contributed to increasing *access to meaningful high-quality content, culturally relevant content*:

– *Culturally relevant content*. This initiative represents an exemplary approach to provide high quality, culturally relevant content in local languages to teachers and students through the use of traditional media such as books as well as through computer software and online resources. The initiative also provided the materials and resources needed for enabling teachers to effectively use the books in their instruction.
– *Early intervention*. The project also underscored the importance of helping developing early literacy as a foundation for further educational development. In the world of global communications, it is critical to ensure that we bridge the digital divide between developing and developed countries through the introduction of IT into elementary school systems where early learning begins (Papert, 1980; Fuehne and Phillips, 2004). Research shows that the new direction in early education is to help teachers become skilled in teaching in new ways that will ensure that all children have the opportunity to learn with the integration of technology. However, to reach this goal in the twenty-first century, teacher educators, teachers, and opinion leaders must be clear on the importance of helping schools and teachers to use new learning tools and strategies and to understand what constitutes developmentally appropriate education for young children, especially when it comes to technology in early childhood education classrooms (Pittman, 2003; van Scoter, 2008).
– *Large-scale curriculum linkage*. The Sunshine program represented large-scale curriculum effort designed to address the needs of learners across cultures and a wide geographic region. In thousands of Third-World schools across the globe, pupils are required to learn in a language different from that of their homes. In other words, they were expected to learn to read and write in a second or third language. For such children, the usual problem of lack of resources and lack of competent teachers is compounded by a lack of exposure to the target language (Elley, 1992; Haddad et al., 1990). The Sunshine Online project provides an example of an approach that may be used in other parts of the world facing similar challenges.

In addition, the initiative assured *access to educators who know how to use digital tools* by explicitly providing *teacher training* for teachers to use the materials and resources in their educational practice. The introduction of print and technology linked together with professional training for teachers proved very successful and is now used in many countries as the basic method for teaching literacy (Block, 2001; Ngoma, 2004). In particular, this approach has proven to be very successful with learners for whom English is a second or foreign language.

Jordan Uses IT to Integrate Water Concepts in the National Curriculum Organizations: Water Efficiency and Public Information for Action, the Jordan Ministry of Water and Irrigation, the Academy for Educational Development launched with funding from United States Agency for International Development, and a number of international corporations.

The Jordan Education Initiative introduces teachers and students in Jordan to the digital age through an ambitious e-learning and Internet education program. It represented an example of the ways that public and private partnerships can create lifelong learning opportunities for people around world. The Jordan Education Initiative (JEI) is an ambitious e-learning project developed through a partnership between the Kingdom of Jordan and Cisco Systems that is poised to be an educational model that may be adopted by many other nations.

JEI got its start in 2003 at the World Economic Forum (http://www.weforum.org/en/index.htm), when Cisco CEO John Chambers challenged companies to work with government and nonprofit organizations to create a focused educational program in one country. As the 2005 World Economic Forum convened in Davos, Switzerland, News@Cisco asked Cisco vice president of corporate affairs, Tae Yoo, for a progress report on JEI and about her views on the next phase of the program. Subsequently, the Jordan Education Initiative (JEI) was created through the innovative development of partnerships with a large number of organizations, including international companies, local companies and government ministries, international donors, and nongovernmental organizations. The initiative supports Jordan's "Educational Reform for a Knowledge Economy" program (http://www.jei.org.jo). Among the objectives are curriculum reform, teacher training, adoption of IT as an enabler of learning, and the improvement of IT infrastructure in schools. One of the key goals of the initiative is the empowerment of local communities through the use of IT as a powerful instrument for the dissemination of skills, knowledge, and capabilities required for economic and social advancement. The project is focused on the need to tackle water issues in the Jordanian school curriculum based on the national need to protect diminishing water resources in a semiarid region of the world. With the present level of resource consumption, Jordan's fragile environment has reached the limits of its carrying capacity. The goals for teacher training under the JEI are to enable discovery learning in Jordanian schools, to serve as a seedbed for innovation and change, and to support educational reform efforts. Moreover, there is a desire to change attitudes, beliefs, and the understanding of education through the introduction and appropriate use of IT. The goals are action- and result-oriented, and the primary focus and point of intervention is the teacher.

Evaluation

The Jordan Education Initiative (JEI) involved a public–private partnership that aimed to improve education in Jordan through effective use of IT, while at the same time building local IT industry capacity and creating a model of reform for other countries (McKinsey and Razor View, 2005).

As stated earlier, objectives of this project included curriculum reform, teacher training, adoption of IT as an enabler of learning, and the improvement of IT infrastructure in schools. Data collection included both quantitative and qualitative data to measure the results using benchmarks directly linked to the objectives of this highly successfully project (McKinsey and Razor View, 2005). The results of the evaluation reported that over 30 global and local partners from public and private sectors actively engaged in this project to create a comprehensive e-curriculum in Math for grades 1–2 now in use in schools. To support this change in the delivery culture of mathematics, full deployment of technology and training to six Discovery Schools (initial startup schools in pilot) was done, and 44 schools will be added in the future. This project has widespread impact that was evidenced by the World Economic Forum, which sponsored similar initiatives in three countries. Discussions continue with more than 12 countries in the region that are interested in an expansion of the model.

Success Factors

In the JEI initiative, the following dimensions proposed by Resta and Laferrière (2008) were taken into account:

– Access to meaningful, high quality, and culturally relevant content.

Broad-based community support. Jordan is a water-poor country with the lowest rate of water consumption per capita in the world. Demand for water far exceeds the supply, and the country has continuously sought to increase its water supply to meet the rising demand. Yet a bigger responsibility lies with the Jordanian citizen to conserve water. By educating the young, one-third of the country's population could be reached, but it was first necessary to provide teachers with the tools and professional development opportunities.

Collaboration. Environmental education in Jordan schools started through the ambitious initiatives of the Royal Society for the Conservation of Nature (RSCN – http://www.rscn.org.jo). Environmental education was implemented in the national Jordanian curriculum. The Ministry of Education, in collaboration with UNDP and partners, developed an environment conceptual framework.

– Access to educators who know how to use digital content and tools.

Professional development linked to curriculum goals. The objectives of the curriculum were based on "Teach-Explore" Stages. Teachers were furnished IT training and resources in workshops on water at the appropriate curriculum levels using a train-the-trainer model.

Broad-based support to develop basic technology skills. According to the McKinsey and Razor View evaluation reports (2005), broad-based support for the project included the Ministry of Education, community groups, schools, individuals, and organizations. A group of 111 teachers was trained on the use of IT and the new e-curricula in the classroom. Scopes of work for the lifelong learning track and local IT assessment were developed, and a program management office was created. In 2005, the Jordan Pilot Expansion Program launched in cooperation with the Jordanian Ministry of Education trained 1,000 teachers in using technology to provide quality learning in classrooms.

Scalability and timing. Scalability refers to expanding the Jordan Pilot initiative to a larger audience following the initial rollout. After successful implementation of a smaller project, a team of "master trainers" was formed in the Ministry of Education. The Intel and Worldlinks programs were rolled out to all teachers in the JEI schools (Discovery Schools). Specialized training on e-curricula and change management was also provided to teachers and principals in many schools. However, further time is required to roll out appropriate training to all teachers, principals, and administrators involved with the Discovery Schools.

– Access to hardware, software and connectivity to the Internet.

Large-scale implementation. The JEI water project represents one example of the effective use of IT to address an urgent national need while also making a large-scale effort to move toward digital equity by taking steps toward connecting all of the country's public schools, developing an e-learning platform, and implementing an ambitious e-government plan to connect to a larger society. These efforts are part of Jordan's goal to build a knowledge-based economy enabling its citizens to become entrepreneurs and participate in industry and the global economy.

Global Teenager Project Creates Virtual Network of Over 250 Secondary Schools in the Developing and Developed World

Organizations: The Global Teenager Project, Mindset, The International Institute for Communication and Development, New Partnership for African Development.

The International Institute for Communication and Development (IICD) launched the Global Teenager Project (GTP) in 1999. IICD is a nongovernmental organization in the Netherlands, which seeks to promote the potential of IT to support economic development (http://www.iicd.org). The Johan Kooij Fellowship (JKF), also based in the Netherlands, provides funding. As of February 2006, the GTP's management operations moved to Mindset (www.mindset.co.za), a South African nongovernmental organization whose mission is to create locally relevant learning content and facilitating channels for delivering these to schools in South Africa and Africa via a developing partnership with the eSchools Initiative of the New Partnership for African Development (NEPAD). A goal of NEPAD is to equip all African primary and secondary schools with information technology resources such as computers, and to connect them to the Internet. The Global Teenager Project is a virtual network of over 250 secondary schools in both the developing and developed world. Its goals are to improve the quality of secondary school education by introducing schools to the exciting new applications of IT, to enhance learning, and to promote intercultural awareness and sensitivity by opening up regular, lively classroom debates in a safe, structured environment.

The Global Teenager Project enables classroom discussions to "go global." It gives secondary schools a kick start in the use of IT and provides students with a safe, structured environment in which to discuss global issues. The project's Learning Circles represent Web-based, virtual environments to support intercultural exchange and learning. The GTP is made up of two complementary activities: The Learning Circles (Riel, 1992) and the Understanding Diversity Project. The learning circles represent a global, school-based collaborative learning initiative, which takes place twice yearly and provides structured opportunities for groups of learners from different countries and different schools to share ideas and discuss issues related to a particular topic or theme using IT. A project facilitator coordinates each learning circle and is responsible for putting the technical systems in place to support the students.

Evaluation

The Global Teenager Project publishes reports quarterly. Instrumentation used in the evaluation can be found on the project's website along with at least four quarterly reports (http://iicd.org). The 2006 report provides information about the expansion and success of the project. It reports that the project has already turned the GTP vision into an everyday reality for 6,000 pupils from 30 countries, and new schools are constantly asking to join. The report indicates that, since it was first launched in 1999, the GTP has grown from three classes to over 250. The impact of the project has resulted in a rapidly expanding virtual network of secondary schools in both the developing and developed world and an upcoming generation of information-literate, knowledge-oriented, culturally aware individuals. There remains room for improvement – especially in ensuring that all coordinators participate in on-line discussions. Although coordinators reported some improvements, many continue to struggle with technical, process, and pedagogic issues.

Success Factors

– Access to meaningful, high quality, culturally relevant content.

Cultural diversity. The project's objectives are to promote cultural understanding and awareness among secondary school learners in different countries. These activities help to bridge cultural and digital divides, enhance learners' IT skills, and provide an opportunity for structured engagement with teachers and learners from different countries in such a way that new and innovative ways of using IT in educational institutions can be modeled for teachers.

Linked to curriculum goals. The Learning Circles content is formed by the participants themselves, and, as such, reflects local contexts. Schools can experiment with new, different, and exciting approaches to both learning and teaching, while sharing their findings with other schools.

– Access to sharing, and exchanging digital content.

Interactive e-learning communities. The Learning Circle concept enables a high level of interaction within learning communities. By expanding the learning environment from a fixed site to the fluid realm of the Internet, the Learning Circles have many benefits that include intercultural exchange, life-long learning skills in critical thinking, teamwork, and independent learning, using IT media. The Learning Circle promotes alternatives for educating women who have previously been marginalized from interaction, without disrupting cultural traditions.

– Access to hardware, software and connectivity.

Collaborative design of digital materials. The success of the project lies in its simplicity. It provides schools with a *tried-and-tested, inexpensive, easily sustainable IT package* that is locally owned. Everyone involved in the Global Teenager Project is looked upon as an equal stakeholder. Feedback is actively encouraged from all those taking part in the learning circles, which enables the GTP staff to constantly improve and refine the project.

Building a Multi Stakeholder Alliance for IT in Education in Latin America

Organization: Fundacion Cisneros, DIRECTV Latin America, Cl@se, and Simon TV from the Universidad Simón Bolívar.

In December 2003, the United Nations organized the first meeting of the World Summit on the Information Society in Geneva (http://www.itu.int/wsis/index.html). The main goal of the conference was to define an action plan for promoting the use of IT in meeting the Millennium Developmental Goals. Among the items established in the Action Plan for bridging the digital divide are two that are relevant:

– The integration of the IT in education, and
– Training in the use of IT.

Actualización de Maestros en Educación (AME) can be translated as "Updating the skills of schoolteachers." AME is an interactive program designed for the basic education of teachers in Latin America, using television and e-learning. AME contributes to the qualitative improvement in the training of teachers in specific areas of knowledge and values. It also facilitates the contact of teachers with new forms of knowledge and information and allows their participation in virtual communities capable of promoting innovation in educational processes. In 2006, the program was running in Argentina, Colombia, Costa Rica, Ecuador, Guatemala, Mexico, Panama, Peru, Dominican Republic, and Venezuela.

Five universities from Latin America and Spain generate the didactic content in two forms: a television mini series with duration of 6–12 h of programming and written material that is posted on the virtual classroom of the Web page: www.ame.cisneros.org. The teachers form groups of two to three persons and watch the classes in the educational centers and at the same time, do the activities posted on the virtual classroom, with the support of the university professors who created the content.

The courses include topics that are academic as well as topics that help the teacher do their job in the context where they are working and compatible with their culture, their sensibility, and their local language. The courses last for ~8 weeks and are offered in all of Latin America in two periods per year so that each period consists of two courses. It is estimated that the groups have to work for 100–140 h to complete the courses.

Evaluation

Since 2003, several formative evaluations have been performed. More recently, the summative evaluation began in September 2006. Evaluations relating to learning objectives, integrity of the program, and more were conducted. The evaluation included a focus on input and output using both qualitative and quantitative measures. The products of the learning activities were evaluated according to a scale established by the University that evaluated the courses. Input and Output Evaluations included performance data for each participant individually (micro) and as a group (macro). The evaluation was to measure the knowledge acquired by the students throughout the IT-infused course taught by teachers trained in the AME program. The evaluation also attempted to determine factors that can affect learning, such as the structure of the course, the learning activities, and the materials and tools used.

In addition, evaluations related to the internal efficiency of the Program. The focus included performance evaluations, managerial diagnosis of the AME Program, and directionality by leadership. Evaluations relating to the external efficiency of the Program included evaluations of the didactic materials: the programming quality, quality of support material, course design, schedules, quality of videos, applicability in the classroom and the community. The complete report is available in multiple languages at http://www.ame.cisneros.org/ProgramaAME/Presentacion/QueEsAME.asp.

Success Factors

– Access to educators who know how to use digital materials.

Private–public partnerships. The AME program is currently implemented in 163 educational centers, which can be individual schools or training centers for teachers. The training centers support university extension programs. Each center has a person that supervises the implementation of the program. Various training centers can form a network and this happens when, for example, a university implements the program in different parts of a country. In these instances, a coordinator supervises the centers that form the network. The AME partners include governments, private enterprise, academia, and civil society. Funding from The Fundación Cisneros has provided the necessary resources to finance the program and provides the strategic planning as well as the administrative support that assures its transparency and functioning.

– Access to hardware, software and connectivity.

Access to audiovisual content. Satellite space from DIRECTV Latin America provides for transmission of the audiovisual content, decoders, and satellite connection to the teachers training centers.

Success Factors for Moving Toward Digital Equity

The analysis of each of the above cases shows how the dimensions proposed by Resta and Laferrière (2008) can be realized in educational initiatives, conducted in various parts of the world and of a different scope. Table 1 provides an overview of the way these projects made the dimensions concrete.

Table 1 Overview of success factors related to dimensions for digital equity

	Projects			
Dimensions for digital equity	Technology and Literacy South Africa	Jordan Education Initiative	Global Teenager Project	Updating the Skills of School-teacher – Latin America
Hardware, software connectivity		Large-scale implementation of e-learning environment	Collaborative design of digital materials	Access to audio-visual content from one source
Meaningful, culturally relevant content	Culturally relevant content in local language	Collaboration between curriculum stakeholders	Provides opportunities for cultural diversity	
	Early intervention	Broad-based curriculum support	Link to local curriculum goals	
	Large-scale curriculum linkage			
Creating, sharing, and exchanging digital content			Interactive e-learning communities	
Educators who know how to use digital tools and resources	Teacher training to integrate technology and printed materials	Professional development linked to curriculum goals		Private–public partnerships to realize teacher training
		Broad-based support to develop teachers' IT skills		
High-quality research on the application of digital technologies	All practices were evaluated to inform decision makers on progress and areas for improvement			

The cases presented above exemplify four key factors cited by Foster and Snider (2000) that determine whether IT adds value to education as learning tools:

1. The quality of the technology resources that teachers and students can access in multiple languages. That is, to what extent are teachers and students provided with access not simply to digital learning tools but to those most capable of enhancing teaching and learning.

2. The quality of uses to which educators and students are putting these technology resources.
3. The adequacy of teacher education that prepares educators to use digital learning technologies to bridge the educational and diversity gaps.
4. The adequacy of exposure to technologically proficient role models.

Based on the analysis summarized in Table 1, seven areas of attention are formulated that may contribute to moving toward digital equity. These areas of attention are as follows:

– Realizing curriculum-relevant content: link to local curriculum goals, and designed with relevant curriculum stakeholders.
– Information and dissemination planning: assuring community support and planning for support during dissemination.
– Appropriate intervention: planning for interventions that are just-in-time for the target group.
– Cultural diversity: providing opportunities for cultural diversity appropriate for the local setting.
– Ongoing support for teachers to advance beyond basic skills.
– Easy and sustainable access to the technology architecture/infrastructure.
– Research-based practices to inform decision makers.

Attention to the seven areas may be important to ensure digital equity dimensions, policies, and procedures that are consistent with the needs of targeted individuals, schools, educational systems, and society. While many ministries and departments of education throughout the world include technology guidelines for students and teachers as a part of "core content" requirements, political mandates are not always effective in influencing teacher practices and education reform without appropriate investment in infrastructure, technical support, and professional development systems. The cases presented, however, clearly demonstrate that educationally significant initiatives can be taken that may help regions, nations, and local communities to move toward digital equity. The factors that contributed to the success of the exemplary cases in this chapter are compiled in Table 1. The table may be used as a checklist to critically review or gauge the success of any project that seeks to move toward digital equity.

Future Trends and Challenges in Moving Toward Digital Equity

To derive benefits from information technology, the challenges of connectivity and access to technology, hardware, and software must be addressed. The Pew Internet and American Life Project and Elon University conducted a study of the perceptions of 1,286 experts of the pervasiveness of the Internet in the next 10 years in education and in our physical environments. The results of the study indicated that there was little disagreement among experts that broadband adoption will grow and that broadband speeds will improve, resulting in more online communication in the next decade (Fox et al., 2005).

According to Rogers and Shukla (2001), IT is creating a dramatically different type of future society, particularly in the nations of Latin America, Africa, and Asia. They predict that potential for communication and social change has only begun to be realized in certain nations and by selected segments of their populations. Similarly, initiatives such as the One Laptop per Child (http://www.laptopical.com) also offer the potential of making computer power more widely available at lower costs. Such trends offer hope that both bandwidth and technology resources will continue to be more accessible to those presently experiencing digital exclusion. As demonstrated in all of the cases, however, the most critical factor in the power of technology to enhance learning remains the teachers' knowledge and skill in the use of IT (Resta and McLaughlin, 2003). Moving toward digital equity will require educators who can match IT and content to specific educational, social, and economical goals appropriate to a given society to realize the full potential of information technologies. Such a strategy must respect the need to build new knowledge on the existing cultural and knowledge foundations that for decades have supported schools and communities to meet human and economic needs. For example, in the Jordan Water Curriculum Project, leaders and teachers modeled usage of appropriate technologies by using IT to develop a teacher-training program to serve as a seedbed for innovation and change to bring about educational reform within meaningful contexts. This empowering strategy led to a model for Jordan about how to use IT to address both a social and economic problem facing their educational system and the government. It is clear that role models are needed at many levels for effective systemic change, but may be different based on the socioeconomic situation and cultural underpinnings. This type of situational role modeling extends beyond the development and demonstration of technological skills to include knowledge bases that generate strategies to extend economic return or yield changes in productivity for a society. For educators to become technology-proficient role models in education, they must become intelligent coaches equipped with a level of technology know-how and knowledge to offer learners instructional environments with new pathways to learning and self-assessment. Research on the diffusion of information technologies suggests that the access-divide, which has received the most attention to date, may eventually be replaced by a learning-divide, a content-divide, and by other types of divides through which the Internet will continue to offer advantages to certain individuals and disadvantages to others (Rogers, 2001). To achieve technology-proficient role models in education to avoid such a direction, educational leaders must prepare teachers differently, provide professional development, and recruit teachers skilled in pedagogy and in using technology in their instruction.

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8.5

THE RELATIONSHIP OF TECHNOLOGY, CULTURE, AND DEMOGRAPHY

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Introduction

Technology has contributed both to the loss of indigenous culture and empowered indigenous peoples to create their own culturally relevant content. We present examples and issues related to the application of IT to cultural preservation initiatives including cultural mapping and the role of cultural heritage institutes in digital repatriation. We close by considering how to balance local control with access to intellectual content in a manner that is respectful of cultural protocol.

Historic Information on Incorporation of Technology by Indigenous Peoples

Indigenous world view is a way of living that balances individual desires and societal needs, present concern and future impact. Today, indigenous peoples are striving to retain their indigenous world view while accommodating and employing IT.

Jojola (1998) observes that in discussions on the impact of technology on community, "mainstream society has relegated Native communities to the background"

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(p. 5). This illustrates the way indigenous peoples have been excluded over time. Some aspects of this treatment reflect racist stereotypes about Native peoples. Even those who claim to hold indigenous cultures in respect may prefer to relegate tribal peoples in a cherished romanticized past. Maintaining this illusion necessitates that tribal communities remain in sheltered, primitive conditions. Tribal cultures sought out and adopted new technologies at various rates throughout history. Some of these technologies fed intertribal competition. Those who had access to key trade routes had first choice of new products such as cookware, sewing implements, and decorative items such as beads. These communities then absorbed these technologies and gave them their own stamp. Today, indigenous peoples adapt IT to serve their needs.

This discussion brings up questions essential to understanding the relationship between technology and culture. What is culture? How is culture lived? What does it mean to be an indigenous person? How is technology impacting indigenous cultures now? How will it impact indigenous culture in the future? Amidst these questions, Nakata (2002) posits that:

> One thing is certain in all of this. Indigenous knowledge is increasingly discussed by all as a commodity, something of value, something that can be value-added, something that can be exchanged, traded, appropriated, preserved, something that can be excavated and mined (p. 283).

It is in this terrain of counter forces, of technology as aide and visionary tool and technology as the next generation of colonizer, that we next discuss the concept of tribal sovereignty.

Indigenous Peoples as Members of Sovereign Nations

While tribal governments deal most directly with local and state governments, their status as self-governing sovereign nations is not well understood. Howe (1998) offers a definition of tribal sovereignty that encompasses four aspects: (a) spatial or a geographic connection to the land, (b) social or personal identity, (c) spirituality, including morality and ethics, and (d) experiential, including involvement in ceremony and cultural observances. This view of sovereignty supports the notion of indigenous world view. The limits of tribal sovereignty, however, are still subject to federal policies that exclude tribal nations from the political independence accorded to other nations (Pritzker, 1999).

The international standing of indigenous peoples is even less understood even though "it is at the international level and within the United Nations that the best hope for long-term protection of indigenous peoples may lie" (Quesenberry, 1999, p. 103), and it is at the international level that indigenous peoples are starting to be recognized.

The World Summit on the Information Society (WSIS) in 2003 was a two-phase United Nations (UN) sponsored event about information and communication. The idea of culturally appropriate ITs was endorsed by the indigenous caucus at WSIS. There, indigenous peoples discussed obstacles and shared ideas for overcoming them. Some challenges to achieving worldwide indigenous participation in a technology-based future included "lack of basic community infrastructure, limited access to modern technologies and the urgent need for gender and age-sensitive capacity building" (United Nations Permanent Forum on Indigenous Issues, 2003, p. 1).

Intellectual and Cultural Property Rights

Just as tribal sovereignty expresses the determination of indigenous communities across the globe to govern themselves, so too these communities have asserted their intellectual and cultural property rights to protect community ownership of their traditional knowledge. Hansen and VanFleet (2003) define traditional knowledge as "the information that people in a given community, based on experience and adaptation to a local culture and environment, have developed over time, and continue to develop" (p. 3).

Numerous declarations of indigenous peoples' rights have placed cultural and intellectual property rights alongside the sovereignty as a fundamental liberty. The Mataatua Declaration on Cultural and Intellectual Property Rights of Indigenous Peoples, for example, statesthat "Indigenous peoples of the world have the right to self determination and in exercising that right must be recognized as the exclusive owners of their cultural and intellectual property" (Commission on Human Rights, 1993, p. 1).

Article 31 of the UN Declaration on the rights of indigenous peoples was adopted by the Human Rights Council in June 2006. The specificity of the UN Declaration owes itself to repeated exploitations of traditional knowledge by governments, pharmaceutical and biotech companies, anthropologists and other academics, to name only a few. The UN declaration also addresses two distinct but related motivations for protection of cultural intellectual property: the right to control the dissemination of traditional knowledge and the right to develop and profit from products of traditional knowledge. Many indigenous communities have specific rules governing what information may be shared and under what circumstances. Researchers, tourists, and entrepreneurs alike have flaunted these conventions when recording or disseminating cultural knowledge. At the same time, information – given freely or stolen – has generated and continues to generate great wealth for these same external entities while the indigenous communities that generated the information receive little or no benefit. Furthermore, the ease of access, the speed of dissemination, the increasing number of users, and the growing sums of money also raise the stakes indigenous communities risk for losing.

Although many have raised objections to indigenous communities' efforts to protect and preserve traditional knowledge, citing the many possible scientific and technological advancements for the free flow of information, indigenous communities have not been advocating a monopoly on their cultural production, only that the "*first* (emphasis ours) beneficiaries of indigenous knowledge… must be the direct indigenous descendants of such knowledge" (Commission on Human Rights, 1993, p.1). Ironically, much of the argument for restricting the flow of indigenous cultural information rests on the belief that if nothing is done to protect traditional knowledge, there will be no new traditional knowledge to share; without a check on the flow of traditional knowledge out of indigenous communities, the communities may not be able to sustain themselves.

What Are the Relations Between IT and Indigenous Cultures?

This section traces some of the problematic issues balancing arguments against using IT with the opportunity of IT in supporting indigenous cultures.

Does IT Erode Indigenous Culture?

Indigenous communities need to engage in intensive discussions about the potential impact of IT on their cultures. There is great concern, especially among elders, about the impact of technology on children.

> Concerns about the impact of IT on youth also extend to the possible ways IT can affect brain development and learning styles: "People whose minds have been strongly influenced by interaction with artificial intelligence can end up wanting and expecting everything to happen right away, and they can have trouble understanding patterns of information that unfold slowly or goals that need to be pursued long term" (Goes in Center, 2001, p. 124).

Elders are concerned that IT can alter verbal communication and memory constructs: "Technology doesn't help you build your memory skills the way that our people learned songs and dances and learned about the culture…" (Enote and Scott, 2005, p. 136). Technology imposes another format of storytelling that "may undermine traditional storytelling and visual modes" (Leuthold, 1999, p. 195).

> Technology that erodes culture also can erode safety by coming between people and the land: "Looking back at my earliest childhood, there was hardly anyone getting lost, but as the years went by, people kind of started using the snow machines and kind of moved away from using the dog sleds, the dog teams, and we had more incidents of people getting lost" (Enote and Scott, 2005, p. 135).

Technology can also disrupt traditional modes of learning "because the actual biological, cultural, and social backgrounds of netizens are indeterminate or easily falsified on the Internet, the respected position elders and wisdom keepers should be accorded is often usurped by unscrupulous imposters" (Howe, 1998, p. 23). Along with shifts in education, communication patterns are demonstrated in a fear of overdependence on technology and its use as a poor substitute for experience and interpersonal contact: "Indians need, perhaps far more than non-Indians, to step outside of technology and away from the machines, to remember who we are and what are the natures of our relationships to this world and to each other" (Two Horses, 1998, p. 42).

As we mentioned earlier, tribal communities fear not only of the ingress of danger through technology but of the egress of culture from the community to the larger world. Cultural protocol limits some knowledge even within communities. Tribal knowledge may be framed by gender. Children's education may also be timed and structured to come about in conjunction with ceremony. Open access to such information may serve to undermine traditional ways of passing on knowledge.

> Others warn Native people that technology is a new form of assimilation. Delgado explained that Native peoples might associate IT with other instruments of cultural appropriation, describing technology "as a product of the corporate western mind; we do not know that the sacred was part of the thought process that produced these objects. For some Native people, this concept, being surrounded by the nonsacred, goes against the very tenets of Native life and thought" (Christal, 2003, p. 80).

In Kamira's view, technology means Maori are even more vulnerable "in areas of further colonization, legally unprotected ownership of knowledge and information, unsupported views about collective guardianship of data, and a high risk of compromising the integrity of knowledge and its distribution" (Kamira, 2003, p. 466). She observes that IT can be a contemporary expression of colonization. Native peoples are especially concerned with image capture and use. Given how they have been presented visually in the past, "it seems inevitable that many Indians will object to the way outsiders portray them and will desire more control over the visual depiction of their culture" (Leuthold, 1999, p. 194). Finally, not all individuals can easily participate in technology. Their use is predicated upon literacy and, in many cases, physical accessibility.

Can IT Efforts Support Indigenous Culture?

Jojola (1998) suggests that in using technology to expand their potential, Native communities could also have an advantage over majority communities, "primarily because they do not talk about community, they live it" (p. 6). Others stress the need for Native peoples to participate in the creation and use of digital technology: "if Indians are to be full participants in the modern world, then they must stake out a place in cyberspace" (Howe, 1998, p. 26). With proper planning, IT can assist indigenous communities. Indigenous communities can unlock this potential when they interpret and apply technologies in ways that support cultural perspectives.

Another argument for the use of IT at the local community level is the sense of confidence and accomplishment achieved by those who learn to use new technologies. Some posit that local video production can bring strength and "foster cultural and political autonomy… Indigenous media both document traditional forms of symbolic participation –powwows, naming ceremonies, feasts – and emerge as new participatory forms in their own right" (Leuthold, 1999, p. 213). Tribal use of technology does not need to result in cultural erosion: "We can make contributions to science and to the general well-being of the earth, while at the same time strengthening and validating our own systems of culture (information management), just as our ancestors used to do" (Goes in Center, 2001, p. 125).

Community Mapping Projects

The Native view of homeland transcends generations and time. As Howe explains, "The social dimension of tribalism relates land and identity to the concept of 'people hood,' a unique tribal identity differentiated from other tribes and from individual Indian persons" (Howe, 1998, p. 22). Traditionally, tribal communities delineated homeland territories through stories, family histories, and ceremony. Over time, large-scale mapping efforts were imposed on indigenous communities as part of colonizing processes. These efforts often ignored traditional knowledge because they were aimed at depriving Native peoples of their lands and resources. Mapping in and of itself was a representation of cultural loss. This section identifies some specific projects employing cultural mapping techniques.

Tribal communities are now employing multiple simultaneous processes to gather and triangulate data to arrive at a new cartography that brings about a community-centered discussion of geography. Indigenous mapping initiatives include broad representation from tribal officials, school-age children, and educators to scientists, artists, photographers, and attorneys. "Such maps are generated in the course of conversations within communities and travel over the territory. They show local names, traditional resources, seasonal movements and activities, and special places" (Poole, 2003, p. 13). A key feature of cultural mapping initiatives is incorporation of Native language, especially in renaming geographic places. A Kootenai tribal member emphasized this primacy of language, noting as follows: "Without the language, who cares about the maps?" (Enote and Scott, 2005, p. 172).

Poole (2003) describes community mapping technologies as follows: "each is an opportunistic and pragmatic combination of high and low technologies and involves community members to varying degrees" (p. 14). Such approaches include technologies, such as Global Positional Systems (GPS) and Geographic Information Systems (GIS) along with oral history methodology, archival study, audio and video recording, and three-dimensional modeling as strategies for mapping their lands using science to acknowledge traditional land use as steps to protect the land, and preserve and demarcate its indigenous history.

The process results in a variety of products, both tangible and intangible. Intangible products included deep discussion, cross-community connections, intracommunity coalition building, and reflection of identity and tribal history. In Australia, for example, tangibles are "galleries, craft industries, distinctive landmarks, local events, and industries" while intangibles include "memories, personal histories, attitudes, and values" (Clark et al., 1995, cited by Young, 2004, p. 5).

Early cultural mapping collaborations took place in various locations around the world – Africa, Central America, Indonesia, and South America. The Tumucumaque Mapping Project in Suriname was critical in preventing the loss of rainforest land (Amazon Conservation Team, http://www.amazonteam.org). One project involved four indigenous communities from 2000 to 2004. These included the Kashunamuit community from Chevak Village in Alaska, the Santa Clara Pueblo of New Mexico, the Confederated Salish and Kootenai Tribes of Montana, and the Native Hawaiian people in the village of Häÿena on Kaua'i. Each community designed new maps instilled with a strong sense of community ownership of the process and the land. For the Cup'ik Eskimo community of Chevak, cultural mapping was a way to document the tradition of subsistence living, especially fishing. Mapping in Hawaii led to documenting the history of a public park, the Limahuli Garden and Preserve, as a step toward restoring ponds, taro cultivation, and the development of a learning center. Cultural mapping to the people of Santa Clara and the Confederated Salish and Kootenai Tribes of the Flathead Nation became part of the effort to recover tribal lands. Their activities led to the first International Forum on Indigenous Mapping in 2004.

Other regional efforts at remapping focused on reverting to original place names. In the end, "The challenge now is having these maps accepted as legitimate outside indigenous communities" (Enote and Scott, 2005, p. 13).

IT and Use in Indigenous Language Recovery

When tribal communities attain economic stability they first attend to basic social services such as housing, healthcare, services for elders, maintaining roads, and supporting governance. At the same time, they strive to retain and strengthen their cultural uniqueness within the pressures of contemporary life. Indigenous languages are key elements among these expressions of cultural uniqueness.

One aspect of colonizing governments was repression of indigenous cultural expression, especially oppression of indigenous languages. As a result, many indigenous languages around the world are threatened and likely to exist only in historical form unless strong language revitalization initiatives are exerted. Among Native communities, the Māori and Native Hawaiian communities are recognized for taking steps to ensure that their languages are alive and spoken especially by younger members of their communities. In these communities, tribal schools are leading the way in language revitalization. After several decades of concerted effort at language recovery, one out of four Māori, some 130,000 individuals, now speak their language (Te Puni Kōkiri, 2002).

Maori language is an official language within Aotearoa/New Zealand. There is a parallel education system with curriculum taught in the Maori language from a Maori pedagogical perspective. This ranges from K-12 and tertiary institutions: A Maori radio station (http://www.irirangi.net/), and a Maori Television station (http://www.maoritelevision.com/) that supports the Maori language. There are also an increasing number of websites that reflect the bilingual nature of Aotearoa/New Zealand: Te Kete Ipurangi (http://www.tki.org.nz/) and Te Ara (http://www.teara.govt.nz/mi) have a vast range of Maori language content online, designed to support the growing Maori immersion education sector. Videoconferencing has also been used to connect Maori language schools with specialist teachers. These initiatives integrated the elements of an online classroom via videoconferencing, teacher laptops and associated IT professional development, and the enhancement of school-based IT infrastructure.

Hawai'i is an appropriate place to support indigenous languages as it is the only state government within the United States that legally endorses two languages. All public schools offer content on Hawaiian culture, and in over fifteen schools courses are taught in the Hawaiian language. Attention to Native Hawaiian language studies extends through postsecondary education where the University of Hawai'i at Mānoa's College of Languages, Linguistics and Literature offers a certificate in Hawaiian and in other Indo-Pacific languages and the country's only 4-year degree in Hawaiian language and a master's degree in Hawaiian (University of Hawai'i at Mānoa, 2004). The Kamehameha Schools, private schools open to Hawaiian students, host Hawaiian language lessons online in streaming videos available in both low-bandwidth- and high bandwidth files (Kamehameha Schools, 2006). Libraries and cultural heritage-centered initiatives are also supporting language recovery. ALU LIKE ("Working Together") is a nonprofit organization founded in 1975 to assist Native Hawaiians gain self-sufficiency (ALU LIKE, 2004). In 1985, ALU LIKE founded the Native Hawaii Library.

Approaches used to study indigenous languages are generally subject to approval and sanction by tribal governments. In some tribal communities, such as the Pueblos of Santa Clara and Santo Domingo in New Mexico, USA, tribal officials have decided that study of their traditional languages must follow only oral transmission models. These communities are often intact culturally, and confident that immersion and mentoring training options will ensure language life. Tribes that allow the use of interactive technology in teaching or reinforcing indigenous languages acknowledge that IT "has the immediacy and flexibility to present and reinforce learning about the relationship between written symbols and the spoken word" (Jacobs et al., 1998, p. 54).

Other communities are exploring other approaches to stabilize their languages. Some of these approaches include using creative arts and traditional storytelling. The Indigenous Language Institute sponsors technology training conferences designed to assist local communities in using technology to produce materials to support their indigenous language recovery initiatives. The University of Arizona is also the summer home of the American Indian Language Development Institute (ALDI), which assists local grassroots language programs (American Indian Language Development Institute, 2006).

There are now many local examples of indigenous use of technology to support indigenous languages, though much remains to be done to organize and coordinate these efforts on a regional or larger scale. Some tribal communities, often in conjunction with academic linguists, are developing electronic reference works such as dictionaries, grammars, curriculum guides, and textbooks to aid in documenting and teaching the language. Many programs involve elders since they are likely not only to have retained aspects of the language but may also know the cultural protocols associated with language use. These resources are especially appealing to tribal members living at a distance from their homelands.

IT and Use in Developing Culturally Responsive Curriculum and Teaching Practices

A multilayer curriculum model consisting of outcomes, interactions, and formats was developed by Downes and Zammit (2001, p. 122) (Figure 1). As indicated in their framework, the curriculum model requires both new pedagogical practices and curriculum changes. The learning materials as content are presented in different formats such as texts, visual, aural, and multimodal texts. Students' learning outcomes

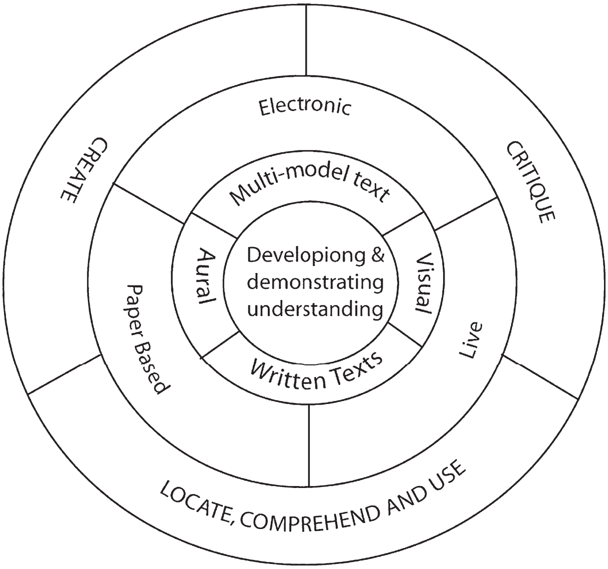

Fig. 1 Downes and Zammit's curriculum model

are observed by their abilities to create, critique, locate, comprehend, and use learning materials. Downes and Zammit emphasize that students' learning competencies in "the digital age" must be multifaceted. Downes and Zammit's approach identifies several important components of education in digitally supported learning environments. The roles of instructors and learners are particularly important: instructors must be facilitators, monitors, and consultants while learners must be engaged by learning materials and must initiate most activities.

Downes and Zammit's curriculum model can be enriched by Cajete's learning styles of Native students for indigenous communities. Cajete's model is a cycle of "being, asking, seeking, making, having, sharing, and celebrating" (1994, p. 23). We can see some similarities between the models of Downes and Zammit, and

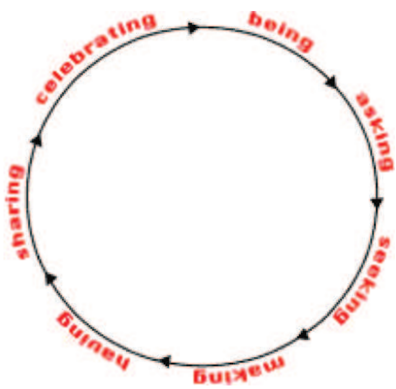

Fig. 2 Cajete's model

Cajete regarding the learning process and can integrate Cajete's indigenous cultural characteristics into Downes and Zammit's digitally supported model. The Alaska Native Knowledge Network (ANKN) is a good example of this integration. The Network has developed a set of curriculum resources to illustrate how "indigenous and Western knowledge systems can be brought to bear in schools through a balanced, comprehensive and culturally aligned curriculum framework adaptable to local circumstances" (ANKN, 2006).

Cajete (1999) points out that "Traditional Native American systems of educating were characterized by observation, participation, assimilation, and experiential learning…" (p. 27). Such a curriculum governs meaningful learning activities and assists Native students to connect themselves to local communities and environments.

Museums and Cultural Heritage Centers and the Use of IT in Digital Repatriation

The Smithsonian's National Museum of the American Indian (NMAI) defines repatriation as follows:

> The process whereby specific kinds of American Indian cultural items in a museum collection are returned to lineal descendants and culturally affiliated Indian tribes, Alaska Native clans or villages, and Native Hawaiian organizations. Human remains, funerary objects, sacred objects, and objects of cultural patrimony are all materials that may be considered for repatriation (NMAI, 2006, p. 1).

This definition outlines relationships among indigenous communities, museums and cultural heritage centers, and material culture. However,the relationship between museums and Native material whose material culture they house, study, and display has not always been cordial. Brumbaugh notes that this tension "is not entirely undeserved. Museum curators traditionally have seen little need to consult with members of the cultures they displayed and promoted …" (Brumbaugh, 1999, p. 220). These differences are likely explained by variations in viewing the cultural object. "A museum endows an object with importance because it represents some kind of cultural value… Indian people who have lived with objects, on the other hand, bring a different perspective to museum collections" (Kidwell, 1994, p. 14). The Native perspective connects cultural objects to a way of life, belief, and tradition.

Native peoples can collaborate on digital repatriation initiatives by building them along indigenous models of learning. Roy and Larsen (2002) described an application of Cajete's indigenous learning styles in the creation of a virtual library of education resources for preservice teachers at a tribal college. Following their example, digital repatriation must consist of the identification of indigenous communities, the needs of the community members, appropriate tools and resources for the needs, and continuous interactions through the digital creation. These considerations are echoed by Seales and Landon's digital museum project in Puertorriquena culture (Seales and Landon, 2005).

While emerging digital technologies bring new ways to acquire, represent, and display museum collections, indigenous community members must perceive the accuracy of the digital content.

Indigenous communities need to express their concerns not only for physical objects but also for their digital copies as well as for digital-born original objects. Seadle (2002) identifies three facets of intellectual property issues and indigenous cultures: law, technology, and permission. A common scenario for these three factors is that who can give permission for using digital technologies to collect indigenous cultures and activities? Furthermore, who can permit digital copies to be disseminated? Those obstacles must be addressed. Worcman (2002) points out that collaborations are needed to create digital cultural resources. She emphasizes that collaborations must help indigenous communities acquire access to digital technologies and the Internet. Meanwhile, digital cultural resources must have a grassroots approach to be accepted and used by indigenous communities.

Tribal communities can work with museum staff to create new models of museum practice. In the United States, tribal schools and the National Museum of the American Indian partnered to produce virtual online exhibits combining digital images of objects and panoramic photography with interpretive text. As a result, children acquired technology experience, information literacy skills, and knowledge of other indigenous cultures, and experienced presenting their work at professional meetings. Christal found that virtual museums helped improve the existing relationships between tribal and nonindigenous communities (Christal, 2003).

One of the potential benefits of a virtual museum is the opportunity to bring together artifacts that have been separated from their contexts. Thus, technology has the ability to reassemble cultural materials and place them, at least digitally, in their original contexts. Constructed locally with culturally specific information, such virtual libraries are progressive steps toward creating an international indigenous virtual museum (Bearman and Trant, 1998).

A Final Word: Cultural Protocol and Balancing Local Control and Access to Intellectual Content

Howe observes that "Tribalism respects the certainty that individuals have differential access to special powers and that some knowledge is proprietary or to be revealed only to certain people or only after proper preparation" (Howe, 1998, p. 23). This is in opposition to the communication patterns in cyberspace that demand instantaneous responses to requests. Christal (2003) found that tribal communities involved in virtual museum exhibit development relied on elders to determine what was sharable with the outside world and what needed to be restricted to tribal community use. This chapter has presented several contexts in which indigenous peoples are employing IT to preserve, share, and interpret their cultural expressions. These efforts are conducted in the maelstrom of challenge and opportunity. Even when electronic resources are ample and consistent, IT project partners must create processes that respect the local tribe's sense of etiquette and propriety. Above all, cultural protocol must be learned and respected so that IT applications might be steeped in cultural tradition and respectful of indigenous world view.

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8.6

GLOBAL PARTNERSHIPS ENHANCING DIGITAL AND SOCIAL EQUITY[1]

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Shrinking World: Global Responsibility

The United Nations (UN) framed the Millennium Development Goals (MDGs) (UN, 2005) as a global strategy for focusing energy into areas of most need around the world. As part of that process, the UN has concentrated its international resources on the issue of using information technologies to guarantee a spreading of the "capital" that comes from technology use. In creating the UN ICT Task Force, the UN focused on the more equitable use of information technology for improving the educational, social, and economic well being of developing populations. The Taskforce promotes partnerships between public, private, nonprofit, and civil stakeholders (Bracey and Culver, 2005) with the aim of ensuring that benefits derived from access to IT assist in reducing the gap between those who use technology and those who do not.

In describing the focus of the Global e-Schools and Communities Initiative (http://www.gesci.org/) as putting IT at the service of education in developing countries and the means by which the MDGs are to be achieved, Kofi Annan (2005) suggested that similar approaches represent the process by which indigenous people in the developing world are empowered. There appears to be no argument against this presumption in the literature. There is, however, a need to recognize ways that potential collateral benefits for the developed and the developing world can be added to this process.

Two-way learning benefits for global partners are described in the following pages. This chapter describes an attempt to connect a development project in Kenya with a local children's conference in Sydney to capitalize on the synergy contained in bringing the two together. It is undertaken as an example of the type of thinking necessary for teachers for the future to be successful in dealing with issues of partnerships, access, and digital equity considerations in an informed and technology-rich global learning environment. It represents the kind of learning event that needs to happen more frequently in classrooms around the globe if digital and social equity issues are

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to be addressed by the next generation. Before exploring those partnerships, however, exploring the impact that interactive technology use can have on the redefinition of the roles associated with learning today is a worthwhile beginning.

The Potential of Technology in Redefining Access to Learning Opportunities

It is possible to capture the asymmetrical impact of the information age by suggesting that there are two kinds of people in this world: those who use technology and those who do not! (Bracey and Culver, 2005; Tongia, 2005). Such a statement clearly defines the boundaries of global social and digital equity provisions in the twenty-first century. The world is divided into those who have access to technology and those who do not.

Those who "do" technology have immediate access to the world's knowledge bank regardless of where they are, or when they want to access it. For these learners, the sum total of the repository of human knowledge, the "global commons of human knowledge" (Breck, 2004, p. viii), is at their fingertips! Those who "do" technology have the ability to communicate and interact with any other person on the globe who "does" technology regardless of where in the world they are. Those who "do" technology are capable of living in the twenty-first century, of contributing, of benefiting from the rapid doubling of the world's knowledge base, of competing, of collaborating, of becoming part of ever-changing networks, partnerships, discussions, resource pools (Friedman, 2005; Peters, 2003). They are served by powerful assistants that are wireless, ubiquitous, pervasive, and digital (Friedman, 2005), and which allows them to be mobile, virtual, and personal at their whim, and with partners and collaborators in any corner of the globe! Those who "do" technology are able to share in the power that comes from unfettered access to knowledge, to others, and to the "capital" that resides in "doing" technology.

In other parts of the world, the majority of those who do not "do" technology often do not have the choice. Therefore, by inference they do not enjoy the power afforded by those with immediate, just-in-time access to knowledge, or access to others. They are, by definition, forced to live in another century, not the one we are in. They may not be able to compete. They cannot be up-to-date. They do not benefit from having their own share of "technology capital" and worse, this lack of technology capital emphasizes the impact of not being able to share in other "capitals" – in the social capital and in the cultural capital that derives from knowing and being known in Breck's (2004) terms of being heard. They are constrained to work in an environment where they are virtually blindfolded and forced to work with outdated definitions of such concepts as "partnership," "communication," "globalization," "competition," "place," and "team" (see Friedman, 2005). The majority of those who do not "do" technology are "not" those who comfortably choose not to, but those who do not have the choice.

Under these circumstances, is it legitimate for teachers or teacher educators anywhere around the globe to "choose" not to "do" technology when it is available, not to encourage global social responsibility in their learners (Gibson, 2007), not to be aware of or adopt some level of ownership or responsibility for rectifying this lack of awareness on the part of all learners, not to learn to understand and tolerate the differences and diversity associated with a twenty-first century existence? Those who learn in this way are cognizant of the potential of partnerships, of collaborating, and of learning how to learn by collaborating across borders, boundaries, and cultural differences using the technologies of the day to achieve local learning goals at the same time as engaging with other learners anywhere in the world (Bracey, 2005; Breck, 2004; Friedman, 2005; Gibson, 2005, Gibson, 2007 in press; Peters, 2003). With these technological and cultural connections, learners with these experiences in their backgrounds are more likely to carry with them deepening understanding and tolerance of the differences and diversity of life in the new millennium and make more appropriate decisions in a global context than their forebears.

The world is changing and transforming rapidly in most places. Friedman (2005) talked about a leveling of the playing field that had occurred for those who were able to "do" technology. He described how individuals could compete effectively and successfully with corporations in any number of business enterprises and service provision industries because of their use of technology. He echoed the entreaties of Breck (2004) who claimed that access to the "global commons of knowledge" was within reach for every individual on the planet if the political will existed to make it happen. Claiming that by giving everyone a handheld device capable of connecting, communicating, and accessing knowledge when it was needed, Breck believed that ignorance and separation around the world would cease and that those populations disenfranchised by dictatorships and terrorist threats would no longer be subjugated. In their book, Technology and Resistance, De Vaney et al. (2000) confirmed this belief by portraying a series of authentic case studies, where, in each case, disenfranchised people around the world were able to free themselves from the tyranny of others through the contextualized use of a variety of technologies. Breck's philosophy, she admitted, had far to go before it realized the goals she claimed it capable of achieving. What she did not yield on though was the need for all individuals to take responsibility for change in this direction. Among her target populations were teachers!

Others have also focused their attention on teachers. For example, in simple network science terms (see Barabási, 2002; Breck, 2004; Siemens, 2005), the simple act of placing learners in the very centre of a dynamic network – a learning web – by providing each with a device capable of communicating and connecting would, according to these writers, redefine the very nature of authentic and engaging learning. In this way, learners would own the process, and learning decisions would be contextualized by those who could most benefit from them and who were most affected by them. It would become the role of the teacher, and by inference the teacher educator, to be wise enough to adjust their roles accordingly.

As a roadmap to this needed redefinition of teacher roles, Breck's (2004) prognostication for learning in this century provided some directions for future educators to consider. "Acquiring knowledge," she believed, "will be achieved in an arena of human teachers, the nets that compose the subjects learned, the digital media that platform these subjects, and the minds of the teachers and learners engaged in the education taking place" (p. 94). Breck believed that interactive networks would separate twenty-first century learning from its predecessors. It was the process of placing the learner in the center of a network through one of these devices and thereby connecting everybody with everything learnable, she contended, that would revolutionize learning. This was the challenge that Breck described for those in the learning profession. There was a learning revolution occurring, she claimed, and it extended to the entire globe. Looking beyond the classroom had become a twenty-first century imperative for teachers of the future.

Within this theoretical framework of connectivism and lateral twenty-first century educational thinking, the context of reaping the benefits of a serendipitous meeting of a large, multistakeholder, ongoing, educational development project in Kenya, and a single educational event in Australia (the inaugural Children's Conference) became clear. Synergies providing varying degrees of mutual educational and social benefit to all participant groups evolved from this example of educationally "different and … lateral thinking" (Curley, 2005, p. 153).

Benefits of International Participation: An Example

Children involved in the Mukuru Technology Partnerships Project (MTTP) (Nairobi, Kenya), a long lasting initiative with government, corporate, and independent contributors, took part in the 2006 Inaugural Children's Conference (Sydney, Australia) – an event designed initially to provide a voice to primary and secondary school children in Australia. A common thread for this collaborative event is the preparation of Teachers for the Future. The title of an initiative at Macquarie University, Sydney, and supported by the Vincent Fairfax Family Foundation, the Teachers for the Future Initiative integrates, inter alia, elements of global social responsibility and the impact of technology on the learning process and the roles of those involved. Combining together during a single day event, these separate projects represent the potential serendipity and synergy possible when collaborations are supported for mutual benefit. Further, this international activity emphasized the growing need to incorporate global attitudes and awareness in teacher education programs that parallels the need to incorporate a growing personal comfort with the presence and use of ubiquitous, pervasive technology tools as part of the learning arsenal for teachers and learners of the twenty-first century. Moreover, the idea of using this focus on technology and global awareness together in the achievement of locally established learning goals in schools, in teacher education programs, and in the achievement of the MDGs through a focus on digital equity issues is the essence of this chapter.

Exploration of these projects in more detail will provide further insight into the full array of learning objectives achieved, and will present an analysis of the value-added component of collaborating on a project with international partners.

The Mukuru Technology Partnerships Project

In 1985, the Sisters of Mercy began working to help the children living under appalling conditions on the streets and in the slums of Nairobi. Today, the Sisters of Mercy operates four primary schools in the Mukuru communities catering to ~4,300 children ranging in age from 5 to 15. Sharing grounds with the primary schools are residential homes for orphans and vulnerable children, a rehabilitation center for street boys, a medical clinic, an HIV/AIDs testing centre, a small community center, and a skills center focusing on woodworking, crafts, and sewing.

In this context, the MTPP brings together the resources of a variety of corporations, educational and community agencies, universities, and individuals from around the world and focuses upon ensuring sustainability of the initiative by working closely with the Ministry of Education and other established educational agencies in Kenya. The MTPP creates a new future for these children by providing experiences in information and communications technology as part of the primary school education provided by the Sisters of Mercy. It equips children from poor economic and educational backgrounds with skills crucial for attaining long-term economic independence and provides the wherewithal for a life of dignity where contributing back to society becomes a goal and a reality.

The MTPP Team

This project is lead by an international team comprising individuals from British Airways, Microsoft, CISCO, Macquarie University in Sydney, and Imagine Education. In combination, these professionals provide a model of international collaboration aimed at solving one specific problem for one subsection of an impoverished population. The team "develops and exploits … individual strengths in providing solutions to international development issues" (Dempsey, 2005, p. vii), and each is dedicated to making a difference, regardless of their organizational affiliation. The project is an example of successful multistakeholder, cross-national, cross-corporation, cross-agency collaboration in developing viable and sustainable solutions to problems around the globe (Annan, 2005; Dempsey, 2005; IFIP, 2005; UN, 2005).

Role of Children

More important is the role played by individual children in establishing a sense of trust and understanding for each other's situations in the context of a worsening geopolitical environment. Adopting a proactive approach to incorporating a global social responsibility focus in the minds and hearts of young learners is the first step in meeting and adding sustainability to the MDGs (UN, 2005). While a total of 113 teachers have undergone first-phase training in the use of ICTs as a result of the MTPP, and more than 500 children from four schools have been involved in using technology in achieving local learning goals related to Science, Social Studies, English, Communication, and Technology, all of these experiences have been based on the concept of computer use in an unconnected, stand-alone application of the technology. In the context of their involvement in the Children's Conference in Sydney, while learning to use computers to enhance their access to the world's knowledge bases, these slum children (their teachers and the international participants) also learnt the value of communicating with others from around the world.

The 2006 Inaugural Children's Conference (Sydney, Australia)

In partnership with the Australian Centre for Educational Studies at Macquarie University in Sydney, Australia, and the City of Ryde, a Children's Conference was organized with the assistance of the Department of Education and Training in New South Wales, and children from eight high schools and five local primary schools. The conference was held to celebrate Children's Week and the right of children to enjoy childhood and to be taken seriously. It supported the UN Convention on the Rights of the Child (Article 12) (UN, 1989), which formally acknowledged that children have the right to be listened to. The conference was designed to give children in these schools an opportunity to express their views and opinions and provided them with the opportunity to demonstrate their talents, skills, and abilities. The conference goal was to produce resolutions for consideration by adults related to the conference themes of "technology, health, and education."

Approximately 200 primary school students took part in the conference. Forty-five high school students acted as mentors, facilitators, and masters of ceremony. During the conference, very few adults were involved. "Guest speakers" included a dynamic young scientist, and an elite young athlete who had competed in the Commonwealth and Olympic Games. A keynote address was delivered in "real time" via interactive video technology by primary school children from a school in the mid-west of the United States. Other conference activities included a series of videotaped speeches by children from the slums of Nairobi who also commented about the impact of technology, health, and education on their lives now and in the future. These formal "speeches" were designed specifically to address the Children's Conference delegates in Sydney. In reality, these speeches became an opportunity for age-mates to talk to each other about topics of mutual concern and significance, without the barriers of time, distance, geography, or culture and supported by technology that became invisible in the face of the intensity of the learning opportunities afforded.

In terms of total impact, the day was replete with contrasting views, cultures, and perspectives designed to expand upon the delegates' understanding and perceptions of the three conference themes, and focus their views of the future in relation to technology, health, and education. A conference website (http://aussiekidsconference.org) was designed to support preconference and postconference activities, and to support the continuing goal of involving children around the world in common, collaborative activities.

Outcomes

Bringing children, teachers, beginning teachers, teacher educators, and support personnel together, from vastly different target cultures (Australia, Kenya, USA), using collaborative technologies, achieved many learning objectives. Significant among them were the creative use of technologies in achieving learning goals in a collaborative setting (De Grave et al., 1996; Hannafin and Land, 1997), and recognition of the value of personal involvement in sustainable projects of global social responsibility as part of a learning event.

Data have been gathered through a series of interviews; field notes taken during meetings, visits, and collaborations in both projects; shared planning events; observations; and archived photographic, video, and audio databases. Further, international team reflections explored the value added to the learning process when boundaries between the projects were removed.

Based on the data gathered at each of the three participant locations around the world, this conference was considered a success as the issues of sustainability, transferability, achievement of local learning goals, increased global awareness, and the use of technology for communicating, collaborating, and learning was clearly in evidence. Success was evident during the day as adult observers from schools, university, local government, and the New South Wales Department of Education physically in attendance at the conference in Sydney agreed with the conference delegates to continue to support the conference in future years.

Further, adult observers supporting the keynote speakers from Kansas were loud in their praise of the impact that participating in the conference had on their students from the perspective of achieving local learning goals related to writing, communicating, media studies, social studies, and public speaking. Informal comments from teachers indicated a growing sense of self-confidence and an increased willingness to collaborate as a team in achieving collaboratively recognized learning goals. During a face-to-face visit to Kansas by the author in the week following the conference, the keynote presenters (7–9 year olds) confirmed the benefits from their involvement including greater comfort with interactive technologies, less fear of public speaking, and a willingness to continue to interact with both Kenyan and Australian students in the future. They displayed a deeper understanding of the skills of their classmates and an overall willingness to learn more about Australia and Kenya.

Children in the slums of Nairobi became aware of the conference through the author and had agreed to participate in videotaped interviews, amazed at the interest that children from Australia had in their opinions about technology, health, and education. They were able to give Australian children advice on how they could be helped to improve their educational experiences. Adults involved in supporting the classroom representatives who participated in the video interviews from Kenya also indicated an increase in self-esteem on the part of the class representatives, but also their classmates, as they realized that there was an audience of age-mates somewhere else in the world who were interested in what they had to say. This was a significant learning outcome for children who struggle to be recognized in their daily lives, as was the opportunity to learn more about the way other participants lived and about the countries from which they came. For the classroom of Kenyan children who were involved in this event through the contributions of their representatives, there was a clear understanding of the impact of their use of technology on their learning. They left the experience, and the virtual collaborations, with new friends in Australia and in North America, with new ideas of what could be achieved, and a new view of their futures, even though most of them had never been outside the slums in which they live. Their vicarious involvement has led to a greater awareness of the capabilities of the technology and an agreement to collaborate more fully in future conferences. During a follow-up visit to Mukuru, the author provided the Kenyan participants with conference T-shirts, conference bags, and giveaways, a photographic record and slideshow of the conference day, and additional information related to the conference.

Interviews with delegates during the day, and subsequently in Kansas and Kenya revealed a serious level of involvement with conference themes, and a sense of “privilege to be involved in such an important conference” (8-year Australian female delegate). The sense that the conference had “achieved something significant today” (12-year Australian male delegate) was clearly reflected in other data collected from both physical and virtual participants. Delegates were engaged throughout the conference with an intense level of participation, expressing ownership and responsibility for the success of the day, “Thank you for the opportunity. I don’t think I shall ever forget this experience” (12-year Kenyan female speaker).

The impact of the conference spanned three continents and extended beyond the day of the event. In preconference activities, conference delegates in Australia, Kenya, and Kansas participated in activities related to the achievement of local learning goals and the conference themes, and prepared for their involvement on the day. One group videotaped interviews of their thoughts related to the conference (see http://aussiekidsconference.com). Others developed projects and wrote stories on the themes. Still others wrote speeches in preparation for their contribution to the conference, drew pictures to assist in their talks, and conducted research to ensure the voracity of their presentations. The photographic archives of the day, and the recorded interviews, provided very strong evidence of children’s involvement during the conference and the overall success of the event.

Preparing Teachers for the Future: A Focus on Teacher Education

In exploring the interactions and connections of the conference in the context of the Teachers for the Future project at Macquarie University in Sydney, much can be drawn into the development of a new approach to teacher education. A variety of learning objectives and audiences become obvious for a teacher education program hosting an international children’s conference. In this learning context, children are able to overcome barriers of culture, traditional pedagogies, adult expectations on their behaviors, self-efficacy, and normal communication patterns. Children can achieve many standards in areas of skills, knowledge, and disposition development, and they can develop a necessary sense of global awareness crucial to the new century. Initial teacher education students can observe children in alternative learning environments being responsible for their own learning and the success of others, where expectations on children’s behaviors can produce credible, defensible, and high-quality results dealing with the big questions of life in the twenty-first century and the role of children in it, and where the teacher education students can understand the power of bringing people together across distance, cultural, and social barriers to achieve increased global awareness and positive results for all involved. Teachers and school leaders can view first hand the value of collaboration with community agencies and international partners around an alternative model of pedagogy, experience constructivist and connectivist (Siemens, 2005) learning theories in action, and develop a comfort level with new technologies and risk taking in the learning process. Overall, the role of teacher educators and teachers in framing the attitudes of the next generation is dependent upon the incorporation of these dispositions into the core knowledge of the profession.

Why are these types of projects of significance? Education is the means by which a skilled workforce is developed and prepared for innovation and the improvement of social, political, and development initiatives (Annan, 2005). Much of the success of improving the human condition globally rests on the development of the peaceful imaginations to which Friedman (2005) referred. Further, incorporating global awareness (Gibson, 2005, 2006, 2007) in teacher education programs responsible for supporting the development of teachers for the future is a significant step forward in ensuring progress toward the MDGs, and achieving widespread support for a global approach to the improvement of the human condition. Unless the existing mental models of new teachers are replaced with an alternative mental model (Senge, 2000) incorporating the recognition of their role and responsibility for engendering in the minds of their students greater understanding and tolerance for differences, and a more global, inclusive view of the world, then the mistakes of history are destined to be repeated. So, creating an impact on the minds of children all over the world is a necessary further step forward in ensuring the MDGs are reached by 2015 at the same time as ensuring a more understanding and peaceful approach to life for future generations. By guaranteeing the sustainability of the event and ensuring that the benefits of involvement are transferable across barriers such as culture, distance, and place as well as less obvious barriers of expectations and traditional practices when it comes to learning, the Children's Conference experience has, and will continue to make, a significant contribution to the learning of the future decision makers of the Twenty-First century. By incorporating this type of experience into the fabric of teacher education programs as an integral component of the initial preparation of teachers, not only will a greater global awareness result for new generations of teachers and learners, but a greater understanding of alternative approaches to learning with technology will be established in the minds of teachers. It is the substance of this type of experience that provides support for inclusion of the foundation principles of the Teachers for the Future Initiative at Macquarie University. The principles underpinning the program propose the following:

- redefining learning for a technology-rich, twenty-first century global environment,
- incorporating a learner-centered, knowledge-building conception of the learning process,
- generating expertise in a variety of approaches to teaching and learning,
- collaborating in the development of partnerships in the learning process,
- creating a "community of learning" orientation to classroom and school cultures,
- integrating global social awareness and responsibility into the educational process,

- championing the use of multiple measures of accountability for student learning, and
- viewing the educational process as a learning, leading, and teaching continuum.

These are the essential criteria that will direct education and teacher education into the future and which can be found in the collateral benefits derived from involvement in projects of this type.

Benefits and Conclusions

There is little doubt that strengthening individuals and communities through education and access to IT is vital to the creation of self-managed, sustainable development. Using IT as the means of bringing people together in the achievement of shared learning goals, building understanding, and spanning traditional and long-established barriers is an imperative for ensuring success for the next generation of decision makers.

Wide-ranging conclusions can be derived from this collaborative event. The steps inferred in the conclusions that follow can be considered to be the building blocks in the development of future sustainable and transferable projects focusing upon the issue of social and digital equity and capable of achieving similar goals:

- It will take the involvement of private and public sectors, and contributions from the local to the global if the issues at the heart of the international community of the twenty-first century are to be overcome (Annan, 2005; Friedman, 2005; Gibson, 2007).
- Many benefits derive from the bold and creative incorporation of local children, teachers, and schools in large authentic projects related to global development, especially if governments, international and multinational corporations, and aid agencies usually removed from the realities of classroom life are included (Bracey and Culver, 2005; De Gomez, 2005; Fonseca, 2005).
- *Worthwhile learning goals are achieved by including, in thinking appropriate to a new global, technology-rich generation, the neighborhood kids from the local classroom who will live with the mistakes of a terrorist riddled era where understanding and tolerance of differences remains low (Apheck, 2005; Breck, 2004)*.
- Learners in the developed and the developing world must take the responsibility to learn in an informed, technology-rich global environment rather than a safe and sterile classroom (Gibson 2007, in press).
- Teachers and teacher educators have the responsibility and the position to respond to digital equity and access issues and ensure all learners are capable of acting and learning in twenty-first century appropriate environments (Bracey and Culver, 2005; Peters, 2003).
- There is much to be gained in the developing and the developed world through the inclusion of children in authentic projects designed to overcome differences

related to diversity, culture, geography, and history and to encourage the development of trust and understanding on a personal level (Annan, 2005; Bracey and Culver, 2005; Peters, 2003; Siemens, 2005).

Many of the building bocks of the information society are the result of large-scale scientific and technological advances of epoch changing proportions. What is even more stunning and more dramatically important is the creative use of these same building blocks in the transformational development of new and effective uses of these technologies in ways that change the lives of individuals in directed and purposeful ways. It is involvement in collaborative conversations of this type between individuals unrestrained by distance, cultural or religious barriers, or the imposed hurdles of poverty, gender, or status that contribute in a real way to a sharing of the digital and social "capital" made more readily available through technology use for all who live in the new millennium. Senge (2000) has indicated that change happens one intentional conversation at a time. This chapter describes one of those intentional conversations!

Note

1. Portions of this description were presented at the 18th annual conference of the Society for Technology and Teacher Education in San Antonio, Texas, in March 2007, and first appeared in the refereed proceedings of that conference.

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Section 9

EMERGING TECHNOLOGIES FOR EDUCATION

9

EMERGING TECHNOLOGIES FOR EDUCATION

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In the Emerging Technologies section of the Handbook we look at technologies on the horizon and explore the new opportunities for teaching and learning that they might well afford. Broadly speaking, there are four themes in this section:

Reducing the Digital Divide

- Universal access to computing is a goal that has been unreachable since computing first entered education. The reality has been that only those with resources were able to gain substantial access to technology. However, with the emergence of low-cost mobile computing devices – from cell phones to exciting new "laptops" – there is a real possibility that access will no longer be a problem for those with fewer resources.
- Brown (Chapter 9.2) explores the use of mobile technologies to support learning in Africa; he puts forth a hopeful, but cautious view that indeed m-learning can support Africa in educating its populace.
- van't Hooft (Chapter 9.3) is concerned with how culture, society, and learning need to be rethought in order for mobile technologies to truly realize their impact on teaching and learning.
- Ally (Chapter 9.4) explores the opportunities that mobile technologies can have in addressing the digital divide.
- Hsi (Chapter 9.5) explores the use of information technologies to support enhanced learning opportunities in museums. The availability of low-cost technologies may well help museums become highly popular, accessible, and productive learning environments.

J. Voogt, G. Knezek (eds.) *International Handbook of Information Technology in Primary and Secondary Education, 847–848.*

Increasing Collaboration Among Learners Using Augmented Reality

- When children talk to each other and to adults, learning occurs. While we have to be careful that there is some substance to the conversations – we are looking for more than social chit-chat, though it too can be a powerful form of learning.
- Educational theory has long known that collaboration encourages motivation and engagement, which in turn, leads to learning. The chapters in this group explore different, but complimentary strategies for supporting collaboration and substantive conversations.
- Clarke, Dede, and Dieterle (Chapter 9.6) focus on the use of multiuser environments where learners are "inside" a virtual world, exploring that world and engaging in conversations with others who are also exploring the virtual world. Clarke et al. argue that the computer can create a very rich context that is exciting and manageable, and that context can lead to enhanced collaboration.
- Jones and Warren (Chapter 9.7) also discuss the value-added of learners engaging with each other in a virtual world. Jones and Warren are keen on the use of three-dimensional and other visual issues to enhance the engagement of the learners.

Theory Meets Practice

- It is exciting when theory and practice work together, hand-in-hand to make each element better. There are two chapters in this section that explicitly link theory to practice – and vice versa.
- Patton, Tatar, and Dimitriadis (Chapter 9.8) explore the use of Trace Theory to inform the design and reflect back on the theory – of a collaboration tool for learners.
- Access does not guarantee effective use, however. Norris and Soloway in Chapter 9.1 describe how a popular instructional model – project-based learning – can provide the framework for effectively using mobile computing devices.

Lessons Learned: May We Take Heed!

- "Experience is a dear teacher, but a fool has no other." Ben Franklin understood that we must learn from the past, lest we waste precious resources reinventing that which has come before. In this final group of chapters, the authors provide hard-learned lessons for trying to implement emerging technologies into real classrooms.
- Drawing on the experiences of schools around the country that have implemented one-to-one laptop programs, Peck and Sprenger in Chapter 9.9 identify ten key issues that must be addressed if such a one-to-one initiative is going to be successful.
- Penuel (Chapter 9.10) provides a more top-level piece of wisdom for those implementing one-to-one programs: make sure a comprehensive solution is being put forward – make sure all the pieces are in place and fit together. While a list is good, the pieces had better be integrated and complimentary.
- Roschelle and Singleton in Chapter 9.11 step back in time and describe how graphing calculators had a significant impact on the teaching and learning of math. Their chapter is full of wisdom that our community needs to heed.

9.1

AN INSTRUCTIONAL MODEL THAT EXPLOITS PERVASIVE COMPUTING

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Introduction

At least in the developed nations of the world, there will come a point – in the not too distant future – when each and every child has his or her own personal computer for use as an educational tool 24/7. Just as pencil-and-paper is ubiquitous today, computers will no longer be a scarce resource and they too will be as ubiquitous as pencil-and-paper. At that point, then, like pencil-and-paper are used today, computers will be used throughout the school day for essentially every learning activity. All the notes from the school day will be taken on the computer; all the elements of an assignment will be done on the computer. Essentially no paper will be generated by the children. We refer to the situation where computers are ubiquitous and no longer a scarce resource as "pervasive computing."

What is an instructional model, then, for how teachers will use a pervasive computing infrastructure? Inasmuch as the affordances of a pervasive computing infrastructure are radically different than the affordances of a limited-access infrastructure, it should not be surprising that the instructional models that work in the latter situation are not appropriate for the former situation. In this chapter we explore the opportunities for teaching and learning that pervasive computing affords and the instructional model that is needed to take advantage of those opportunities.

The organization of this chapter is as follows:

– First, we explore the current situation where computing use is severely constrained by limited access.
– Next, we look into the future and discuss the challenges involved in making a prediction about future technological change.

J. Voogt, G. Knezek (eds.) *International Handbook of Information Technology in Primary and Secondary Education, 849–860.*

– Third, we identify the elements of the pervasive computing infrastructure.
– Fourth, we then discuss how project-based learning (PBL) resonates with pervasive computing, and how pervasive computing supports the enactment of PBL.

The Current Situation: Limited-Access Computing

In 2002, 60% of the teachers in the USA had one computer (or less) in their classrooms (Norris et al., 2003). In 2002, 65% of teachers surveyed said they had access to a computer laboratory once (or fewer times) per week. Although more computers are surely available to teachers and students than were available 5 years ago, it is safe to say that to a first order approximation, half the teachers in the USA still only have one computer (or less) in their classroom and half the teachers in the USA still have very limited access to a computer laboratory. For all intents and purposes, computer access is a scarce resource in today's classrooms.

Inasmuch as computers are scarce resources, teachers use them as part of their curricular activities. For example, in a unit on the "water cycle" a teacher may schedule a computer laboratory for students to engage in a Web quest to find information about the water cycle. Or, the teacher may ask the students to use a concept mapping program such as Inspiration to lay out the elements of the water cycle, or define the key terms in the water cycle. Since time on the computers is limited, teachers will typically have the children do only a part of the unit on the computer and the rest of the unit in pencil-and-paper. Teachers and students, then, use individual applications on the computer to carry out specific, isolated learning activities as specified by the curricular unit.

In sum, the use of computing in school today is ad hoc, opportunistic, and inconsistent. Indeed, for many teachers, using computers with their students is a burden since teachers themselves must oftentimes figure out how to use computers with their curriculum.

The Transition to Pervasive Computing: Predicting a Disruption

In general, the past is a predictor of the future. However, this guideline is not accurate when it comes to making predictions in the world of technological development. Indeed, in technology, you can bet that the past is not a predictor of the future! Continuous change – linear growth – is not an adequate model for predicting the future in technology. Rather, disruptions – discontinuities, nonlinearities – are the norm in technology growth (Moore, 1999; Christensen, 2000). For example:

– Few pundits – let alone the person on the street – foresaw the enormous impact of the Internet on society, on the world in such a short time space. In five short years, the world changed, forever, because of the Internet.

– In 1975 Bill Gates, a college dropout – from Harvard University, no less – predicted that everyone would have a computer in their homes. If there had been a consensus around that notion, if everyone thought that personal computers would play a dominant force in our everyday lives, then Gates would not have been able to build an empire – in less than 20 years – that touches the lives of literally billions of people every day, and has catapulted him ahead of all the energy titans, the transportation barons, etc., to a position where he is the richest man in the world.

In this chapter, we are making a prediction that in the not too distant future there will be a transition to pervasive computing. However, for that prediction to be true, then the past is not a predictor of the future, and a disruption must occur since a linear extrapolation of cell phone ownership, for example, will not support the prediction of ubiquitous prevalence of cell phone ownership.

We believe that there are indicators that support the prediction that a disruption will indeed occur. For example, studies are pointing out the already high ownership of cell phones among youth in the USA and in Europe. And, the America's Digital School Survey (The Greaves Group and The Hayes Connection, 2006) found that 85% of the school administrators polled planned to provide each student in their districts with a "computing appliance," where computing appliance was purposely left vague in the survey. Thus, we feel that there is justification to predict that a disruption will occur and cell phone penetration will be exceedingly high – approaching 100% – and thus education needs to prepare itself for this transformation.

To be more concrete, within the next 5 years – the not too distant future – a fundamental shift will occur:

Each primary- and secondary-aged child in the developed nations of Europe, Asia, and North America will have his or her own cell phone that will have substantial computing power; for example, the cell phone will be capable of accessing the Web through a Web browser and supporting the authoring of multimedia documents.

That shift does require a disruption, and only time will tell whether that disruption does occur.

Should educators bother to explore the opportunities that would arise should such a disruption occur? One might argue: the likelihood is so low for such a disruption to occur, it simply is not worth anyone's time to even think through how we might leverage the disruption for educational benefit. Such a narrow view seems imprudent.

It does seem prudent that at least some educators spend time considering the implications of such a disruption and prepare accordingly. Indeed, in this article, we are not arguing that people drop what they are doing and focus on making pervasive computing the core of their pedagogical framework. However, we are challenging the educational community to open up their minds to a possibility that has a nontrivial chance of actually coming to pass.

The Elements of a Pervasive Computing Infrastructure

The personal mobile device is just one piece of the computing infrastructure that must be in place in order for schools to take advantage of pervasive computing. Here we list other elements of that infrastructure, and who will provide them.

– The Mobile Learning Environment: In the past, schools have sought to keep their computing environment homogenous. For example, schools are typically “Windows” schools or “Apple” schools. Moreover, schools do not like to mingle different versions of hardware and software, within those two camps. However, over the past 5 years, schools have seen an influx of equipment, and many of the schools are less homogenous than before – and less than they might want. As we move forward, there will be an increase in heterogeneity; computers are changing much more rapidly than in the past and there simply is no way for a school to stay homogeneous.

Such experience is valuable; it will help schools cope with the tremendous heterogeneity of devices when schools permit children to bring in their own personal mobile devices for curricular use. It is not inconceivable that in one class of 30 students there will literally be 30 different cell phones in use.

To address the situation where a classroom may well have such extreme heterogeneity of hardware devices, schools will need to provide a layer of software that will, in effect, homogenize the devices and make them ready for use in an educational setting. That layer of homogenizing software has been termed the “virtual learning environment” (VLE).

The cost of the VLE software may be borne by the school, at least initially. Schools will initially purchase site licenses for the VLE and distribute them to the students. However, over time, the VLE may well be included in the list of supplies that a child needs to purchase at the start of the school year.

– Network Connectivity: Who will provide network connectivity within the school? Schools might well split off their administrative network from their curricular network. The curricular network provider could be the telecom operator, e.g., T-Mobile, Sprint, etc. Keeping a wireless network up and running with high reliability and high availability currently requires a serious staff – a staff that few schools, at least in the USA, can afford to maintain. Again, for the purposes of this chapter, we will just assert that there will be a provider of the network, be it a telecom operator or the local school or district networking team.
– Special Purpose Computing: Schools will need to provide special purpose computer gear for student use. For example, schools may purchase several “video-editing stations” that are expensive, high-end computing environments in which students can manipulate video productions. Also, there will be a myriad of issues such as backup support, etc., that schools will need to work through in order to provide reliable computing for the mobile devices.

A pervasive computing infrastructure is multifaceted, with the mobile device – the cell phone – being but one component. Schools will need to be imaginative in how all the components are developed and integrated.

Pervasive Computing Enables Project-Based Learning

The availability of pervasive computing infrastructure in a classroom does not ensure that mobile devices will be used productively. A model of instruction that is compatible with pervasive computing is needed and it must be adoptable by teachers.

Project-based learning (PBL) is one such model. In PBL a teacher puts forth a theme or driving question and identifies a set of learning activities that help the students explore the theme. A well-designed PBL assignment provides a coherent, cohesive framework for the various learning activities. The learning activities build off each other; they compliment one another.

PBL is not a rigorous pedagogy. Educators are developing design guidelines (Blumenfeld et al., 2000) to help teachers and curriculum specialists in constructing productive PBL assignments. Indeed, PBL is not without its critics, its challenges, and its variations. However, PBL has reached a level of acceptance in K-12, at least in the USA and in the UK such that using it as a model for classroom instruction is quite appropriate.

There is a clear mapping between the learning activities in a PBL assignment and the learning activities that can be carried out on a VLE-supported mobile computer. With an appropriately designed VLE, the functionalities that are exposed to the student should correspond to the learning activities in the PBL assignment. For example, if the PBL lesson calls for the construction of a concept map, then there must be a concept-mapping tool in the VLE-supported mobile computer.

There is significant value in the marriage of PBL and pervasive computing for teaching and learning. While in the limited-access case, students use the computer for isolated, independent activities, with the lion's share of the work being done with pencil-and-paper; in a PBL assignment, enacted in a pervasive computing environment, students do the entire unit on the VLE-supported mobile computer. The VLE scaffolds the students in enacting the PBL unit. An appropriately designed VLE scaffolds students so they can:

– *see the entire PBL assignment* at one glance so as to better understand the interactions among the components;
– *keep track of their work* since the files on the mobile computer will be backed up to a school server; losing pieces of paper was inevitable, in contrast;
– *work at their own pace* since the assignments are all displayed in a coherent representation.

As well, an appropriately designed VLE provides scaffolds for the teachers. For example, the scaffolds in a VLE make it easy for teachers to design PBL assignments to support differentiated instruction by simply adding or subtracting learning activities from the assignment specification.

PBL is but one instructional model that may be compatible with a pervasive computing infrastructure. Indeed, as the educational community has more experience with pervasive computing environments, there will surely be new instructional models that arise, which will leverage the affordances of the mobile computing device.

In the next section, then, we provide a concrete example of how a VLE implemented on a mobile computing device can support PBL.

An Example of Virtual Learning Environment to Support Project-Based Learning

Although VLEs are still early in the development cycle for mobile computing devices, there is one such VLE that we can use to illustrate the potential that pervasive computing can have in supporting a PBL instructional model. In particular, GoKnow! has developed the mobile learning environment (MLE) that runs on Windows Mobile, Windows CE, and PalmOS operating systems. These operating systems provide support for the vast majority of mobile computing devices on the market today.

In what follows, we use GoKnow's (http://www.goknow.com/) MLE with a Water Cycle Project to illustrate how a VLE-supported mobile learning device can enable a student to complete a PBL-style assignment.

The Water Cycle Project: A Middle School Science and Language Arts Project

In Figure 1, we see a screen from GoKnow Learning's MLE that depicts a project template for a Water Cycle Project. (In this chapter to lend concreteness to the discussion, we have invented a child, Lucinda, to represent students engaged in learning.) All the learning activities in the project are available at a glance. From a learner's

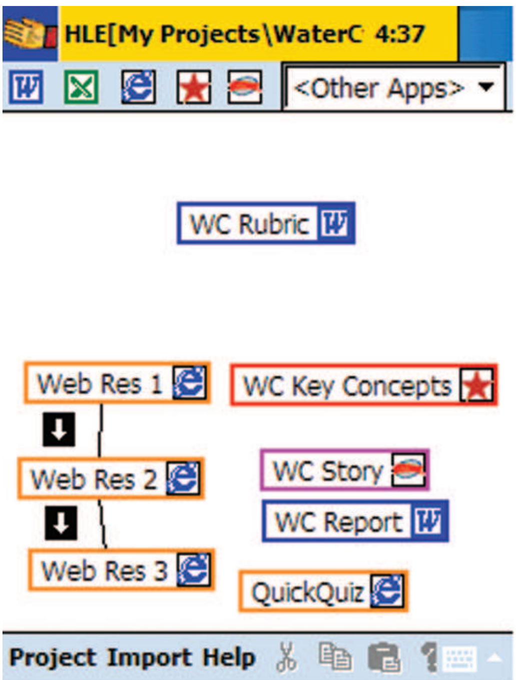

Fig. 1 Lucinda's teacher's Water Cycle Project template in mobile learning environment

perspective, he or she sees the entire project and can decide which components to work on and in what order.

Sometimes a teacher may well want the students to work on the learning activities in a specific order. The MLE enables the teacher to specify such an order using the links among the activities.

Perhaps a metaphor will help the reader to better understand the role that MLE plays in supporting learners:

– View MLE as a "container" that holds two types of resource nodes: content and learning activities. Teacher-supplied content resources contain information that the teacher provides to the student, e.g., the rubric, the instructions, valuable Web pages, e-Books, etc. Learning activities are carried out by students and typically result in artifacts produced by the students.
– Students move between the resources and the learning activities in the project template. For example, tap on the Water Cycle Rubric (WC Rubric) resource node and Pocket Word opens (Figure 2); close Pocket Word by tapping the ok and the student is returned to the "container" in Figure 1.

Tap on the "Web Resource 3" (Web Res 3) and Internet Explorer opens. In Figure 3 we see a Web page containing information about the water cycle. This resource node was provided by Lucinda's teacher to her students to start them off. This "Web research" resource node, like the Project Rubric resource node, was provided by the teacher to the students.

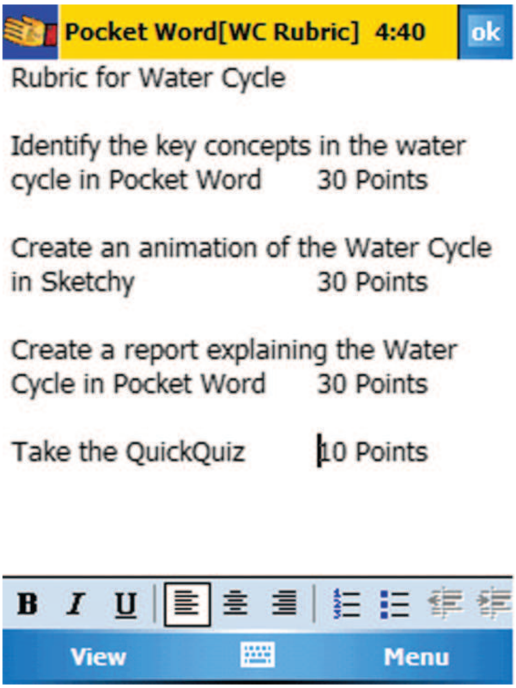

Fig. 2 Lucinda's teacher's Water Cycle Rubric in mobile learning environment project

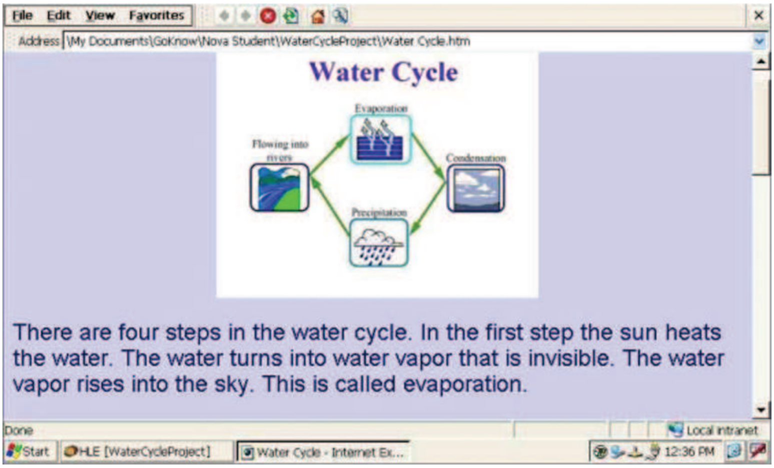

Fig. 3 Lucinda's teacher's Water Cycle Web resource

The teacher found the website about water quality (The Water Cycle, n.d.) on the Internet and saved the key pages from the website onto her device. MLE enabled the teacher to import the saved Web pages into the Water Cycle Project.)

Following the project rubric for the Water Cycle Project, Lucinda is directed to produce three representations of the water cycle. In Figure 4 we see Lucinda's concept map representation of the water cycle created in PiCoMap. In Figure 5 we see Lucinda's animation created in Sketchy. And, in Figure 6, we see a text report on the water cycle, yet another representation of Lucinda's evolving understanding of the water cycle.

Pedagogically, it is well known that students learn more effectively when they can engage in learning activities that have them producing "multiple-linked representations" (MLR). Because MLE provides the students with an *integrated* suite of tools, it is easy for students to engage in MLR learning activities. Thanks to a VLE such as GoKnow!'s MLE, learning through MLR is a routine, day-in, day-out learning strategy, not a special, one-time per semester opportunity.

In Figure 7 we see that a new node has been added to the project template for the Water Cycle Project. Lucinda's language arts teacher, one of the teachers in Lucinda's 7th grade team, is making use of the students' existing science report in a language arts activity. The language arts teacher wants to work on adjectives. Rather than making up arbitrary sentences for the adjective activity, the language arts teacher can use – actually reuse – her students' water cycle report. In the language arts lesson, the teacher asks her students to add an adjective to each sentence in their water cycle report; and to indicate the change, she asks them to highlight the added adjective. In Figure 8, we see Lucinda's water cycle report for the language arts activity. Lucinda has added two adjectives, "tasty" and "water."

There is significant pedagogical value in reusing the students' science report for a language arts assignment. First, the students can see the impact of the language arts lesson in a real and motivating context – a document created by the students

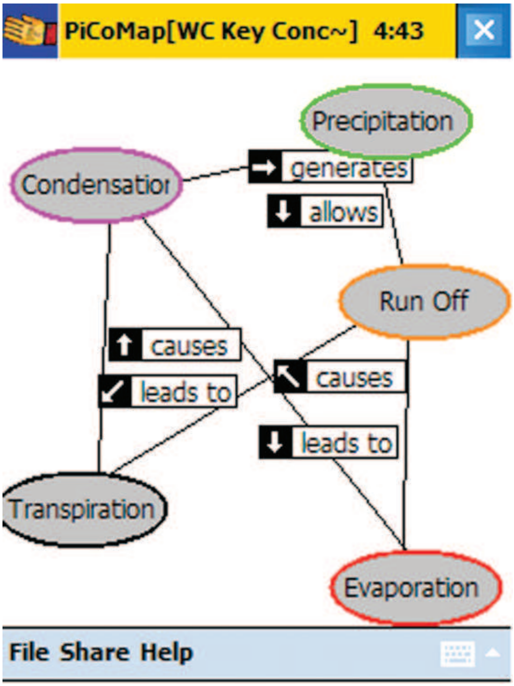

Fig. 4 Lucinda's water cycle concept map in PiCoMap

Fig. 5 Lucinda's water cycle animation in Sketchy

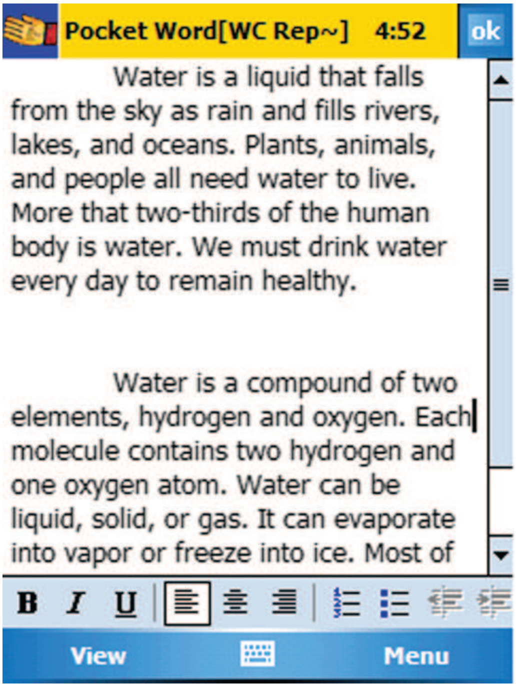

Fig. 6 Lucinda's water cycle report in Pocket Word

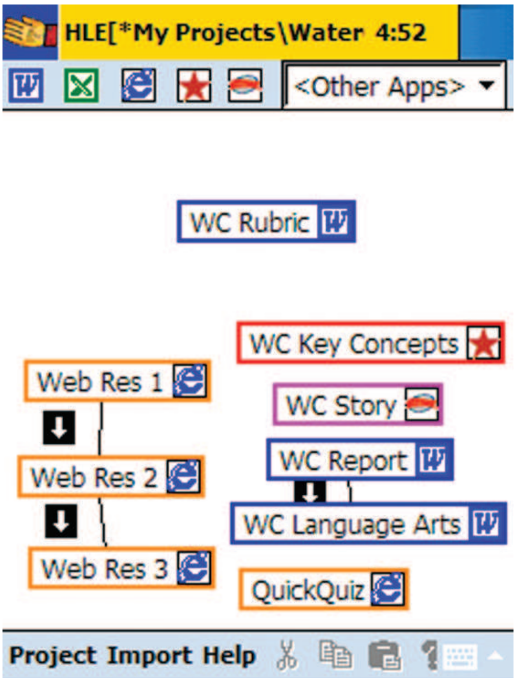

Fig. 7 Lucinda's language arts teacher's project template in mobile learning environment

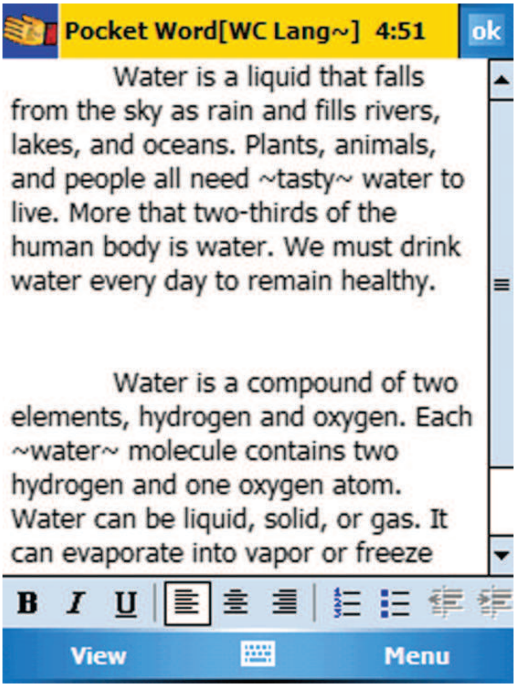

Fig. 8 Lucinda's language arts assignment. Based on her science report in Pocket Word

themselves. Second, in reusing their science document, the students must reread and review the science content in their document, thereby providing the students with another opportunity to better understand the science issues. Since in MLE students have access to all their artifacts, it is easy for a teacher to "reuse" existing documents for new learning activities.

GoManage is part of GoKnow's MLE; it enables students to back up their work to a server. In addition, Lucinda's language arts teacher will be sending Lucinda feedback on her language arts assignment using GoManage's feedback mechanism.

Concluding Remarks

If the disruption that we described earlier does occur, then K-12 education is about to go through a significant transformation: classrooms will go from limited access to computers to pervasive access to computers in only a few years. Such change is unprecedented in K-12 and it is not surprising that proclamations of this magnitude of change are met with skepticism and disbelief. It is our position that such a disruption has a significant chance of actually happening and thus it seems prudent that at least some educators think through the implications of such an outcome – before the outcome arises.

For those willing to explore a potential future, then, we have focused on how K-12 can take advantage of this transformation from limited-access to pervasive access computing. We have argued that at least one model of instruction, PBL, can make use of pervasive computing, assuming that an appropriately designed VLE exposes a set of tools that are common across the heterogeneous mobile computing devices.

Finally, we wish to point out that pervasive computing is not an all or nothing proposition. Some aspects of pervasive computing will occur, without question, e.g., computing devices will be put in the hands of more and more children as we move into the next decade. For example, projects such as the MIT One-Laptop-Per-Child project is seeking to put low-cost devices into the hands of children in developing nations. Cellular phone use for teaching and learning is exploding in Africa (Brown, 2008). In the UK, too, there is a significant movement to transform cellular phones into learning devices. Change is already in the wind! Thus, our intent in this chapter is to offer some ideas on how educators can take advantage of the new opportunities that arise when technology plays a larger role in the daily lives of children.

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9.2

M-LEARNING IN AFRICA: DOING THE UNTHINKABLE AND REACHING THE UNREACHABLE

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Introduction

Owing to the exponential growth and development of the Internet in the past few decades and the experimental use of the World Wide Web and e-mail in education, e-learning emerged as an educational concept during the 1990s and has grown into a globally accepted, even necessary mode of delivery in most educational institutions. Further Internet developments in the past decade brought about a greater need for wireless connections and the development thereof. Wireless communication received an enormous boost when mobile phones reached the market. By 2000, landline telephones and wired computers were beginning to be replaced by wireless technologies. The whole world literally went mobile as the millennium dawned. Besides mobile phones, other wireless and mobile computational devices such as laptops, palmtops, personal digital assistants (PDA) and tablets also rapidly entered the market – some devices, of course, with more success than others for particular markets.

In the past decade we have become familiar with the term e-learning, and now m-learning is emerging. The following comprehensive definition of Urdan and Weggen (2000) provides an adequate basis for distinguishing between m-learning and e-learning:

> The term e-learning covers a wide set of applications and processes, including computer-based learning, Web-based learning, virtual classrooms and digital collaboration. We define e-learning as the delivery of content [and interaction] via all electronic media, including the Internet, intranets, extranets, satellite broadcast, audio/video tape, interactive TV, and CD-ROM. Yet, e-learning is

J. Voogt, G. Knezek (eds.) *International Handbook of Information Technology in Primary and Secondary Education, 861–871.*

> defined more narrowly than distance learning, which would include text-based learning and courses conducted via written correspondence. (p. 8)

M-learning is a subset of e-learning. E-learning is the macro concept that includes online and mobile learning environments. The following simple definition of Quin (2000) helps to explain this: "M-learning is e-learning through mobile [and handheld] computational devices" (p. 1). [Author's addition within square brackets]

M-learning is a natural extension of e-learning and has the potential to make learning even more widely available and accessible than we are used to in existing e-learning environments. The role that communication and interaction plays in the learning process is a critical success factor. It is in this context that m-learning can contribute to the quality of education. It offers opportunities for the optimisation of interaction between lecturers and learners, among learners and among members of Communities of Practice.

Why M-Learning in Africa?

One's first impressions and perceptions when thinking about the ideal target market for m-learning would probably be something like *a First World learner population that is already highly ICT literate, uses the latest handheld device and either is in full-time employment or merely prefers studying at its own pace, place and time*.

However, this description does not fit the majority of learners in Africa. Why then m-learning in Africa? Well, the answer is quite interesting. Because of the lack of fixed-line infrastructure for ICT (cabling for Internet and telecom) in certain areas in Africa, the growth of wireless infrastructure is enormous – even more rapid than in many First World countries.

The East African (2002) reported, "… the communications sector in Uganda is growing rapidly. Nua Internet Surveys (July 15, 2002) reported that, according to the National Information and Communication Technology Policy, the number of mobile phone subscribers in Uganda grew from 3,500 in 1996 to a total of 360,000in 2002."

Wachira (2003, p. 1) reported the following about Kenya:

> When Vodafone UK sent Michael Joseph to Kenya in July 2000 to set up Safaricom, a cell-phone service operator jointly owned by Telkom Kenya, he did not expect the subscriber base to grow beyond 50,000 connections. Today, both Safaricom and rival KenCell Communications (partly owned by Vivendi) have nearly 1.3 million cell-phone subscribers. This set-up is deeply rooted in the traditional African communal mode of living, which many urban dwellers haven't abandoned. (p. 1)

Shapshak (2002) reported that the adoption rate of mobile technologies in Africa's developing countries is among the highest rates globally and forecasts estimate almost 100 million mobile users in Africa by 2005. Between 1997 and 2001, the number of mobile phone subscribers in Africa annually had a triple-digit growth rate.

The number rose further and increased by more than 1,000% between 1998 and 2003 to reach 51.8 million (International Telecommunication Union, 2004).

It is thus obvious that the adoption rate of mobile technologies is exceptional in Africa. Also evident is the fact that Africa is actually leap-frogging from an unwired, nonexistent e-learning infrastructure to a wireless e-learning infrastructure.

According to Brown (2004), we can therefore differentiate between two ideal target markets for m-learning: learners who either are without infrastructure and access or are continually on the move. In other words:

- first World learners who are the workforce on the move with state-of-the-art mobile devices, and
- third World rural or remote area learners with mobile phones.

Overview of Current M-Learning Activities in Africa

In some African countries there are many projects and in others m-learning is still nonexistent. The majority of projects outside of South Africa, but still in sub-Saharan Africa, are funded and supported by European and US agencies. In Kenya, for example, there are several European-Union-funded projects with onsite support from personnel from various European countries.

The summary here provides an overview of activities across the African continent.

Mobile phones are used for the following purposes:

Administrative learning support

- Administrative information
- Access to examination and test marks via a mobile service number or m-portal
- Access to financial statements
- Registration data via mobile service number or m-portal

Academic learning support

- Communication and interaction (bulk short message service (SMS) and interactive voice response
- Assessment (Multiple choice questions/quizzes)
- Feedback on assignments and tasks
- Motivational and instructional messages

The use of PDAs, smartphones and pocket PCs for the following purposes:

- Classroom "tools" for note-taking, scheduling, etc.
- Beaming (via Bluetooth) in classrooms to share notes, hand in assignments, etc.
- Assessment: assessing performance and providing automated results and feedback
- Coursework, scheduling and assignments in wireless environments; language learning through SMS
- Just-in-time and on-the-spot information for field workers and field studies
- Experiential learning and fieldwork

- Personalised learning (appreciation for individual and learner-specific learning process)
- Mobile composing (music composition on PDAs)
- Contextual and local awareness (e.g., at museums)
- Mobile tutoring
- Mobile blogging (moblogging – blogging on mobile devices)
- Courseware and multimedia on PDAs, including distribution and streaming
- Human language technologies (HLT) (speech-to-text, voice recognition)
- Collaborative activities via multi-user applications
- Collaborative learning and discussion groups

The integration of m-learning with established e-learning environments:

M-portals and SMS-gateways

- SMS-portal integrated with learning management systems or learning content management systems, e.g., WebCT
- Mobile tutoring
- Moblogging
- M-assessment (e-assessment on mobile devices)
- Collaborative learning and discussion groups

Wireless environments

- Pilot wireless classrooms
- Hot spots and wireless LANs on campus

Examples of M-Learning in Africa

To provide more specific examples of some of the m-learning projects and activities in Africa, it would be appropriate, at this stage, to share the following examples at the University of Pretoria in South Africa.

Examples of Projects with PDAs

At the University of Pretoria, two projects have been launched using personal digital assistants (PDAs).

In the first project (from 2004 to 2005), an m-learning project in the Faculty of Health Sciences, PDAs were used in the clinical assessment sessions of medical students. Performance was assessed and automated results and feedback were provided. The project leader is Prof. Ina Treadwell of the Faculty's Skills Laboratory. Project software was funded by HaPerT software in Vienna, Austria. Research is being done on the impact of PDA use on assessment quality, student performance, and efficiency and effectiveness (impact on administrative load, time, paper work, human errors, calculation errors, record keeping, duplication, costs, etc.). Since the project is still in progress, no official results are as yet available. However, the feedback received thus far is extremely positive regarding efficiency, effectiveness, and cost-savings.

In the second project (from 2004 to 2006), an m-learning project in the Faculty of Engineering, Built Environment and Information Technology, students in a fourth-year course have been issued with PDAs to use in a pilot wireless e-learning environment. PDAs are used for queries, content delivery, interactive distributed simulations, notices, database access, collaboration, etc. The project leader is Prof. Etienne Barnard of the Department of Electrical, Electronic and Computer Engineering in the University's Faculty of Engineering, Building Sciences and Information Technology. HP is funding the project. In this project, research is being done on human language technologies (specifically in the fields of speech recognition and speech-to-text, and voice user interfaces), the ability to stimulate collaboration with PDAs, mobile sharing of software and resources, multi-user applications and resources (multi-player games are popular), and wireless VoIP (Voice over Internet Protocol). Since the project is still in progress, no official results are as yet available.

Examples of Projects with Mobile Phones

The University of Pretoria started using mobile phone support during 2002 in three paper-based distance education programmes because more than 99% of the 1,725 students (2002) had mobile phones. The profile of these students in 2002 was as follows: The majority live in rural areas; 100% are full-time teachers; 77.4% are English second-language speakers; 83.8% are between the age of 31 and 50; 66.4% are women; 0.4% have access to e-mail; and 99.4% have a mobile phone. The majority of these learners live in remote rural areas with little or no fixed-line telecom infrastructure.

Many of the staff at the University were, understandably, sceptical about the idea of using mobile technology to support rural distance learners. Some of the arguments put forward by the sceptics were as follows:

- "These students are not ICT literate."
- "The telecom infrastructure in rural areas is almost non-existent. The students don't have access to the Internet – not even to basic e-mail."
- "The nearest post office is 60–100 km away. Now you want to use 'high tech' to support these rural students?"

However, a bold step forward was taken and the unreachable was reached with m-learning support.

Mobile phone support to these rural distance-learning students entails sending bulk, preplanned SMSs to

- All students.
- Students of a specific programme for general administrative support as well as motivational support.
- Specific groups of students extracted from the database for specific administrative support (customised group SMSs).
- Small group or individual SMSs to specific students extracted from the database on an individual basis for specific administrative support.

Examples of SMSs sent for *administrative* support are provided in Table 1.

The advantages and successes have already been significant. In response to a reminder for registration for contact sessions, 58% of the learners registered before the closing date, compared with the normal expected percentage of below 40%. In response to a reminder of the contact session dates, 95% of the learners who had registered for the contact sessions attended. Learners respond in mass and almost immediately to information provided in SMS messages.

From a logistical and financial point of view, the successes are also significant. Using print and the postal service to distribute the necessary information to learners would have cost 20 times the cost of the bulk SMSs. The SMSs provide immediate and just-in-time information, while the posted information would have taken between 3 and 18 days (depending on the remoteness of the learner) to reach all the learners.

Table 1 Examples of administrative support through bulk SMSs

SMS message	Purpose	Result
Dear Student. Your study material was posted to you today. Enquire in time, quote your tracking number: PE123456789ZA, at your post office. UP	• Since students do not visit their rural post offices that often, many packages are returned. If students know that a package has been dispatched, they make an effort to fetch it on time	• A significant drop in returned packages and accompanying costs
If you have not submitted Assignment 2, due to late dispatch of study material, you may submit before 19 Sept. Do this urgently to help you pass your exam. UP	• Extension of assignment submission date owing to a late dispatch of study material • Encouragement to complete the assignment	• Normal assignment submission statistics
ACE Edu Management contact session block 1 from 7–9 July for modules EDM 401 EDO 401 ONLY, changed to Town Hall Main Street KOKSTAD. New letter posted. UP	• Urgent notification of a change of venue for a specific contact session	• All the students arrived at the correct venue (as far as we know)
Dear Student. We have not received your registration for the Oct exam. Please fax registration form or letter not later than Thursday 31 July. UP	• Encouragement for examination registration • Notification of the deadline for examination registration	• Increase in the number of examination registrations, compared with previous examinations
April exam proved that students attending contact sessions are more successful. Please attend July contact session. Register per fax before or on Friday 6 July. UP	• Encouragement for contact session registration • Notification of the deadline for contact session registration	• 58% of the learners registered before the closing date, compared with the normal rate of below 40%

After the successful implementation of bulk SMSs for administrative learning support, the University of Pretoria took the project to a higher level and started to do the unthinkable: academic learning support on mobile phones for rural distance learners.

The University of Pretoria started using SMSs for academic learning support in November 2004 in a module of one of the three paper-based distance education programmes in the Faculty of Education, namely ACE: Special Needs Education: Module LPO402. The leaders of this exciting m-learning project are Mr Carl du Preez (Department of Educational Psychology) and Mrs Jeanne-Marie Viljoen (Unit for Distance Education).

The pilot project comprises four categories of asynchronous academic interventions during the 6-month cycle of this module from October 2004 to April 2005. The four categories are as follows:

- Academic instructional messages (regular bulk SMSs messages).
- Interactive voice response for frequently asked questions (FAQs). Students phone in to a “FAQ number” and receive answers from the programmed system.
- SMS quizzes. Multiple choice questions are sent to students and a simple answer choice is sent back via SMS; answers and feedback are provided for each quiz.
- SMS question–answer system. Students ask questions, via SMS, regarding a given preselected topic and automatically receive an answer from the system via a comprehensive programmed matching system (text database).

Examples of SMSs sent for *academic* support are provided in Table 2.

Bear in mind that the limitation of having only 160 characters available (including spaces) for an SMS text message poses interesting challenges when it comes to formulating an SMS message. It is a real challenge to formulate the correct message that provides the exact information you want to communicate without the possibility of misunderstandings or misinterpretations. One poorly formulated SMS can create total chaos with financial and many other implications.

Premises for M-Learning in Africa: Lessons Learnt from Pilot Studies at the University of Pretoria

Lessons learned from the projects discussed earlier lead to the establishment of a few important premises for m-learning in Africa, which can be summarised as follows:

- M-learning is a supportive mode of education, not a primary one.
- M-learning provides flexibilities for various learning styles and lifestyles.
- The most appropriate mobile device for learners in Africa is a mobile phone.
- Possibilities and latest developments in mobile technologies must be tested against practicality, usability and cost-effectiveness.
- The use of multimedia on mobile phones must be tested against the envisaged learning outcomes.
- The major focus of m-learning should be more on communication and interaction than on content.

Table 2 Examples of academic support through bulk SMSs

Category	SMS message/voice response	Purpose	Envisaged outcome
Instruction	LPO 402 student: study section on Assets p 43–44 in Tutorial Letter 1 before answering 1.4 of Assign 1. This is also important for your Project & Assign 2. UP	To provide a study hint for a difficult assignment question that is normally answered incorrectly by students, to prepare students for contact sessions, and to provide a hint for the project and follow-up assignment	An increase in the quality of assignment answers, and an increase in the quality of contact session interaction
Interactive voice response	*SMS message* LPO 402 student: phone 0124203111 to hear more about the most import concept in this module, the asset-based approach. UP *Voice message when student reaches 012 420 3111* Hello LPO 402 student. We will now discuss some frequently asked questions on the asset-based approach that will enhance your understanding of this important concept. Press 1 to hear what the asset-based approach is. Press 2 to hear what makes it so unique. Press 3 to hear why you should use it. Further voice responses are then available at each number indicated.	To personalise automated learning support. Students can listen to mini-lectures and explanations in the voice of their teacher.	An increase in learning motivation as well as an enhancement of learning with deeper understanding of certain key concepts. It also "personalises" the interaction. All of these require further research to confirm the anticipated outcomes.

Q&A	Dear student: See section C no 2 page 20 in Assignment Workbook. For any assistance SMS your questions about these guidelines for educators via reply SMS.	To afford students the opportunity to clarify issues and questions without the high cost of a lengthy telephone call; to provide asynchronous learning support; and to lessen the impact on the call centre or the faculty's telephone tutoring.	An enhancement of achieving the desired learning outcomes. Other successes have not yet been determined. This requires further research.
Quizzes	*First SMS message* 1st question: Asset-based initiatives are clarified in a) learning guide p 14, b) Assets textbook p 14, c) tutorial letter p 5. Reply with a, b, or c & send *SMS if reply was correct* Correct! The asset-based approach is ecosystemic. Ecosystemic approaches emphasise a) interrelatedness, b) individuality, c) neither. Press & send *SMS if reply was incorrect* A needs-based approach emphasises individuality and an asset-based approach emphasises interrelatedness. Press C & send *[And it continues in this way for up to 5 questions.]* Last SMS in quiz Correct! You are on your way to reaching the 2nd and 3rd outcomes of this unit. Now read pp 15–18 in learning guide. Good luck! Bye	To review important content, to provide tutoring in order to reach the desired learning outcomes, and to provide remedial support on identified learning shortcomings.	The envisaged outcome is an improvement in the quality of assignment answers and the achievement of the desired learning outcomes. Other successes have not yet been determined. This requires further research.

An ideal model for m-learning in Africa might look far more advanced by 2010, compared with the model currently used in pilot projects. We should, however, keep in mind that issues such as the cost of mobile and wireless technologies for the user and ICT illiteracy will probably still restrict some learners in Africa to use mobile phones for a few years. The cost of more advanced mobile technologies will eventually decline as the technologies continue to develop, but m-learning in Africa will be through mobile phones for many years to come.

Conclusion

The projects described in this chapter are in higher education. However, it should be noted that similar projects can be implemented just as successfully in secondary K-12 or even primary education. The only difference will be the content. We should not underestimate the ICT and especially mobile ICT literacy of our primary and secondary learners. They grew up with these technologies and use them spontaneously as part of their daily lives. M-learning is most successful when the learning activities are integrated with the normal daily use of the technologies in the hands and pockets of our learners.

M-learning has already started to play a key role in e-learning in Africa. It should be noted that m-learning has brought e-learning to the rural communities of Africa – to learners that one never imagined as e-learning learners only a few years ago.

M-learning is the gateway to e-learning for most learners in Africa as the rapidly growing wireless infrastructure increasingly fulfils their access needs. Africa is leap-frogging from an unwired, nonexistent e-learning infrastructure to a wireless e-learning infrastructure. The statistics in this regard are already significant proof of this process.

The inconceivable is happening and those in rural Africa who could not be reached only a few years ago, are now being reached. Through m-learning we are doing the unthinkable and reaching the unreachable!

The role of m-learning in the future of e-learning and open and distance learning in Africa should not be underestimated. M-learning in Africa is a reality that will continue to grow in form, stature and importance. It will become the learning environment of choice.

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9.3

PERSONAL, MOBILE, CONNECTED: THE FUTURE OF LEARNING

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Introduction

Computing is real life (Roush, 2005).

The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it (Weiser, 1991).

Even though schools at all levels have invested heavily in technology over the past two decades, digital tools are still playing a relatively minor role in teaching and learning processes. While one could point to many reasons for this lack of impact, including limited access, a lack of staff development, or inadequate technical support, a more likely reason is the disconnect between school and society. Because of this gap, students often perceive that what they learn in school and the tools that they use for learning there are not relevant to their lives (Farris-Berg, 2005; van't Hooft, 2007; van't Hooft et al., 2007). In fact, many educators try to maintain spatial and temporal boundaries between school and society by banning new technologies such as cell phones and social networking sites such as MySpace. At the same time, these boundaries are gradually eroded by emerging digital tools and the students who use them on a daily basis. This chapter explores the divide between teachers and students, the technologies that could increase the size of this gap, and what educators need to reconnect teachers and students, and education and life.

Today's K-12 students are different from students 20, 10, or even 5 years ago. Many communicate, learn, and think in ways that adults often do not fully understand. Students choose digital tools that tend to be disruptive such as SMS, Instant messaging, social networking sites, and video sharing, while teachers are more likely to choose technologies that support existing and more traditional ways of teaching and learning (Hedberg, 2006; Lenhart et al., 2005; Project Tomorrow, 2006).

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The difference in technology use has to do with control. In an age of ever-stricter limits on youngsters' physical space, coupled with their age-old desire to escape adult supervision, teenagers visit social networking sites and use mobile communication tools to hang out, form social groups, and develop their personal identities virtually (Boyd, 2006; Romeo, 2004). At the same time, educators tend to control, limit, or ban the same technology for reasons of safety or distraction. The real reason is often the fear of the unknown, because current digital tools were not part of the world in which they grew up. The result is a society in which adults have broad access to their own PCs at work while students have to share limited and filtered technology resources at school. The resulting tension between youngsters and adults with regard to technology use for learning should therefore come as no surprise.

Many pieces have been written about innovative trends in (educational) technology (e.g., Breck, 2006; Norris and Soloway, 2004; Research Center for Educational Technology, 2006; Roush, 2005; Thornburg, 2006). Despite the fact that digital tools will continue to change in ways we cannot possibly imagine, current visionaries agree that future digital tools will be

- Personal (one-to-one access)
- Mobile (always-on-you technology)
- Networked and connected to the Internet 24/7 (always-on technology)
- Accessible (cheap and easy to use)
- Social (allow for creating, sharing, aggregating, and connecting knowledge)
- Multimodal (support different media, including text, image, sound, and video)

Given these characteristics, it is obvious that the ways in which we interact with knowledge and information are changing. Society has picked up on this shift, but current education practices have done relatively little with the ever-increasing digital connectivity, instead hanging on to outdated approaches such as distant learning and "link cherry picking" (Breck, 2006, p. 43), the practice of adding a few reference links to existing lesson plans.

According to Breck (2006), learning should occur online because current knowledge has moved there. She calls this the "global virtual knowledge ecology" (p. 44). Therefore, Breck argues for schools to adopt a new *attitude* toward the Internet, take advantage of a new *access* to information, and above all, benefit from the new *aggregation* of knowledge made possible by the Internet's open content and "interconnectivity within and among subjects" (p. 46). Just being able to access information on the Internet for learning is not enough. Being continuously networked with information and people for learning is the key.

Besides a change in what we access, we are also changing how we access it. Younger generations are increasingly accessing the Internet by way of personal, mobile, and Internet capable devices, wherever and whenever the need arises. When interacting with their mobile devices, they tend to "interact with other users [and] interact with more than one computer or device at the same time" (Roth, 2002, p. 282; see also Cole and Stanton, 2003; Mandryk et al., 2001). Because digital tools are increasingly personal, mobile, and connected, they lend themselves well for both individual *and* collaborative learning, encourage the use of technology in everyday activities, and enable students to understand digital tools as lifelong-learning tools (Inkpen, 2001; Sharples, 2000; Thornburg, 2002), eventually leading to the type of ubiquitous and "invisible" computing that Weiser (1991) envisioned.

Rethinking Teaching, Learning, and Technology

For anytime, anywhere, lifelong learning using personal, mobile, and networked devices to work, the changes that are needed in education go beyond deciding what technologies are best. Digital tools change constantly, but connectivity and mobility of the learner and/or technology are here to stay. In addition, the core skills that employers require for twenty-first-century jobs are very different from the ones that many schools are still teaching, and include digital-age literacy, inventive thinking and problem-solving, effective communication and teamwork, and high productivity (Anderson, 2008; Lemke, 2001; Thornburg, 2002). Because of these societal developments, educators need to reexamine "the validity of many of the assumptions [related to education and schooling] that have remained unchallenged for decades" (Thornburg, 2002, p. 97). School should be seen as a process, not as a specific location in space and time. Rethinking schooling in order to meaningfully and effectively incorporate digital tools and the new skills described earlier should happen in three areas: teaching, learning, and technology.

Rethinking Teaching

To take advantage of the possibilities, teaching must be continuously redefined within the changing context that new tools create. Teachers must rethink their pedagogy (how we teach), boundaries (where we teach in space and time), and curriculum (what we teach).

First, teaching should be reconceptualized as "conducting learning," putting more responsibility for learning on the learner. *Pedagogy* can be defined as the art and science of teaching, the strategies, techniques, and approaches that teachers use to facilitate learning. Because ubiquitous technologies enable students to easily switch from learning individually to working collaboratively, and to access a wide variety of tools and information, pedagogy can and should be enriched and customized with materials and strategies that are appropriate for individual students as well as small and large groups. As a result, teaching needs to be seen more as the facilitation of personal *and* social learning. Traditional definitions of teacher and student may no longer apply, as the boundary between the two will become increasingly blurry, and frequent switching between teaching and learning will become more commonplace.

Second, teaching can no longer be restricted by spatial and temporal *boundaries* that current educational systems impose. The Internet, social software, and wireless mobile devices enable relevant and meaningful anytime, anywhere learning, even when teachers and students are not in the same physical or temporal location. This is an extremely important argument for using digital tools for learning, as the disconnect between what students learn in school and the knowledge, skills, and attitudes they need to succeed in life has a tremendous impact on current educational problems, including lack of student motivation, drop-out rates, and a lack of high school graduates who have the necessary skills and knowledge to enter the workforce without substantial amounts of training in the workplace (Partnership for 21st Century Skills, 2004). The fact that the competition for jobs is increasingly global makes the chasm between school and "real" life an even larger issue (Friedman, 2005).

The area of transcending or changing boundaries in teaching is an important yet tricky one to reconceptualize. It necessitates a reconsideration of the locus of control. In a digital environment where learning is no longer confined by boundaries that are set by teachers and administrators, more control (and responsibility) is transferred to the learner. In environments where these boundaries are set, students often find ways around them, learning new things *despite* what they are being taught.

Third, the *content and focus* of teaching must be redefined to be relevant and useful to students and to meet the needs of the twenty-first-century world. As younger generations are increasingly turning toward small and portable technologies and the Internet, and are using digital tools in new and innovative ways, educators should take heed. Students are often far ahead of their teachers in technology skills, but they do need guidance in how to responsibly and safely "use digital technology and communication tools to access, manage, integrate, and evaluate information, construct new knowledge, and communicate with others" (Partnership for 21st Century Skills, 2004, p. 6).

Rethinking Learning

Mobile, connected, and personal digital tools can support both individual *and* social construction of knowledge simultaneously in virtually any context. In particular, students need to be given more control over their own learning. Four areas in which learning should be redefined as more learner-cantered are engagement and motivation, individualization and choice, collaboration and peer learning, and learning for all students.

First and foremost, learning should be *engaging*. A motivated student invests in learning activities and tailors them to his or her needs. Digital technologies engage students when they are used for learning in ways that are meaningful, relevant, flexible, and hands-on (e.g., Farris-Berg, 2005). Because many school-aged children already use digital tools for daily, personal use, teaching students that these same tools can be used for lifelong learning should not be a big jump as long as their use is engaging and motivating. As students become more involved in their learning, they can pursue more complex, inquiry-based, self-directed, and extended learning tasks.

Second, realizing the full potential of digital tools for learning involves *individualization* and student choice. Students can choose because they have access to a wealth of resources beyond the limited resources of the typical classroom (McClintock, 1999). Access to rich collections of materials in a variety of media formats makes it possible to tailor resources and activities. It is up to teachers to guide students in making sensible choices, not to tell them what they should know. Individualized learning with digital tools often yields unique, creative, and high quality work as well, involving higher-order thinking skills and a wide variety of representations to communicate what students have learned.

Third, learning in ubiquitous computing environments needs to be redefined in terms of *collaboration*. While individualization of learning is important, it is fundamentally a social activity (Lave and Wenger, 1991; Vygotsky, 1978). If it is to be student-cantered, learning must involve at least some collaboration, focus on the processes *and* the final product, and emphasize critical thinking skills over memorizing facts. Many digital technologies afford unique supports for collaborative and peer learning activities. Through social software tools and wireless communication, students can easily share and/or work collaboratively (whether this takes place across the classroom or the world), often resulting in higher quality interactions and student work.

Finally, learning needs to be reconceptualized to provide *equal opportunities for all* students. In this context, digital tools can be used to bridge the digital divide, as well as support learning for those students who are struggling in more traditional learning environments, have special needs, or are considered to be gifted and talented (Swan et al., 2005). Equal access to digital tools is a pressing issue in education for a variety of reasons that are related to economic equality and growth, social mobility, and democracy. In societies that are increasingly dependent on online resources it is usually the poorer and underserved segments (e.g., rural areas, inner cities, migrant workers) that lack the access to resources they so desperately need. This lack of access is mirrored in many schools that serve these types of populations, although recent trends in cell phone usage may begin to alleviate problems of access (e.g., see Blunt, 2006).

Rethinking Technology

This area of reconceptualization is probably the trickiest one of the three, and arguably the most important one, as it has important implications for rethinking the other two. The first step in rethinking teaching and learning within a context that includes an amalgam of digital tools is simple, yet radical. Educators need to give technology serious yet critical consideration, without discarding it right off the bat as unsafe, distracting, or unusable. As described earlier, ubiquitous computing environments change traditional learning in that they increase engagement and motivation, provide individualization and choice in addition to increased opportunities for collaboration and peer learning, and learning for all students.

Educators also need to come to understand the different ways in which younger generations are using a variety of tools as an integral part of their lives (e.g., see Lenhart and Madden, 2005; Lenhart et al., 2005; van ‘t Hooft, 2007). This is easier said than done, as the proliferation of new devices and the innovative uses students come up with often leaves adults trailing in the dust. As a result, teachers are often hesitant or plain opposed to the use of digital tools such as cell phones, handheld computers, instant messaging, and blogging for learning, because they do not understand the tools and are afraid of the negative impacts without considering the potential benefits. Students will continue to use technology in their lives whether schools let them or not, and schools are at least partially responsible for working with students on how to use it in safe, productive, and responsible ways, both in and outside of school. Only then will schools and children be able to make the most out of the available technology, while being aware of the hidden dangers such as cyber bullying, Internet predators, or identity theft.

A second step involves a balanced approach to rethinking teaching, learning, and technology. Digital tools are used in all kinds of different jobs to communicate, and to gather, process, disseminate, and access information. Successful companies and individuals adopt new technologies as they see fit and adjust their practices if need be. Increasing globalization, telecommuting, and outsourcing are prime examples. Yet, while the real world adapts to innovations, many educational systems are trying to force the same technology into an outdated educational model to do more of the same, using technology as an add-on. In fact, we need to stop thinking about technology *integration* altogether, but instead see technology as an agent of *transformation* that will enable us to do new things in new ways (Prensky, 2006; Thackara, 2005) and help schools truly prepare students for the world that lies beyond. The current gap between school and the real world is in the long run going to hurt students, putting them at a disadvantage in a world that is increasingly connected, digital, global, and multicultural. If schools do not learn how to embrace the digital tools that students use matter-of-factly in their personal lives and prepare students for the world they will become irrelevant (Friedman, 2005; Gates, 2005).

Once educators learn to consider digital tools in constructive ways, and become involved in a systematic and systemwide rethinking and transformation of teaching, learning, and technology, a third step is to create the actual ubiquitous computing learning environments, both in space and time. Some key elements include the following:

- Access in terms of variety and adequate amounts of digital tools, both hardware and software. A one-tool environment can become very restrictive very quickly, and does not mirror the real world, nor does an excessively filtered Internet.
- A learning environment that transcends the boundaries of the school building and school day.
- Student involvement in decisions that involve the acquisition and use of technology for teaching and learning (Farris-Berg, 2005).
- A supportive, flexible, and sustainable learning environment for both students and teachers. This includes staff development, administrative, curricular, and technical support, and reasonable freedom for students to experiment with tools (Microsoft Education, 2005).
- Support, involvement, and input from the community as well as parents (Thornburg, 2002).

An Example

So what would a ubiquitous computing environment for learning look like? One example of what the future may hold can be found in Philadelphia, where Microsoft and the School District of Philadelphia have collaborated to create a school of the future. The school was designed as an "empowered community where learning is continuous, relevant, and adaptive" (Microsoft Education, 2005). Technology is being used in all areas of learning, such as curriculum delivery, community involvement, and content creation, dissemination, and assessment. Students and teachers are using a variety of technologies as appropriate, and include wireless laptops with high-speed Internet access and smartboards linked to resources from many entities, all in an environment that includes flexible learning spaces and an interactive learning center (Maskova, 2006).

Another example is MyArtSpace, a UK learning pilot that connects learning between schools and several museums using mobile phones and personal Web space. It allows students to navigate physical, personal, and virtual spaces. "The aim is to make a day out at the museum part of a sequence that includes setting a big question in the classroom, exploring it through a museum visit, reflecting on the visit back in the classroom or at home, and lastly presenting the results. The technology provides the essential link across the different settings" (Vavoula et al., 2007).

Conclusion

The current educational system is far removed from where teaching and learning would be in an ideal world. Systemic changes will take lots of time, effort, and resources. So how do we get from where we are now to where we want to be and should be? Obviously, we cannot move from one to the other without some intermediate steps. Whatever these steps may be, they should at least include the following components (see also Breck, 2006; Hedberg, 2006; Thornburg, 2002):

- Community involvement and support (from both adults and children).
- Creating better matches between learning tasks, technology, and context (including workforce needs), both in and outside of school.
- Breaking down the existing barriers between school and community; i.e., learning does not end when exiting school at the end of the day. It is anywhere, anytime, and lifelong.

Personal, mobile, and connected technologies can and should play an important role in this process, as they can provide the bridge between institutes of education and their surrounding communities in many different ways. Digital tools that learners are already using on a daily basis should be seriously considered as tools for learning in formal learning environments. Only then will learning become the "seamless, ubiquitous, cognitive experience" that Breck envisions and that will be relevant and meaningful to our children.

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9.4

USE OF WIRELESS MOBILE TECHNOLOGY TO BRIDGE THE LEARNING DIVIDE

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Introduction

A major problem the world is facing today is the gap between students who have access to learning resources and support for learning and development and others who do not have access. As a result, the literacy rate and education level in remote areas and developing countries are very low, resulting in a low standard of living (see Resta and Laferrière, 2008, in this Handbook for information about adult illiteracy rates worldwide). Students who live in developing countries and in remote parts of the world and those who cannot afford to go to school do not have access to learning resources for intellectual growth and development. The inability to access education is due to the long distance from the nearest school or library, lack of transportation, not enough finance to attend school, family responsibilities, and having to work at a young age. In addition, in some remote locations, there are not enough teachers to teach, coach, and mentor students. As a result, there is a gap between those who have and those who do not have access to learning materials, which is called the learning divide. The definition of the learning divide is the gap between those who have access to learning materials and those who do not have access because of technical reasons, financial reasons, and location. Because of the learning divide, millions of young minds are being wasted and robbed of their intellectual and creative potentials. Educators have the responsibility to eliminate the learning divide to make sure that students in remote locations and in developing countries have adequate access to learning resources and support.

The use of wireless mobile technology in remote locations and developing countries may improve students' accessibility to learning materials, and therefore narrow the learning divide. Mobile distance-learning programs can de designed to allow

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educators to reach students in remote locations and developing countries. Mobile distance learning is the delivery of electronic learning materials, with built-in learning strategies, for delivery on mobile technology to allow access from anywhere and at anytime (Ally, 2005). Included in mobile distance learning is supporting student learning through online collaboration and mentoring and building of learning communities using emerging technology. The technology allows for both synchronous and asynchronous support which could cater to students with different learning styles (Ally and Fahy, 2005). Synchronous communication technology could be used to provide immediate feedback and online collaboration, while asynchronous communication could be used when students need extra time to reflect or complete a task before collaborating with other students.

There are initiatives underway to develop affordable emerging technology for students of developing countries to access learning materials and information from their locations and to facilitate mobile distance learning, such as the one laptop per child (OLPC) initiative from the Massachusetts Institute of Technology (OLPC, 2006). In addition to having wireless capability, these emerging devices will require little power or the use of alternate power sources, which makes them ideal for remote areas and developing countries.

This chapter will discuss how emerging technology can be used to bridge the learning divide, how to design learning materials for delivery on emerging technology, and providing support using these technologies.

Capabilities of Wireless Mobile Technology

According to Rheingold (2003), mobile technology will be common in education since they are becoming ubiquitous. As a result, educators must prepare to design and delivery learning materials on these emerging technologies. There are many benefits of using emerging technology to bridge the learning divide. Mobile technology can be used in mobile distance learning to allow students to access information and learning materials from anywhere and at anytime. With the use of wireless technology, mobile devices do not have to be physically connected to networks to access information, which is a major limitation in remote locations and developing countries. At the same time, mobile devices are small enough to be portable, which allows students to take the device to any location to access information or learning materials. However, before mobile technology can be effectively used in mobile distance learning, the learning materials must be designed properly and in the context of the learner so that the learning is meaningful.

The Design of Learning Materials for Wireless Mobile Technology Devices

Before educators can use wireless mobile technology to deliver learning materials, the learning materials must be developed for the devices and in the context of the students so that the learning is meaningful to the students. There have been limited attempts to design and deliver learning materials using mobile wireless technology. The European MOBILearn initiative has been conducting the groundwork on the design for mobile learning by investigating pedagogical models and guidelines for designing for mobile devices to improve access of information by students (MOBILearn, 2004). Ally and Lin (2005) developed an intelligent agent to recognize the mobile devices students are using and format the content for specific mobile devices. In this way students have the flexibility to use a variety of mobile devices to access learning materials. There is also ongoing research in the area of Mobile Libraries on how to format library resources materials for delivery on emerging technology (Ally et al., 2006).

Since human beings have limited processing capacity in working memory, information should be chunked. When developing learning materials for mobile technology, the materials must be in electronic format and must be developed in small chunks. Chunking is important for mobile technology that has small display screen, such as cell phones, PDAs, etc.

The materials must be developed in the form of learning objects which give students the flexibility of accessing learning materials from anywhere and at anytime to meet their learning needs. A learning object is defined as any digital resource that can be reused to achieve a specific learning outcome (Ally, 2004; McKenney et al., 2008). Learning objects are stored in digital repositories and tagged for easy retrieval. An information object is information presented in different formats, such as text, audio, graphic, or video, that are not tied to a learning outcome. A learning object consists of one or more information objects. Information objects and learning objects allow for instant assembly of learning materials by users and intelligent software agents to facilitate just-in-time learning and information access by students in remote locations and developing countries. A learning session using a mobile device can be seen as consisting of a number of information objects sequenced in a predetermined way or sequenced based on the user needs. The learning object approach is helpful in a constructivist approach to learning where students will access learning materials just in time as they complete projects.

When designing learning materials for mobile distance learning, the students must be kept in mind since students have different learning styles and preferences (Mayer and Massa, 2003). For example, visuals can be used at the start of a lesson to cater for students to get the big picture before they go into the details of the information. For active learners, strategies should be used to give the learner the opportunity to immediately apply what they learn. To encourage creativity, there must be opportunities to apply what was learned in real life applications so that students can go beyond what was presented. The use of wireless mobile technology will make it easier to cater for students' individual differences since the system can be programmed to determine students' preference and prescribe the appropriate learning strategy based on the preferences.

Designers of mobile distance-learning systems must develop intelligent agents to learn about the student during interaction with the student and adapt the interface to meet the student needs and preferences. Intelligent software systems can be built to develop an initial profile of the user and then present materials that will benefit the specific user, based on the user profile. As the intelligent agent interacts with the user, it "learns" about the user and adapts the format of the information, the interface, and navigation pattern according to the user's style and needs. Knowing the user needs and style will allow the intelligent software system to access additional materials from learning object repositories and other networks to meet the needs of user (Cook et al., 2004). The interface must allow the student to access the learning materials with minimal effort and move back and forth with ease. The flexibility of moving back and forth within a lesson is important in project-based learning, since students should be able to jump to different parts of a lesson as required.

To facilitate exploratory learning and to allow students to explore during the learning process, a constructionist approach to learning must be used. Learning must be project-based to allow learners to build things, to experience the world by doing things rather than passively listening to teachers, to think critically, and to develop problem-solving skills (Page, 2006). Papert (1991) describes constructionism as "learning-by-making," which suggests that learning should be an active process. Mobile technology facilitates project-based learning since students can learn anywhere and anytime. For example, as students complete a project in their natural environments, they can use the wireless mobile technology to access just-in-time information as they complete the project.

When using mobile technology, an appropriate interface is required for students to interact with the learning materials. A simple interface must be built to prevent cognitive overload of the student. One way cognitive overload can be prevented is to organize the information on the device in the form of concept maps. Students will be able to use the concept map as a navigational tool to access different parts of the learning resource. Tusack (2004) suggests the use of a form of concept map called site map as the starting point of interaction in a lesson that users can link back to in order to continue with a learning session. Concept maps may also support the learning process. A concept map or a network diagram can be used to show the important concepts in a lesson and the relationship between the concepts rather than present information in a textual format. High level concept maps and networks can be used to represent information spatially so that students can see the main ideas and their relationships in a lesson. There are tools available to develop concept maps for mobile devices. Luchini et al. (2004) describe a tool called Pocket PiCoMap which is used to develop and edit concept maps on mobile devices.

Use of Wireless Mobile Technologies in Practice

There are many projects that are investigating the use of mobile technology in education. Ally et al. (2007) reported on a project that redesigned English grammar lessons for delivery on cell phones. The contents of the lessons are in the form of learning objects that allow for flexible delivery on mobile devices. The lessons also consist of evaluation items to give students practice on the use of English grammar and to test students' achievement. The English grammar lessons can be accessed by students who are studying English as a second language. Because students can use wireless mobile technology to access the lessons from anywhere and at anytime, they can stay in their home countries and remote locations to access the learning materials. The mobile delivery system was tested on a group of students. Results showed that students like the flexibility of learning anywhere and at anytime using their cell phones. Student performance also improved upon completion of the lessons. Because of the wireless capability of mobile technology, students from anywhere around the world can access the English grammar lessons to improve their English. Recent statistics showed that people in developing countries are acquiring cell phones at a fast rate for personal and other uses. These cell phones can also be used by children in the developing countries to access the English grammar lessons to learn English.

Mifsud (2005) investigated students' perception when using handheld devices to learn. Data were collected using observations and interviews with primary school students and teachers over a 4-week period. Students reported that they prefer to do their writings on the handheld device rather than on paper. There could be many reasons for the preference to use the handheld device for writing. One explanation could be that young students are familiar with the technology and they are comfortable using it. Another explanation is the flexibility the handheld provides for writing of text. One could also conclude that the novelty of the device could be a reason why the students prefer the handheld for writing. The study also reported that students used the mobile device both at home and in school, which indicates that they used the mobile device to learn anywhere and anytime. An important result from this study is that students saw the mobile device that was assigned to them as a personal device.

As a result, they customized and labeled the device, and it was not open for other students to look at. An important conclusion can be made from this study. Students look at mobile technology as being part of them and not something external. They are very comfortable using the device. The researcher concluded by suggesting that in order for mobile technology to be more acceptable as a delivery tool for learning materials, teachers must accept the technology and be comfortable using the technology. This will require extensive teacher training on the design and delivery of learning materials using mobile technology.

Conclusion

As mentioned in the introduction section, the learning divide is present because students are long distances away from schools, there is lack of transportation to attend schools, some families do not have the finance to send their children to schools, there are no libraries in remote locations, and there is a lack of teachers to teach students. The following paragraphs describe how emerging technologies can help overcome these problems to bridge the learning divide.

The use of emerging technology, such as mobile devices with wireless capability, will allow access of learning materials and information from anywhere and at anytime. This emerging trend will allow students who live in remote locations and in developing countries to have access to learning materials and information without having to leave their communities and, at the same time, assist them to learn in context.

For example, mobile devices will allow students to use Global Positioning Systems to determine which students are in close proximity so that they can meet with these students to work face-to-face on collaborative projects. The face-to-face interaction is important for some learning outcomes, especially for younger students to develop their interpersonal and intrapersonal skills. Because of recent initiatives to make computing power more affordable to all, there will be exponential growth in the use of mobile devices to access learning materials, since the cost of the devices will be lower than that of desktop computers and students can access information from anywhere and at anytime. Hence, educators should design courses for delivery on the emerging technology and they must be able to function in this new delivery method. This has implications for teacher training. Teachers must be able to develop learning materials in the student context, using familiar examples and materials that students in remote locations and developing countries can relate to. However, the teachers do not have to be in the same locations as students to teach the students. They will be able to use the emerging technologies to teach and tutor the students from a distance. However, there are some challenges that should be addressed before the use of wireless mobile technology can be implemented in education, especially in remote locations.

Teachers must be trained on how to design courses and use the mobile technology to deliver instructions to students. Courses must be designed in the form of learning objects to facilitate delivery on small screens. At the same time, less text and more information-rich medium such as video, graphic, picture, and audio must be used when delivering learning materials on mobile devices. The teacher's role will change from being a presenter of information to a tutor and facilitator of learning. For the delivery of the learning materials, a learning management system for mobile technology must be in place to help the teacher and student manage the teaching and learning processes. In remote locations, there must be affordable wireless access for students to be able to access learning materials from anywhere and at anytime. Countries that do not have the infrastructure to access the Internet can skip the task of laying wires for hard-wired connection and go directly to the wireless infrastructure.

From an implementation point of view, the use of wireless mobile devices would be more economical since it does not require the building of the infrastructure to wire buildings. The challenge for teachers is how to standardize the design for use by different types of devices. To make the learning process transparent for students and teachers, it is important to build intelligent software agents into emerging technology so that most of the work is done behind the scene, minimizing the input from students and the amount of information presented on the screen. Finally, educators, innovators, and manufacturers of emerging technology must work together to develop technology that can be used to enhance learning and delivery so that the digital divide can be decreased or eliminated. An excellent example of this type of initiative is the development of the $100 laptop (OLPC, 2006), which will be used by students in remote locations and in developing countries.

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9.5

INFORMATION TECHNOLOGIES FOR INFORMAL LEARNING IN MUSEUMS AND OUT-OF-SCHOOL SETTINGS

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Introduction

In the last two decades, early K-12 education technology experiments have generated many rich educational experiences and instructional resources that incorporate multimedia content, digital video, large data sets, visualizations, and collaboration tools. Tested and evaluated through scholarly and empirical research, many early ideas have become successful blueprints for current educational uses of technology. While information technology (IT) continues to transform primary and secondary education in important ways, it is also transforming learning in everyday settings and in informal learning institutions that offer educational programs and opportunities to school-aged learners. There is a growing recognition that most young people spend more of their hours in learning environments outside of school and that this informal learning time is equally important in their overall preparation for future work and lifelong learning (Rennie et al., 2003; Bransford et al., 2006). Many innovative educational applications, tools, and experiences are being specifically designed to capture the interests and attention of learners to support everyday learning.

Transformed by the presence of IT, informal learning institutions (such as public libraries, museums, zoos, aquaria, community outreach centers, and after school programs) are creating freely available educational resources accessible over computer networks and the Web to create extended learning opportunities outside of formal schooling. Concurrently, informal learners are assimilating new IT technologies and transforming them into new practices and applications to support their curiosity and interests.

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This chapter begins by providing examples of IT applications to illustrate how IT is being used across multiple informal learning settings. These examples are then followed by a closer look at how learners are using information technologies in novel ways.

IT Transforming Informal Learning Institutions

Information technologies are being used in museums and science centers to augment learning with onsite visitors before, during and after their visits, as well as to extend the reach of institutions to remote learners.

Technologies for Informal Science Learning in Museums
IT Augments the Museum Experience (Kiosks and Immersives)

A prevalent use of IT in museums is found in computer kiosks or computer touch screen displays that provide additional interpretation of objects or exhibitions using interactive multimedia. They often provide interactions not possible in the physical context of museums, such as time lapse experiments, zooming by powers of ten, or making the invisible visible through virtual magnification. While computer kiosk technology itself is not new, informal learning institutions contribute different activity structures to engage school-aged audiences with new science topics. One example is Nanozone© (http://www.nanozone.org), which is both a website and an exhibition at the University of California Berkeley's Lawrence Hall of Science (USA). Targetted at 8- 14-year-old audiences, the content focuses on four areas of nanotechnology: size and scale, nanotechnology scientists as people, new applications, and the change in physical properties at the nanoscale. An interactive floor exhibit in a public science center called *The FabLab* allows three visitors to play collaboratively in a game scenario to answer four open-ended questions related to the life of a scientist and nanoscale research. Teams are asked to select a hypothesis that answers one question, then interview 15 university graduate students through prerecorded digital video, to gather data to test their theory. Teams then have the opportunity to compare their final conclusions with those of the last several teams to visit the exhibit.

Other innovative applications have been developed in science centers that make use of full-body interactions, often using haptic feedback, video conferencing technology, and high-speed networks to support real-time applications. Immersive digital interactives (cf. Eric Siegel, NY Hall of Science) are a new genre of physical exhibits that use an infrared interface, computer projections, and shadow-capture to create full-body interactivity with a digital world. For example, museum installations by artists (e.g., Zachary Booth Simpson, http://www.mine-control.com/) have enabled visitors to create snowflakes constructed from virtual water molecules that begin to freeze when the visitors put their hands on a wall projection, or walk across a virtual pond to create ripples and interference patterns. Through direct experience and manipulation with virtual objects, the informal learner builds their intuitions about basic scientific phenomena. Through whole-body movements, a visitor can paint a virtual canvas to create Mondrian paintings or play a group game of sorting giant coloured marbles. Some exhibits take advantage of force feedback systems and video conferencing to enable visitors to arm wrestle in real-time with another visitor in a remotely located museum via a mechanical arm at the New York Hall of Sciences (USA), the Tech Museum, and four other locations. Unlike small-screen kiosks, which can be replicated on the Internet for home use, these uses of IT take full advantage of the public learning space in museums.

Information technologies such as wireless handheld technologies (e.g., PDAs, MP3 players, or mobile phones) have also been used in museums for object interpretation and education at the Exploratorium, the Getty Museum, Liberty Science Center, and the San Francisco Museum of Modern Art. Interactive multimedia content delivered via wireless networks provides historical context or background science information to a visitor's handheld device to promote further appreciation and learning from exhibitions (Exploratorium, 2005; Hsi, 2003). Audio guides, available on familiar devices such as Apple iPods and personal cell phones that young learners use everyday, also make it more appealing to visitors and easier to access the learning materials (Samis, 2007).

IT Extending the Museum Experience (Pre- and Post Activities)

IT can also extend onsite museum experiences with pre- and postvisit activities that are made available on the Internet. For example, previsit activities at the above-mentioned Nanozone exhibit (downloadable from the website http://www.nanozone.org) help parents and educators introduce sizes and products at the nanoscale to learners before visiting. Expanding previsit activities from an exhibit-centric model to a museumwide approach, the Exploratorium in San Francisco (USA) has developed learning resources called "Pathways" for educators who take children on field trips to the museum (http://www.exploratorium.edu/pathways/index.html). Two formats are provided that allow either a guided pathway that provide a set course of exploration, or an open pathway that suggests creative ways for the educator to structure a field trip to motivate learners.

In addition, the Exploratorium has experimented with radio frequency identification (RFID), a tagging technology. Visitors can use RFID to link to personal media created and captured onsite (such as digital photo of the visitor taken from a heat camera exhibit). This media is stored on a Web server for later viewing at home or in a school classroom on a personal Web page along with other suggested online and off-line inquiry activities (Hsi and Fait, 2005; Fleck et al., 2002). Similarly, the Tech Museum in San Jose (USA) has been using RFID chips embedded in plastic bracelets worn by visitors to track which exhibits have been visited and to trigger exhibits to display information, and to allow visitors to access results of genetic experiments visitors carried out while at the museum. In these examples, IT is used to provide extended learning opportunities to link a museum learning experience to further learning activity taking place in other settings.

IT for Distant Learners and Browsers of Museum Experience

Science centers and museums have also developed standalone virtual explorations using the Web to promote interest in science among remote learners. The Exploratorium websites on everyday science topics such as music, cooking, sports, and gardening as a starting point for learner engagement, combining digital video interviews of local community members, online bulletin boards, and animations to engage learners of all ages. In one media interactive on the Accidental Scientist Music site, multiple users from any location around the world can join a virtual drum circle to collaboratively create rhythms and sounds from different instruments.

Web syndication tools such as Real Simple Syndication (RSS), a tool that allows content to be automatically drawn from a content-rich website and published onto a different website, have allowed learners to receive the latest science news in French from "Sciences Actualites" offered by the Cité des Sciences and Industries or in English via "Science Buzz" (http://ltc.smm.org/buzz) from the Science Museum of Minnesota (USA). Learners can subscribe to news feeds that are then published dynamically onto their personal or school's websites to follow the latest stories in science, as well as pose questions to scientists and participate in community-wide discussions via a Web-based bulletin board on the website.

Digital Libraries to Organize Collections in Art and Science Museums

Another place in which IT is helping to transform informal learning institutions is in the area of digital libraries, which provide organized access to high-quality learning and teaching resources for educators and school-aged children. Digital libraries provide multiple views of the structure of a domain, an approach that has been found to be important for learning (National Academy of Sciences, 2002). For example, the US National Gallery allows users to search their database in several different ways: artist names, the medium used to create the art, or subject themes (http://www.nga.gov/collection/srchart.shtm#site). Combined with a general zooming image viewing tool, learners can study close-ups of art masterpieces on their virtual field trips to the gallery. They can also create their own paintings, starting with a template from an online original art piece and virtual stamping and colouring tools. The Brooklyn Children's Museum has used their digital library to create an online museum called "Collections Central Online" (http://www.brooklynkids.org/emuseum/code/emuseum.asp) where learners can try their hand at drawing one of the 27,000 different cultural artefacts and natural history specimens available for viewing and exploring via the Web. While examining a digital library record of a kpwan mask, for example, learners find out about the Baule people of the Ivory Coast, local material resources used to make masks, their rituals and celebrations, and other related artefacts found in West Africa.

Another digital library is the National Science Digital Library (NSDL) created by the National Science Foundation to provide organized access to high-quality resources and tools that support innovations in teaching and learning at all levels of science, technology, engineering, and mathematics education. The NSDL includes collections such as Fun Works EDC (http://thefunworks.edc.org/), which support awareness and learning about science, technology, engineering, and math careers for girls, as well as collections of hands-on inquiry-based activities and images from a Microscope Imaging Station exhibit from the Exploratorium Digital Library (http://www.exploratorium.edu/educate/dl.html). A recent shift in the creation of digital collections is marked by social networking in which, rather than cataloging by professional librarians and archivist, distributed users not only annotate and tag items in the collection, but use folksonomies to browse personal collections in website using Web services tools. Internet search tools, combined with the organization and tagging provided by digital library projects, allow students to benefit from just-in-time access to learning resources in and out of school.

IT for Educational Outreach and After-School

After-school programs have also used IT, often to encourage youth to be discerning new media consumers and fluent new media producers. Around 6.5 million students are already in organized after-school programs in the USA, and the number of students attending these programs is rapidly growing (Noam et al., 2003). Not surprisingly, after-school programs have been the focus of recent national policies and state initiatives as a place to provide remediation, homework assistance, tutoring, and other educational enrichment to youth in low-performing schools (TERC, 2004; US Department of Education, 2003). In addition to providing these resources, exemplary after-school programs incorporate youth development strategies – they structure activities to encourage students to develop and follow their interests, make choices about learning activities, and construct their own understandings (Educational Development Center, 2002). For example, in a Chicago-based research project, researchers are investigating how urban youth develop new media literacy that is personally meaningful and intertwined in their interactions with friends and family, at school, after-school, and in their communities, given that access to both informational and human resources are limiting factors that prevent youth from fully developing new media literacy (N. Pinkard, personal communication).

Similarly, the Fort Worth Museum of Science and History (USA) offers a program called "Design IT Studio" where minority and low-income 7th and 8th grade students create projects springing from the children's own cultural backgrounds and interests, incorporating commonplace materials with digital media to naturally create fluency in IT. Students use IT programming tools to be creative, including use of the MicroWorlds program (http://www.microworlds.com/) to connect the real world to virtual environments. For instance, students used these technology tools to make sensors that track the movements of squirrels and wind in the trees in the museum courtyard and then display the results graphically, create robotic music makers, and animate their own stories. In these examples, the IT and its setting are designed with pedagogical supports provided by workshop facilitators and mentors to encourage inventiveness, creativity, and ownership using IT tools as a medium for constructive activity and learning.

Informal Learning Transforming IT Activities

While it is evident that IT is transforming different informal learning contexts, settings, and institutions, informal learners are concurrently assimilating new IT technologies and transforming them into new practices and applications to support their curiosity, interests, and hobbies.

Distributed Data Collection

IT is providing access to previously inaccessible authentic practices. One example is citizen science projects, which allow youth to engage in scientific practices side-by-side with learners of all ages. In the 1990s, tools were rapidly developed to allow communities to form around hobbies and interests, allowing the Internet to be a social gathering place by supporting international correspondences, community discussion boards, and other online discussions via early technologies such as listservs, bulletin boards, and Internet relay chat. As early as 1986, the largest networked-based curriculum (National Geographic Society's Kids Network (TERC, 1990) engaged kids in being citizen scientists, reaching over 250,000 children. These early innovations allowed children to collect environmental data, share it across the network, and analyze the resulting combined data. These activities are still being supported by IT that permit distributed communities to contribute data, such as the Great Backyard Bird Count (http://www.birdsource.org/gbbc/), sponsored through the Cornell Lab of Ornithology (USA), in which citizen scientists and hobbyists can contribute bird lists to a database for monitoring the numbers, kinds, and distributions of birds across the USA and Canada. An individual learner who has access to the Internet from home or the public library can now access and be apprenticed in authentic science practices in truly global investigations.

Low-Barrier Authoring and Media Creation

As IT tools enable users to tailor their online learning environments with Web 2.0, learners, especially teens, are taking advantage of creating their own messages and adapting tools to meet their needs (Lenhart and Madden, 2005). For example, learners are creating publicly viewable online journals, online avatars, personal profiles, website bookmarks, podcasts, animations, and webcasts. Like the citizen science projects, these technologies allow users to engage in a community of practice, but they also support users in active identity construction. A learner's view of him or herself (and his or her abilities) is an important factor in their learning and making life choices, and online environments that allow identity construction empower youth to explore personal and moral issues (Bers, 2001). A personal Web page authored by one person is now being replaced with blogs, also known as weblogs. Blogging is currently popular especially among young adults to share new discoveries, personal adventures, and other timely information. Similarly, wikis, which allows simple Web pages to be built collaboratively and quickly, have also allowed distributed participants to coauthor stories and art around interests, hobbies, and fan clubs, such as Fiction Alley, a site for Harry Potter fans (http://www.fictionalley.org/). The act of creating the Web pages in this context mirrors learning-by-doing and writing in guilds to build literacy practices of all the participants. With more sophisticated end user and developer tools, learners can now take the form of two-dimensional avatars such as those found in Whyville.net, an online community with online games and text chat for youth. MySpace.com has enabled the creation of personal profiles, listing friends, favourite websites, image collections, and other personally meaningful digital information.

IT is also enabling social bookmarking with tools such as del.icio.us and ma.gnolia.com which allow users to save Web addresses in publicly accessible repositories, and to augment the saved addresses with customized keyword tags (which can be as straightforward or as idiosyncratic as the users would like them to be). This kind of structured bookmarking provides another way to learn by pointing the student to bookmarks made by friends or those with similar interests (e.g., http://www.stumbleupon.com), another form of peer-to-peer learning.

Authoring need not be limited to Web pages. Audio museum guides, once designed only by museums, now can be created as a podcast by anyone and shared in an online commons, such as the Exhibit Commons hosted by the Liberty Science Center. From a learning perspective, learners can construct their own knowledge about an exhibition, share divergent points of view, and be active contributors rather than passive recipients of knowledge. In another example of low-barrier media creation, Flipbook Deluxe, a free animation tool (http://www.benettonplay.com/toybox.php) on the Internet, allows school-aged children to be expressive and creative via a simple Web interface, and contribute their animations to a global community and guild of other creators.

Webcasts offered by science centers are no longer one-way media experiences. When live webcasts are combined with live text chat, near real-time e-mail responses from producers, and virtual worlds, webcasts turn passive viewing into active participation. In a recent experiment, a live webcast of the March 2006 solar eclipse was projected in a virtual amphitheatre developed in Second Life (http://www.secondlife.com/). Participants from around the world viewed the totality of the solar eclipse in a virtual meeting place while holding online conversations, answering each other's questions, and capturing and sharing digital snapshots of the event (Rothfarb et al., 2006). With the wider availability of broadband Internet, three-dimensional virtual environments are providing another venue for informal learning.

Digital Learning Games

The role of online games for learning and teaching has recently been capturing the attention of school-aged children, researchers, designers, parents, and educators alike. Because of their motivational hold on youth (from compelling narratives, activity structures, scaffolding, dynamic feedback, high-quality imagery, personalization, and collaborative opportunities), online games are being studied as a possible venue for education (see Barab et al., 2006; Gee, 2003). Researchers, social scientists, and philosophers of education are studying language, representations, and collaborations that take place in massively multiple player online role playing games (e.g., World War Craft, City of Villains, Civilization III), and in specific cases, designing online game environments for the purposes of study learning, discourse, and development (see Quest Atlantis, http://atlantis.crlt.indiana.edu/) (Gee, 2003; Squire and Jenkins, 2004; Steinkuehler, in press) Rather than focusing on learning "content," the learning potential comes from the actions and decisions made by the player in a complex system of resources, social interactions, negotiations, and spatial navigation. In addition, newer Internet-based games are spawning companion websites that allow youth to trade or auction online items that they create in the game, such as avatar clothing, virtual tokens, and other accessories online, as well as make screen recordings of their favourite period during game play to share with other online players as evidence of an accomplished feat in the game. These games need not be solely online: the prevalence of Internet-capable devices (such as cell phones) allows players to engage in mixed-reality experiences that often combine real-world wayfinding with online game content – an approach easily adoptable by informal learning institutions.

Trends for the Future

As more IT (like ubiquitous wireless access, Web-enabled phones, and low-cost portable computers) becomes widely available, research and development will need to view IT not only as a tool for productivity and training in formal settings, but also as a context for designing meaningful informal learning experiences: creating interactions, online social spaces, media-rich representations, interest-driven activities, and communities for learning as bridges to formal schooling and to personal interests and everyday hobbies.

A general trend is that information technologies are becoming more and more distributed, changing the scope and geographies of children's learning environments. Learners have multiple opportunities to take a more active role in defining and choosing when and what activities they engage in and with whom in everyday settings. However, ensuring that IT will be used effectively to advance education will require careful design and evaluation to ensure that the settings and social contexts of IT use are both ethnical and prosocial, providing equitable access to a diversity of groups and users while also allowing personalization to occur.

The increasing global prevalence of portable digital capture technologies and high-speed networks is spawning a huge community of amateur media producers. New media literacy to critique authentic, reliable sources of digital information will need to be part of the educational process to ensure that the next generation of learners can discern fact from fiction, critique the quality and reliability of evidence from digital sources, make informed opinions, and synthesize new knowledge (see Hsi, in press). Young learners will need these skills to be able to navigate and make sense of the wider scope and geography of their domain, to take advantage of the many extended learning opportunities possible through IT. Informal learning institutions – museums, community-based after-school programs, science centers – have an opportunity to work with schools to bridge the experiences of children to provide a more coherent learning experience.

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9.6

EMERGING TECHNOLOGIES FOR COLLABORATIVE, MEDIATED, IMMERSIVE LEARNING

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Introduction

Three complementary technological interfaces are now shaping how people learn, with multiple implications for K-12 education (Dede, 2002).

- The familiar "*world-to-the-desktop*" interface provides access to distributed knowledge and expertise across space and time through networked media. Sitting at their laptop or workstation, students can access distant experts and archives, communicate with peers, and participate in mentoring relationships and virtual communities of practice. This interface provides the models for learning that now underlie most tools, applications, and media in K-12 education.
- Emerging *multi-user virtual environment* (MUVE) interfaces offer students an engaging "Alice in Wonderland" experience in which their digital emissaries in a graphical virtual context actively engage in experiences with the avatars of other participants and with computerized agents. MUVEs provide rich environments in which participants interact with digital objects and tools, such as historical photographs or virtual microscopes. Moreover, this interface facilitates novel forms of communication among avatars, using media such as text chat and virtual gestures. This type of "mediated immersion" (pervasive experiences within a digitally enhanced context), intermediate in complexity between the

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real world and paint-by-numbers exercises in K-12 classrooms, allows instructional designers to construct shared simulated experiences otherwise impossible in school settings. Researchers are exploring the affordances of such models for learning in K-12 education (Clarke et al., 2006; Barab et al., 2004).

– *Augmented reality* (AR) interfaces enable "ubiquitous computing" models. Students carrying mobile wireless devices through real world contexts engage with virtual information superimposed on physical landscapes (such as a tree describing its botanical characteristics or an historic photograph offering a contrast with the present scene). This type of mediated immersion infuses digital resources throughout the real world, augmenting students' experiences and interactions. Researchers are starting to study how these models for learning aid students' engagement and understanding (Klopfer et al., 2004; Klopfer and Squire, in press).

How Collaborative Mediated Immersion Helps Teaching and Learning

Immersion in virtual environments and augmented realities shapes participants' learning styles, strengths, and preferences in new ways beyond what using sophisticated computers and telecommunications has generated thus far, with multiple implications for K-12 education. Dede (2005) describes learning styles enhanced by mediated immersion in distributed-learning communities based on MUVE and AR interfaces: (a) fluency in multiple media; (b) learning based on collectively seeking, sieving, and synthesizing experiences, rather than individually locating and absorbing information from some single best source; (c) active learning based on experience (real and simulated) that includes frequent opportunities for reflection; (d) expression through nonlinear, associational webs of representations rather than linear "stories" (e.g., authoring a simulation and a webpage to express understanding, rather than a paper); and (e) codesign of learning experiences personalized to individual needs and preferences. These capabilities reflect students' media-generated learning strengths and preferences on which instruction should build to maximize educational effectiveness.

If we examine students' technology use outside of school, we see these shifts in learning styles happening in their informal, voluntary educational activities. For example, although one kid sitting in front of a console game is still prevalent, collaborative, mediated gameplay is rising. X-box live and Nintendo DS devices enable participants to interact during gameplay across distance and space. Massive multiplayer online games, such as the World of Warcraft (Blizzard Entertainment) and Everquest (Sony Online Entertainment), bring players together online where they can interact in a virtual collaborative context. Emerging communities such as "modding," in which users create new content for games (often contributing to a shared database of models), and "machinima," in which users create new content via video capturing techniques, are further shaping how kids now express themselves via collaborative digital experiences. Youth are forming networked communities around games and movies, in which they share codes and strategies and build collaborative clans working together to fulfill quests. In their learning processes, many of these distributed communities among kids parallel the activities of twenty-first century professionals in knowledge-based workplaces.

Despite the proliferation of sophisticated technology use outside of schools, typical classrooms seldom leverage any of the three interfaces described earlier for teaching and learning. Moreover, when employed computers and telecommunications are generally used to streamline the delivery of content, ignoring information technology's capabilities to (1) support learning in real-world contexts, (2) connect learners to experts and communities of peers, (3) provide visualization and analysis tools for thinking with data, (4) scaffold problem-solving that enables more complex reasoning than possible otherwise, and (5) enable opportunities for feedback, reflection, and revision of knowledge construction (Bransford et al., 2000). To provide visions of how this situation could improve, we offer two examples from our own research of how interfaces for immersive-mediated experiences can now shape students' learning in K-12 education.

Multi-user Virtual Environments

MUVEs can offer learning experiences intermediate in complexity between follow-the-recipe laboratory sessions and the intricacy of real world situations inaccessible to K-12 students, such as tracking the spread of a disease in a community. A project funded by the National Science Foundation to enhance middle school students' educational outcomes in science is conducting design-based research on one such MUVE-based learning experience, River City (http://muve.gse.harvard.edu/rivercityproject/). Students leave their classroom setting to travel through a historically accurate nineteenth century virtual city (Clarke et al., 2006). They try to figure out why people are getting sick and what actions can remove sources of illness. They talk to various residents in this simulated setting, such as children and adults who have fallen ill, hospital employees, merchants, and university scientists. Participants go to different places in the town and collect data on changes over time, acting in gradually more purposeful ways as they develop and test hypotheses. They help each other and also find experts and archives to guide them. Further, students use virtual scientific instruments, such as microscopes to test water for bacteria. This immersive simulation allows them to conduct an experiment by changing an independent variable they select, then collecting data in the city to test their hypothesis. Students not only hypothesize what would happen if a sanitation system were built – they can actually visit the city with a sanitation system added and see how this change affects the patterns of illness. To illustrate these capabilities, the following vignette portrays a student experiencing the River City MUVE as an engaging means of learning inquiry, biology, and epidemiology through collaborative mediated immersion.

Violet reenters the time portal. She looks around and sees that the rest of her classmates are filtering in behind her. She selects a date and is teleported back in time to July 1879. Violet finds herself in River City, a nineteenth-century industrial city plagued by illness. She is standing by the train depot and starts to walk toward the hospital, the location she and her teammates have designated their meeting area. Violet sees her classmate Jabbers and waves; Jabbers waves back. Violet observes that the rain has stopped and that there is manure in the street. The streets look dirty!

Violet stops to talk to Lance Henry, a man who works in the hotel, and he tells her that it has not rained in weeks and that a summer storm was needed to wash the filth and manure out of the streets. Violet then interviews Miss Howell, another resident of River City who is on her way home from the market. Miss Howell tells her that there were not many people in the market today. Violet ponders what is keeping them away: the fear of getting sick, or all the mosquitoes and bugs. Violet records her conversations with Lance and Miss Howell in her data log. Back in April, Miss Howell complained about the mosquitoes by the bog.

This is Violet's last opportunity to collect data before developing a hypothesis. After doing exploratory research, she and her team identified that the bog was a problem. They observed many mosquitoes by the bog and were told that children who play near it have bug bites. In contrast, Violet's friend Jabber and his team identified the effluent pipe flowing into the river from the wealthy neighborhood as their problem. Violet is glad that each team gets to choose its own problem to explore, because she is interested in learning more about the mosquitoes.

During the remainder of the curriculum, Violet and her teammates will refine their hypothesis, and then design an experiment. They will visit River City two more times in order to conduct the experimental and control portions of their research method. In April, they observed the heavy rains and the run-off caused from the streets into the river. The river was overflowing, and the number of illnesses increased. They took water samples and bug counts with digital tools they brought from the twenty-first century and discovered bacteria in the water; the counts were higher by the tenements and the bog. Violet and her team also noticed that the mosquito counters were highest near the bog and dump; at that time, there were hardly any bugs by the middle of town. She is curious to see how things have changed since April.

Violet sees her teammate Ward is already at the hospital. He sees her and types, "I just spoke with Aaron Nelson; he says that things are busy. People are coming in with stomach aches, coughs, and fevers. People in the hills are sick, but they don't have upset stomachs. What do you think that means?" Violet types back that she does not know. She looks at her notes from previous visits to the city and reminds her teammates that, in April, Dr. Wright told them that a lot of the people who had stomach aches were guests at the hotel.

At that moment, Jenny arrives on the scene. The teammates divide the town into three sections. Violet wants to explore the tenements and take more water and bug samples there. Ward is interested in analyzing the hospital admissions chart and interviewing the nurses and doctors for more information on the illnesses. He wants to visit the hotel also. Jenny wants to go to the University and the wealthy home area. The three split up, sharing across distance their ongoing findings using teammate chat and virtual screenshots they can send to each other.

Two days later, Violet is back in the time portal. After working face-to-face with her teammates to develop a hypothesis and design an experiment, she is traveling to River City to collect data. The team hypothesized: If we drain the bog, then the number of mosquitoes will go down and so will some of the illnesses, because the mosquitoes are breeding at the bog and then making people sick who are bitten. Yesterday, the team collected data on the "control" part of their experiment. They visited River City in the fall of 1879 and documented the patterns of people getting sick. There were 37 cases of upset stomach, 33 cases of fever and chills, and 22 cases of cough. The bug station readings were highest near the bog and tenements. The team interviewed many residents and collected data around their hypothesis.

Today, they are focusing on the experimental part of their experiment. Their independent variable is the bog – if the bog is drained, will the total number of illnesses go down and which symptoms of illness will decrease? The team predicted that the number of people with fever and chills will decrease because those symptoms seem to be related to spending time near the bog. The only difference between the control world they previously measured and the world they are now studying is that the bog is drained in this "experimental" world.

Violet enters at the train depot and immediately opens her clickable map, which has a flashing dot that shows her where she is standing. She clicks on the bog and is immediately teleported to it; Ward and Jenny are already there. As they walk around, the team sees the bog has vanished. Violet takes a digital picture for her virtual notebook. It's really gone! We drained it. Let's go find some data and see what changed.

Jabbers is sitting at the computer next to Violet. He looks at her computer screen and notices that the bog is gone in her version of River City. He turns back to his computer screen and teleports to the bog. The bog is there in his version of River City. He points to his computer screen and shows Violet. They both see that their avatars are standing by the bog; however, in Violet's version of River City the bog has been drained, and in Jabbers' version the bog is still there. Jabbers tells Violet to teleport to the scenic lookout where the effluent pipe is emptying into the water. Their avatars are now standing at the scenic lookout. In Jabber's version of River City, the pipe is gone. He and his team built a water treatment station. He walks over to it in his world. In Violet's version of River City, the pipe is still present. Violet does not have the water treatment station. Because the virtual world is a simulation, students sitting next to each other can see different worlds based on their experiment and the variable they choose to change.

Violet says that she cannot wait until the classwide research conference in two days. She is looking forward to hearing about the other teams' experiments. She decides to go back to the control world and take a picture of the bog for before and after contrasts. Then, she will collect experimental world data to determine how draining the bog affects the illnesses in River City.

Augmented Reality

In contrast to MUVEs, mediated immersion in augmented reality (AR) intertwines physical and digital contexts. Students interact with virtual people, artifacts, and experiences that are infused into real physical settings via a wireless mobile device (WMD).

Each WMD is equipped with global positioning system technology that correlates the students' real world location to their virtual location in the game's digital space. As students move through a physical location, such as their school playground or sports field, a map on their handheld displays digital objects and virtual people who exist in an AR world superimposed on the real world. Thus, AR provides collaborative mediated immersion similar to MUVES, but with different capabilities for learning.

Alien Contact! is one such AR simulation, part of a project funded by the US Department of Education Star Schools program (http://isites.harvard.edu/icb/icb.do?keyword = harp) designed to teach math and literacy skills to middle school students. Students work in teams of four to figure out why aliens have landed and whether they are friends or foes. Each student takes one of four roles – chemist, computer expert, linguist, or FBI agent, thus working in teams comprising the four different roles. The role of a participant determines the information and experiences provided to that learner. Each team member is given different data, and they must collaborate to solve the problems they encounter (jigsaw pedagogy). For reasons of space, we provide only a short vignette from this curriculum, now in its early stages of development, illustrating how immersive aspects of AR offer experiences different from MUVEs.

As Matt and his other team members walk across the campus toward the library, he watches a dot representing his location move across the map on his handheld computer. His movement in the physical world is being tracked through a global positioning system that is synched with the virtual world in his WMD. He is walking through the campus of a local university looking for Dr. Fibonacci, a physicist who has information about why the aliens have landed. This is the team's second day collecting data. They have already talked to other witnesses and experts, including a newspaper reporter, a security guard, and a nuclear expert. He and his teammates have collected data that seem contradictory; the team is not sure whether the aliens have landed to collect uranium for dangerous purposes, have accidentally crashed on earth, or are conducting explorations prior to friendly overtures. Matt hopes that Dr. Fibonacci will provide them with more information to clarify the situation.

As Matt walks, a beeping noise indicates that he has found Dr. Fibonacci and a screen pops up on his handheld computer showing a photograph of this virtual person. Dr. Fibonacci provides Matt with evidence that the aliens may have crash landed. In his role as the chemist, he receives somewhat different data from this virtual character than does each of his teammates in the various complementary roles. In addition to interview text, Dr. Fibonacci gives Matt a document that contains a mathematics puzzle that he and his teammates must collaboratively solve. The answers to these puzzles unlock virtual evidence boxes that are located throughout the game space. These puzzles require the students to exercise mathematics and literacy skills. Matt reads through the document and then beams his ideas about solving the challenge to his teammate Rebecca, who is in charge of organizing their responses. As Rebecca puts together their answers to create the complete code necessary to unlock the box, she reads out: "1, 1, 2, 3, 5, 8, 13." Matt remembers that sequence from math class last month and exclaims, "Hey, that's the Fibonacci sequence!" The students note that there might be formulas behind all of the clues. His teammate Adam points out that the code that unlocked an evidence box yesterday involved knowing the Pythagorean Theorem.

Matt and his team walk toward the virtual location of evidence box in a different part of the campus. As Matt walks, he periodically looks at the map on his handheld computer to see whether he is getting closer. For some reason the dot that represents him on the map is not moving toward the location of Gate 2; he starts to move in a circle watching his movement on the map. Janet, another teammate, calls out to him and points to her map: "We are walking west, but the evidence box is located toward the east near that tall building" (she points toward the building on the other side of the campus). Matt had been so excited about finding the box that he read his map incorrectly. "You're right. Look, it is located 90° from where Dr. Fibonacci was – it is a right angle. Let's go." As he approaches the coordinates of the evidence box, a screen flashes on his handheld device asking for the secret code. He types in the sequence, and the box in the virtual world opens. Inside are alien documents and artifacts that contain data around the problem. Matt examines a document about uranium that is hard to decipher because the aliens have encoded it linguistically and mathematically. As the chemist on the team, Matt has collected a lot of data about uranium; as best he can tell, this document seems to provide more information about its various uses beyond nuclear weapons. He records notes in his data log and beams them to each of his teammates.

These vignettes contrast how MUVEs empower creating contexts inaccessible in the real world while AR enables the infusion of virtual contexts within physical locations. In both MUVEs and AR, knowledge is grounded in a setting and distributed across a community, rather than isolated within individuals. As a result, collaborative interpretation of complex experiences becomes central to learning. Contrary to conventional K-12 instruction where knowledge is decontextualized and explicit, in MUVEs and AR the learning is situated and tacit: Problem-finding is central to problem-solving. This parallels the nature of twenty-first century work, as well as the learning styles and strengths of today's digital-age students.

Conclusion

Emerging interfaces for collaborative, mediated immersion are shaping the types of skills and knowledge society values, the ways people can learn, and the characteristics of individual students (Dede, 2005). To better prepare students for the future, we need to integrate these emerging technological interfaces into instructional design and pedagogical practices. In order for students to compete in the emerging, global, knowledge-based workplace, they need appropriate knowledge and skills: media and information literacy; the ability to think critically, recognizing and solving complex problems; effective communication and collaboration skills, both face to face and across distance; and creativity (Anderson, 2008; Partnership for 21st Century Skills, 2004; Lemke, 2001). MUVE and AR interfaces, while not the only ways to provide students with these skills, have the advantage of situating learning experiences in collaborative, mediated, immersive educational environments comprising multiple learning modalities. Using these interfaces creates a shift in how students participate in educational practices, which in turn shapes their identities as learners (including their engagement and beliefs about their abilities to learn (Greeno, 1997; Wenger, 1998). Enabling multiple learning modalities ensures that students are being taught in ways that reflect their learning styles – fostering success for the many students who do not perform well in traditional classroom instruction. For example, research on River City has found that students who do not perform well in traditional instructional settings do well in River City (Clarke, 2006; Ketelhut et al., in press-a, in press-b). Further, engaging in learning that is situated in authentic contexts and is motivating for students may empower transfer of academic learning to real world contexts and situations.

Research on MUVE and AR environments is in its infancy, yet we believe studying these interfaces may deepen scholars' and practitioners' understandings of how different learning modalities shape learning and as a result offer new opportunities for assessment. While we outlined the above-mentioned scenarios in the context for learning, we envision immersive simulations being designed for the purpose of assessing student learning on such skills as inquiry, problem-solving, and complex-reasoning. We hypothesize that various students will perform better using different variations of these interfaces or combinations of learning modalities – one size will not fit all. If we can identify through research how individual student characteristics shape that person's learning under various instructional conditions, then we can better customize teaching to individual needs.

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9.7

THREE-DIMENSIONAL COMPUTER-BASED ONLINE LEARNING ENVIRONMENTS

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Introduction

Three-dimensional (3D) computer-based online learning environments take elements of massively multiplayer online entertainment technology and overlay collaborative and unified communications tools to create an interface that offers unique advantages and affordances for education. These environments move beyond current Web- and text-based methods for instructional delivery to create new Internet-based delivery methods that can facilitate new interactions, higher levels of engagement, and deeper learning. While games are the most prominent examples of the interface, research is showing that the use of this technology in nongame settings can positively impact learning and communications among students and with their teachers.

Sakamoto (2001) has stated that the purpose of education is to (1) convey skills and (2) transfer culture. While classroom instruction has been successful over the years at accomplishing these goals, we are now faced with an increasing population of students receiving their education from Internet-based solutions that are primarily text- or Web-based (Arbaugh, 2000; Paulsen, 2003). The Web has received widespread acceptance and use for creating and supporting learning activities across disciplines within education (Hill, 2001). However, these text-based systems are not as effective as communicating these requirements as newer immersive approaches (Dillon and Gabbard, 1998).

3D Computer-Based Multiuser Online Environments

The current generation of 3D graphical online multiuser environments for entertainment began in 1999 with the release of Everquest, developed by Verant (Sony, 2003).

J. Voogt, G. Knezek (eds.) *International Handbook of Information Technology in Primary and Secondary Education, 911–920.*

Today, 3D online multiuser environments are most commonly seen in computer games, where they are called MMOGs (massively multiplayer online games), MMOPWs (massively multiplayer online persistent worlds), MMORPGs (massively multiplayer online role-playing games), and a number of other subgenre names (Answers.com, 2005; Kent, 2003). Some online multiuser games have subscriber populations that rival many North American cities (Whiting, 2002). World of Warcraft in 2006 had over 6 million subscribers to its online virtual world (Woodcock, 2006).

Multiuser environments work on a client to server architecture (Answers.com, 2005; Privantu, 2004). The server organizes the sharing of information between users who are simultaneously connected to the virtual environment (also called a "persistent world"). The world is persistent because it operates whether or not the user is logged on. Users run a client that connects to the server. The technology on the client requires an Internet connection, sufficient computer performance, and 3D video graphics to support the required type of presentation and interaction. While the latest computer games require state-of-the-art computers and graphics adapters, educational environments can be designed to work with more mainstream computing and Internet requirements commonly found in educational settings. This is important because most schools suffer from a technology deficit that impacts the level of performance and graphics of their computers when compared to current consumer computing.

When an environment is built and displayed correctly, the user intuitively understands the space as displayed. For example, in an environment representing a building, users feel as though they are walking the halls of the building, or are engaged with other users in discussions, or are immersed in a training situation. The user moves through and interacts with the environment using the keyboard, mouse, or other haptic devices. As the user moves, the computer generates new graphics in real time to give the user feedback on their position in the environment. This gives the user the feel of movement through space. Placing objects in a contextual 3D framework gives users known reference points and creates a framework for communications and interactions. Students at remote sites assume control of a representation of themselves, also called an avatar, which acts as a simulated identity for the user (Baudrillard, 1994). This takes place in a shared created environment such as a school building, park, or any other space. The Java-based 3D online learning environment used at the University of North Texas (Figure 1) segments the environment into conversation areas so that learners can move their avatars to areas for small group or private discussions. This environmental space creates a context for the user.

Immersive environments can be created using any data set and are limited only by the available data or cost to create the environment. Created Realities Group (CRG) (http://created-realities.com/) has created a 3D online multiuser environment that displays NASA's Mars Orbiter Laser Altimeter (MOLA). Figure 2 shows a screen shot of the summit of Olympus Mons. MOLA collected elevation data (heights) of the surface of Mars as part of the Mars Global Surveyor mission. Students in distributed locations are able to login, move over the virtual Martian surface, and perform math and science exercises using actual Mars topography data.

Educational Environments

Online educational environments are termed 3D MOOs (multiuser object oriented), multiuser virtual environments, or 3D online learning environments. Learning environments have strong ties to their text-based cousins, dating back to the 1980s (Holmevik and Haynes, 2000), but now provide highly collaborative, immersive environments that promote interactions among students and with the teacher. The commonality among games and educational environments is that each creates a context and scaffolding for interaction using 3D presentations to engage and immerse the user. The main difference is that learning environments are geared towards having users achieve an educational objective. The cost of attaining this educational objective may be considerably less to achieve than the cost to develop an entertainment title. As an example, a very expensive, high-fidelity military flight simulator would support one type of immersive instruction while the much simpler and very low cost learning environments used at the University of North Texas can foster interaction and feedback for university courses. The range of cost in a learning environment depends on the target audience and required outcomes. As computer performance on low-cost personal computers and console devices increases, these types of systems allow teachers to provide students with unique online collaborative learning opportunities in the areas of language, science, computer graphics, and other fields (Chen

Fig. 1 University of North Texas's 3D online learning environment using Created Realities Group Framework

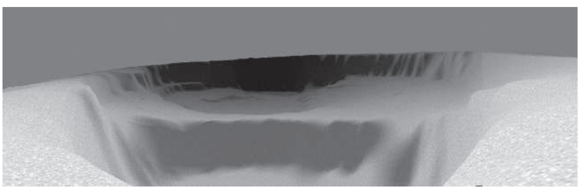

Fig. 2 Mars 3D environment generated in real-time based on NASA Mars Orbiter Laser Altimeter data on Olympus Mons, Top Cone (MARS_19.0_227.0) using Created Realities Group Framework

et al., 2004; Jones, 2003). The following is a short review of current examples of the technology being used in educational settings.

River City

Using a multiuser virtual environment experiential simulator (MUVEES), the River City project at Harvard University encourages K-12 students to explore historical locales working with peers to answer scientific questions (see also Clarke et al., 2008). The setting allows students to time travel virtually with the task of solving mysteries in late 1800s America. The curriculum provides a multiuser digital world with a city having a river running through it, different forms of land that impact local water, industries, and other institutions that play a part. Students explore the town and gather data to answer questions related to larger mysteries. The online project uses a collaborative learning-by-doing activities approach to learning. River City uses the Activeworlds, Inc. technology.

A pilot study of River City suggested that use of the MUVEES most benefited students with high perceptions of their own thoughtfulness of inquiry. These students scored higher on the posttest and had higher content pretest scores (Dede et al., 2006). In addition, students in the experimental group believed that their teachers were engaged less in pushing them for understanding than when they began using the product. Finally, student skills in reading, writing, computer literacy, and collaboration showed improvement by the end of the study (Dede, 2006).

University of North Texas

The Department of Learning Technologies, University of North Texas, has been using a 3D online learning environment to support college course delivery since 2003 for undergraduate and graduate students. The program uses the software in support of graduate course delivery. The environment was created using Created Realities Group Framework. In addition to supporting the display of the 3D environment and associated graphics and avatars, the client supports integrated voice that allows students to talk to each other within their virtual areas. The client also supports collaborative tools such as whiteboard and overheads as required to support discussions and feedback.

The initial research at the University of North Texas focused on student satisfaction comparing face-to-face, Web-based, and 3D online learning environments for course delivery. Research has shown that students felt that the 3D online learning environment provided the same level of satisfaction and interaction as did the face-to-face course (Jones et al., 2005). When the 3D online learning environment was compared to the Web-based course delivery, students felt that the 3D online learning environment provided a much richer and satisfying learning experience. The 3D online learning environment, using a similar amount of bandwidths as the Web-based course, has shown the ability to more easily create learning communities within the first three weeks of an online course, which text-based solutions take considerably longer (Jones, 2006).

Appalachian State University

The Instructional Technology program at Appalachian State University in Boone, North Carolina, has extended its degree program into a 3D multiuser virtual world, named AET Zone (Cox, 2006; Jones and Bronack, 2006). AET Zone is an innovative online medium for supporting a community of practice among distance-based students, faculty, graduates, and support staff. It adds elements of space, movement, and physical presence, along with conversational tools, artifacts, and metaphors not usually found in more traditional Web-based counterparts. AET Zone was constructed using Activeworlds, Inc. technology (Mauz, 2001). All required courses are offered to off-campus cohorts based in locations near their homes or their workplace or both.

Each course within AET Zone is unique in appearance and operation according to the nature of the content and the form of interaction that is desired to meet course goals. A course on media design is organized that has physical levels through which students progress. All classes have web-based discussion boards, forms for entering information to be shared with classmates for discussion, links to resources and readings, and audio chat areas where small groups can meet to discuss their projects. While the virtual world is an integral component of the program, faculty and students do meet face-to-face regularly in courses at the beginning of the program. The numbers and frequency of meetings are reduced as the members of a cohort gain understanding of what is expected and how to proceed during the latter stages of the program.

Quest Atlantis

Quest Atlantis, a National Science Foundation funded 3D multiuser virtual environment, was designed to allow students to participate in science inquiry, literacy, and social learning activities in K-12 education (Barab et al., 2005). The driving science fiction narrative is intended to encourage students to inquire into difficult, persistent science problems such as human and natural environmental activities that impact water quality in fictional and local watersheds. Learning activities called "Quests" encourage students to study and propose solutions to problems that fall under a number of themes ranging from environmental awareness to creative expression. *Quest Atlantis* uses the Activeworlds, Inc., technology.

Research related to *Quest Atlantis* has focused on different thematic units such as *Taiga*, which focuses on scientific inquiry into water quality issues; *Rhino World*, in which students learn about the endangered black rhinoceros; and *Anytown*, in which students practice writing descriptive stories as they investigate mysteries and petty crimes (Barab et al., in press). Findings of research on *Quest Atlantis* have shown improvements in student motivation to learn (Tuzun, 2004), improvements in student understanding of complex science concepts in a relatively short period of time (<10 h) on standardized test items (Barab et al., 2008), and improvements in student writing as measured by standardized state writing prompts (Warren, 2006). These findings are encouraging and indicate the possibility that similar learning environments can be beneficial for students.

Chalk House

Chalk House is the first in a series of situated learning modules developed as a collaboration between Created Realities Group and the Design + Research Collective for K-12 education. It is a 3D online learning environment in which game play and engaging narrative are placed into the environment to provide the students opportunities to improve their literacy skills, namely, reading, writing, comprehension, problem-solving, and critical thinking. As students solve the puzzles of the old house and file their reports with the Editor, their writing skills are expected to improve, along with critical thinking and reading comprehension, based on research into problem-based learning and the use of other similar learning environments. The 3D environment focuses on formal learning outcomes tied to No Child Left Behind (U.S. Department of Education, 2001) standards in the USA.

Cognitive Scaffolding

The main mechanism behind the outcomes seen when using the 3D online learning is the ability of the technology to provide cognitive scaffolding to the user. The 3D environment provides a framework for the user to integrate into existing cognitive strategies (Jones and Bronack, 2006). Cognitive strategies, as defined by Gagne, are the specific means by which people guide their intellectual functioning (Gagne and Merrill, 1990). These are methods that people use for learning, synthesizing, creating, and making other cognitive functions more efficient or effective. The motif of the real-world context presented by the 3D environment allows the user to understand the basic rules and skills learned from real life and then build onto that existing scaffold more quickly and easily. When a user encounters something in the environment that is new or different, the user constructs or adds a new framework to his understanding. This is supported by Bruner's (1961) and Piaget's (1972) work in constructivism, where the learner is a builder of knowledge. This explains why students feel more comfortable about communicating with each other over e-mail after having used the 3D online learning environment, because they feel they have already met even if it is only in the form of their avatar. Students feel more satisfied with the communications, because they feel they have actually met with other students and the teacher although it was via a graphical interface.

Educational Affordances

The term affordance, originally proposed by Gibson (1977, 1979), refers to the relationship between an object's physical properties (artifacts) and the characteristics of an agent (user) that enables particular interactions between agent and object. Norman further extended the concept to define "perceived affordance" (Norman, 1988, 1999). This definition has been valuable, although commonly misused, especially when discussing the design of interactive systems. Kirschner (2002) has further extended the term "affordances" in the context of computer-supported collaborative learning (CSCL) used in education. He defines the educational affordances for CSCL as "those characteristics of an artifact (e.g., how a chosen educational paradigm is implemented) that determine whether and how a particular learning behavior could possibly be enacted within a given context (e.g., project team, distributed learning community). Educational affordances can be defined – analogous to social affordances – as the relationships between the properties of an educational intervention and the characteristics of the learner that enable particular kinds of learning by him/her" (p. 19).

What this means for 3D online learning environments, which are in a similar domain with CSCL, is that the virtual environment has to be more than just an engaging, visually stimulating, social environment. In order for a 3D virtual environment to be a learning environment, it must fulfill the learning intentions (both required and perceived) of the instructional designer, teacher, and the student. 3D virtual environments designed for entertainment tend to be less flexible than those designed to meet specific learning outcomes, since the underlying design of the entertainment software initially did not consider education as a requirement. Instructional designers and teachers tend to bend their learning requirements to fit the limitations or requirements of the platform they are trying to implement. Engagement and interaction alone do not translate to learning. This has been a fallacy impacting both games and simulations used for educational outcomes. Proper classroom technology integration and instructional design are required for games, simulations, or 3D online learning environments to be successful.

The Future of and Barriers to Educational Integration

3D online learning environments are poised for success because the technology is now commonly available to the end user. They provide a bridge from the direct instruction methods of e-learning deployed during the 1990s to the future of online collaborative learning spaces. They employ the same technology that universities and schools already use to deliver their Web-based courses. The cost for a school to implement the simplest form of 3D online learning system to supplement Web-based or other types of distributed learning is minimal. The 3D online learning environments discussed earlier, used in simplest configuration, provide (a) increased student satisfaction about their courses and (b) increased discourse similar to face-to-face or video conferencing. Both of these benefits were accomplished while using existing networking and server infrastructure.

3D online learning environments are benefiting from advances in technology that earlier approaches lacked, thanks to the explosive growth of the computer entertainment industry. The combination of affordable consumer technology (personal computer and console) and Internet access, along with scalable server technology, makes it possible for 3D online learning environments to emerge as the next generation distributed learning technology. Driving the use of virtual learning environments is the fact that "distance education is more than the simple transfer of an existing instructivist's verbal lecture to an electronic textual/image/audio environment that is enclosed within the prepackaged structure of an off-the-shelf Internet-based course administration application. A critical component in any distance education environment is the human factor (Morgan and McKenzie, 2003). The role of people and the interaction among them in the distance education environment is essential to the development of a high functioning distance education class (Palloff and Pratt, 1999). (Walker, 2003, p. 2.2)"

The key is that 3D online learning environments bring students and teachers to the front of the interaction. They share the roles of both creators and consumers of knowledge and learning, thus breaking the isolated roles commonly seen in Web-based methods where teachers are subject matter experts who create and students are the consumers of that information. 3D online learning environments make this possible, because the environment promotes equality of communications and interaction. For classes taught using the 3D online learning environment, they meet in open areas where students move around and form discussion groups as needed to support course interaction. These classes do not use a setting that imposes strictures on student communication. When students do meet in a classroom environment, the dialogue tends to be much more one-sided – that of question and answer or directed instruction from a sole arbiter of information. In a fully interactive world that allows users to contribute content there is no limit to what students can add to the learning environment and the learning itself.

Within the last few years, the technical entry barriers for students to use 3D online learning environments such as high bandwidth requirements, computer processor performance, and graphics card acceleration have been reduced to the extent that deployment now makes economical and instructional sense (Jones, 2004). However, wider scale deployment faces other barriers, of which the most profound is the perception that 3D belongs only to the world of gaming (Lombardi and McCahill, 2004). Additional barriers include (1) cost of content creation (e.g., environment, objects, and interaction) and its ongoing maintenance, (2) content migration from platform to platform due to the rapidity of technology evolution annually, (3) the disparity between the quality of technology available to a 3D game enthusiast vs. an educational consumer, and (4) the risk-averse nature of policy makers in education regarding emerging educational technologies such as these. The manner in which these barriers are overcome will determine the future and success of 3D environments in education.

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9.8

TRACE THEORY, COORDINATION GAMES, AND GROUP SCRIBBLES

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Coordination in Learning

The role of sociality in learning is a tenet of modern pedagogical theories based on the learning sciences. Collaborative learning is an important area of research that seeks to take advantage of this. Techniques such as the jigsaw classroom and reciprocal teaching emphasize the cooperation and interdependence between learners. As computing becomes more pervasive and ubiquitous, distributed, highly coordinated activities for learning are becoming more and more important. But as collaborative patterns of engagement (DiGiano et al., 2003) multiply and automated tools, such as pattern-based editors (Dimitriadis et al. 2007), increase the potential for variation and creativity in the design of collaborative learning experiences, there is an increasing need to better understand and account for the low-level coordinative conditions that make them possible. The nature of coordination, especially participant-driven coordination, in collaborative learning, is undertheorized and underexplored. When we design collaborative activities in relationship to technology, we need to understand the relationship between the high-level instructions given to students, and their individual behaviors, interdependencies, and outcomes. To do this, we employ trace theory modeling.

That is, a collaboration designer can specify the desired overall pattern (“jigsaw,” “peer instruction,” “literature circle,” etc.) at the high-level plan view perspective, leaving the dynamic particulars as an unexamined black box that is either too complex, or too unimportant, or both, to bother with as a design task. There are, however,

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a number of compelling reasons for attempting to consider the patterns of interaction from individual concurrent dynamic levels as well as from high levels. First, as an instance of patterned behaviors emerging from simple rules, it is fascinating and important science in its own right (Wolfram, 2002). Second, there is accumulating evidence (Kollar et al., 2003; Zurita et al., 2003) that the real power of collaborative learning comes not from the seamless flow implicit in the plan view, but rather from the "seams" in the group understanding that emerge and are closed in the collaborative process. Finally, allocation (implicitly or explicitly) of power and responsibility in classroom collaborative processes is well known to be an important factor in the opportunity to learn (Cohen and Lotan, 1995; Johnson and Johnson, 1999; Slavin, 1996). These processes are essentially hidden at the plan level of collaboration, but may be more amenable to systematic exploration with coordination games, that is, games in which coordination among the players is an important feature.

In this chapter, we address the problem of how to understand complex, fine-grained coordination by first introducing Group Scribbles, a tool for group collaboration and coordination. We then introduce a formal language, trace theory, for describing the coordinative properties of the interaction. Finally, we present two examples of alternative coordination structures for versions of the jigsaw pattern, addressing the nature of participation and the potential for equity in implementation of the pattern.

Group Scribbles

A key problem in using technology (1) to support complex coordinated learning and (2) to explore the nature of complex coordinated learning processes is finding an infrastructure that flexibly supports a wide variety of interaction patterns. Group Scribbles does both.

Group Scribbles (Brecht et al., in press; Roschelle et al., 2007; see, e.g., http://groupscribbles.sri.com) provides a *representation neutral* way for educators to rapidly design new shared distributed collaborative and group learning activities without the need for additional programming. It allows users to interact by posting or taking "scribble sheets," which closely resemble Sticky Notes™, to a "public place." The technology is representation neutral in that anything that a student wants to represent for his/her own purposes or to show another can be drawn or typed on a scribble without special provisions that allow the computer to recognize and operate upon it. Meaning is created by two mechanisms: (1) posting content that will be interpretable by the viewer and (2) arrangements of the scribble sheets in relation to one another and in relation to background images that are easy to create and import. The meaningful arrangement of objects in space is at once an extension of individual human intelligence, and a mechanism for creating, maintaining, and extending meaning in distributed cognition contexts.

All participants in a Group Scribbles session have their own computers. Each computer has a two-paned window. The top is a public work area that is shared between participants and is identical on each person's screen. The lower pane is the user's personal work area, or "private board," with a virtual pad of fresh scribble sheets on which the user can draw or type. Scribbles can be arranged by dragging and dropping in this private area. Alternatively, they can be shared and arranged by dragging and dropping them onto the public board in the upper pane. Other participating clients monitor the space for such activity and update the client's display; so other people will see a scribble sheet almost as soon as it is dragged into the public space. The original creator or other users may interact with public scribbles in a variety of ways, such as browsing their content, repositioning them, or moving one from the public board into their private space. New public boards can be created to support multiple activities or spaces for small groups to work.

Group Scribbles has been used in many demonstration sessions, informal workshop meetings, and even in real classes, all over the world (Singapore, USA, Spain) since its first release in mid-2006. It is a general-purpose representational tool that can easily be used to express views, use diagrams, point out joint conclusions, try to reach an agreement, obtain common conclusions, or even vote. Four examples demonstrate its functionality and representational flexibility.

Example 1: A world map. Figure 1 shows a typical warm-up use. The person conducting the exercise has drawn or downloaded a hand-drawn world map as

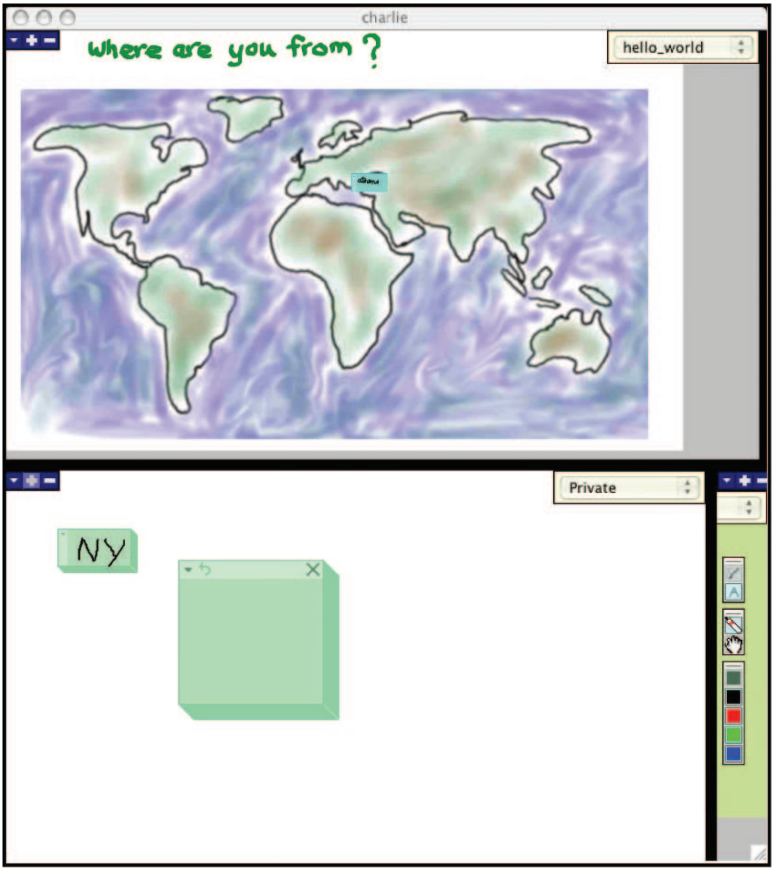

Fig. 1 Users can create annotations in their private board and then drag them to the public board where others can reposition them or drag them back to their own private board

a background image for the public board. This person has then asked the participant to write their name on a scribble sheet and then place the scribble sheet on the board near their home location or their birthplace. The exercise thus leads naturally into other getting acquainted discussions, or to talk about the diversity or uniformity of the group.

Example 2: A changing assessment. Figure 2 is drawn from a real classroom use of Group Scribbles in Spain in November 2006. The teacher has drawn a number line in the background. He has then asked students to assess themselves by posting scribbles along the number line that he had drawn. The left pane shows their assessments prior to the class activity and the right pane after the class activity. This rating promotes discussion of what they have learned through the exercise in a nonpejorative way; they can talk about the class as a whole, or individuals without labeling particular individuals.

Example 3: A planned activity. Figure 3 shows a more complex activity in which a set of boards and background images was offered to student participants. The instructor provided the backbone of a central public board that could be used to provide a general overview of the planned activities. Students followed the general plan. They also used "stickers" for awareness purposes, updating each other about where they were in the plan, and thus contributing to a better coordination. Low-level interactions

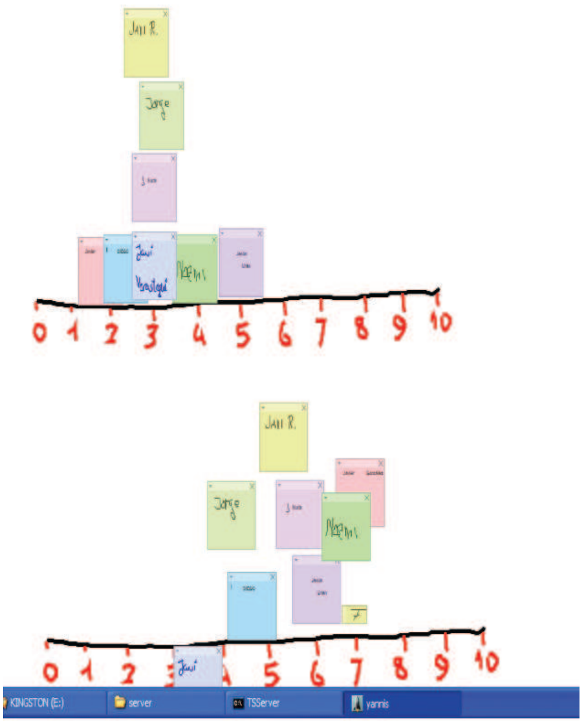

Fig. 2 Self-assessment of students before (activity 1, *left*) and after the session (improvised activity on the same board as in activity 1, *right*)

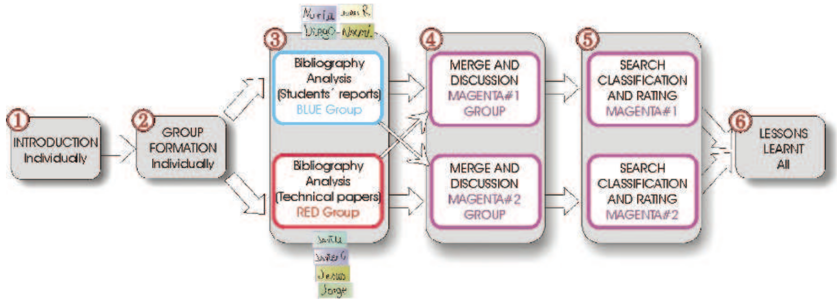

Fig. 3 A planned activity flow diagram included at the public board of GS. Note the awareness stickers during the experts' activity (jigsaw CLFP) of the analysis phase

were handled through social protocols, as e.g., the group formation, or the voting procedure of the most important conclusions (Dimitriadis et al., 2007).

Example 4: Representations of fractions. Another example of Group Scribbles focuses on the power of shared representations in learning and the relationship between individual and group endeavor. In this example, the teacher puts up a grid with columns. Each column is labeled by a scribble sheet that has a fraction on it: $1/4$, $1/3$, $2/3$, $1/8$, and so forth. Students are then asked to draw one of those fractions and post each sheet with drawings as elements in the column. Some students draw the fractions as portions of a single whole. Others draw them as a quantity from a set of objects. Yet others draw them as a position on a number line. The teacher can then ask the students to reflect on these different representations by asking students to rearrange them to form groups of like representations.

Naturally, these activities can be supported by other groupware systems with special purpose facilities. However, Group Scribbles is very promising and useful for exploring underlying correlates of coordination because it is very easy to use and, most important, to change. No special setup is required except for the actual materials to be coordinated: the map, the activity plan, and so forth.

Group Scribbles and Coordination: Key Aspects of Design Enable a Focus on Coordination

Group Scribbles is also important in enabling the study of coordination because of the clean underlying organization of the coordinative actions. Group Scribbles appears very simple. However, this belies the fact that its features were inspired by the goal of enabling theory-based exploration of coordination patterns and their interaction with content.

Building blocks of coordination. Group Scribbles is an example of *Zensign*, the idea that what you leave out of an interface is as important as what is put in (Harrison et al., 2007). The encapsulation of free-form content in movable blocks (scribbles) allows for a full spectrum of activities ranging from almost pure coordination (in which the scribbles are used primarily as counters or tokens, as in examples 1 and 3) to almost pure content aggregation (as in example 4). By *not* focusing on the features that a machine can provide by knowing about the contents, we *do* focus on the tokens that people exchange and arrange to attain meaning.

Thus, Group Scribbles is not directly related to a domain, inquiry process or even a particular problem-solving approach. For example, instead of embedding a typical set of steps of scientific inquiry in physics as WISE (Linn, in press), Group Scribbles allows teachers and students to set all necessary conditions.

Small (but generative) set of actions. The coordination between machines is accomplished by posting, taking, and arranging the scribble sheet building blocks in the public or private spaces. Users' actions include these, which are inherited from the underlying tuple space implementation and which also support robust intermachine connectivity (Wyckoff et al., 1998; Carriero and Gelernter, 1990), and three other kinds of actions. A *tuple space* provides a repository of *tuples* that can be accessed concurrently and has been employed as the theoretical base for the highly successful Linda coordination language (http://en.wikipedia.org/wiki/JavaSpaces).

First, it is important to remember that users learn a great deal from simply looking at the display of their own or public boards. Second, users can use the pen and eraser to draw backgrounds or they can download image files as backgrounds. Third, they can set up new, shared boards.

Background-structured groupings. Scribble sheets can be and usually are structured by placement on relevant background images. These images provide location-based organization and contextualization. Background images function like a backdrop in that they help contextualize learning activities similar to the way painted scenery helps situate a theatrical performance. This is obviously true of the world map in the first example, but it is also true of simple tabular structure such as that provided in example 4.

Scribble-structured groupings. Scribble sheets can be used to contextualize or annotate one another. Stickies are used this way in example 3 when users indicate where they are in the process.

Small footprint. The Group Scribble client software was designed to have a small code footprint, and be usable with a quite modest allocation of screen real estate. As such, it can be used unobtrusively in conjunction with other applications, on small devices or even as the coordination component of primarily non-computer-based activities.

Socially mediated protocols. What might be considered a design deficit – namely, the absence of technology-based mechanism to *enforce* coordination protocols beyond the contention resolution embedded in the primitive actions – is, in fact, a design decision. It supports the coordination from which rules, roles, turn-taking practices, and high-level activities can emerge (Tatar et al., 2008).

These design decisions position Group Scribbles almost at the opposite extreme of the highly scripted coordination protocols that are often employed in CSCW or workflow environments. However, this does not mean that the design of Group Scribbles is antagonistic to specification. Instead, it means that Group Scribbles is designed in such a way as to support the analysis of different mechanisms and approaches to the specification of coordination. For example, the design tension

(Tatar, 2007; Tatar et al., 2008) between specification and freedom to create has already been partly studied in a real learning setting, as shown in example 3 (Dimitriadis et al., 2007).

Three kinds of exploration are enabled by the design decisions in Group Scribbles. First, the entailments of *participant driven* as compared to centrally administered coordination are brought front and center. Second, *spontaneously generated elaborations* or appropriations of coordination protocols are enabled. Finally, an important parameter distinguishing alternative embodiments of coordination patterns is the *assignment of responsibility*; e.g., who (or what) is in charge of which aspect of the protocol, a question made moot by assigning enforcement to the technology.

Group Scribbles is important because it allows teachers to create coordinated activities for learning. It is an unobtrusive, supportive, and flexible shared environment on which the participants can play out the full spectrum from content-rich to coordination-centric "games." Development of novel activities is central.

However, Group Scribbles is more than a tabula rasa for coordination. The underlying mechanisms in which it is implemented are as follows: the simple "scribble sheet" tokens of exchange and the simple operations involved in exchange allow us to use it as a laboratory for understanding and explaining coordination at a much finer grain of detail than previously possible. However, one final thing is needed to do this: a powerful and broadly applicable formal descriptive language – trace theory. With this formalism we can begin to (a) investigate how control of the pattern might be distributed and (b) explore the potential consequences of alternative detailed patterns, all while preserving the overall structure as an emergent property.

Using Trace Theory to Describe and Specify Coordination Structures in Group Scribbles

Although modern theories of learning deriving from the Learning Sciences (for example, as represented in "How People Learn" (National Research Council, 2000), stress the importance of both small group work and emergent uses of technology, these tools are underutilized in educational practice. One reason for this is doubt. When people use distributed coordinated systems in learning, a question constantly arises about their benefits for the individual and for the group. Is one person doing all the work, while others are idle? Is one person doing all the same kind of work and never engaging in new areas or topics? Is everyone busy and productive most of the time, or are they spending long times waiting for others? When we introduce a new technology that impacts coordination, these questions deepen.

Trace theory (Dill, 1989; Benko, 1993; Benko and Ebergen, 2002) is an important tool in helping to understand the properties of particular implementations of activities with Group Scribbles. It is a formalism that was devised and refined as a means of specifying, designing, and verifying the design of the independent yet mutually influencing behaviors of interconnected arrays of circuit components in chips. These behaviors are like the classroom behaviors we wish to promote and understand: *collaborative*, *asynchronous*, and *delay-insensitive*.

From a formal perspective, coordination games may be described as a set of allowable event sequences, together with distribution of responsibility among the participants for initiating and concluding events, and rules for each participant regarding allowable initiations and conclusions under their control. The main components, detailed in Appendix 1 online, of the formalism include (1) regular expressions over an alphabet, (2) projection onto a subalphabet, and (3) weaving of specifications to yield coordinated sequences.

Consider a collaborative learning activity such as the jigsaw classroom (Aronson et al., 1978; Slavin, 1980). The jigsaw creates a situation in which one student or a set of students are mutually interdependent on another student or a set of students to perform subtasks to fulfil the demands of the whole project. In a two-by-two jigsaw, for example, each of four participants will be asked to act alternately in two roles, as an expert (say as a dissolved oxygen or benthic organism expert in a water quality activity) and as a project participant (surveying water quality at a particular site). At various times, the dissolved oxygen and benthic organism experts, respectively, meet to discuss issues related to their particular focal areas, and then site teams meet to carry out some aspect of the water quality survey of their assigned site, and the process repeats. In the Group Scribbles context, a meeting means going to a particular public boards and posting and arranging Scribble sheets in such a way to accomplish the tasks. Figure 4 shows a background image to support at least one version of this activity.

We can trace the coordination going on through the system, and (with more effort) by coding face-to-face interaction in relationship to the machine patterns. Regular

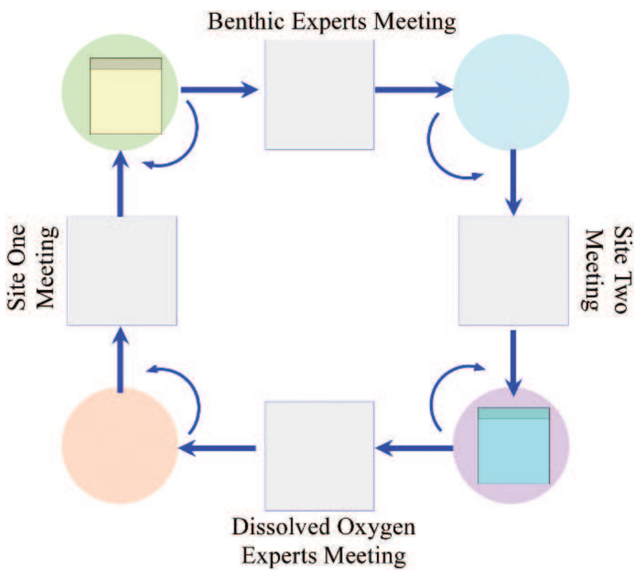

Fig. 4 Organizing background image, with two scribble sheets, for the Group Scribbles implementation of the equitable leadership pattern

expressions can describe an important portion of this pattern. If we denote by *B* the meetings of the benthic organism experts and by *1* the meetings at one site, the experience of a particular participant who happens to be a benthic organism expert can be described *B;1;B;1;B;1;…* or more succinctly in regular expression notation as [*B;1*]*, where the star means that the pattern repeats. This means that the person alternates between meeting with other benthic organism experts and meetings with the project team at the site, with no other kinds of events in between. Similarly, the experience of the other benthic organism expert can be described as [*B;2*]*, while the two experiences of dissolved oxygen experts can be described as [*D;1*]* and [*D;2*]* respectively.

In this way, regular expressions allow us to express something important about the experience or behavior of these individuals in fulfilling the injunction of the task. But regular expressions are inherently sequential.

By themselves, they do not allow us to represent event sequences between individuals, because the order of cross-individual events is asynchronous and only loosely coupled. That is, the meeting at one site of experts must come after the benthic organism experts meet but may come in indeterminate order with respect to the meeting at another site of experts. Events are also delay-insensitive in that the meeting of experts at site 1 must follow the meeting of benthic organism experts but it depends on the availability of all the experts who are supposed to meet, which in turn depends not on a clock but on whether they have fulfilled prior obligations.

For this, we build on two mathematically provable properties of the trace theory formalism. The first of these is projection onto a subalphabet. Projection onto a subalphabet is a way of specifying the overall observed pattern and locating meaningful element sequences within it. The second is the weave, which is the interleaving of observed or requested subpatterns into complex produced outcomes. Projection is not simply the inverse of weaving in that it is useful for describing slightly different cases. For example, projection is useful in designing an implementation of a specification to include "auxiliary" events that aid in the implementation but do not otherwise affect the overall pattern.

Projection and weaving mean that we can use trace theory to relate the properties of individual actors to the observed properties of the group and see whether they compare and we can also relate the properties of the group to the observed properties of individual actors. We can use trace theory to describe one and predict the other.

But projection and weaving are most interesting when they reflect not only dependencies in the order of action but interdependencies. We can describe interdependencies in interactions by enlarging the language slightly. The simplest game is a repeating event, *A*, where the set of sequences is given by [*A*]* (zero or more successive instances of event *A*). To make this into a game involving coordination, we assign responsibility for initiation of *A* (denoted *A!*) to one player and responsibility for conclusion of *A* (denoted *A?*) to another.

This enlargement allows us to describe one of the first games we play with babies: to hand them a ball that they eventually drop and then we hand it back to them. In this game, event *A* is the handing over and taking of the ball by the baby. Event *B* is the dropping of the ball, and event *C* is the picking it up by the adult. Initially, the adult engages in activity [*A!*] and subsequently in [*C; A!*]. The baby engages in [*A?;B*]. Interdependence of action occurs when the adult waits for the baby to take and hold the ball, so that the adult's action of putting is the baby's action of taking. Interdependence does not occur when the baby has dropped the ball, and indeed play enters into a new phase when the baby learns to hand or throw the ball back. In the two-person case of "catch," the actions are isomorphic and joined to one another, so that the participants engage in [*B?; A!*] and [*A?; B!*]. If more players are involved, then the actions of each are joined only to the actions of the person who puts the ball in one's hand and those who take it from one's hand. That is, for the three-person case, event [A?;B!]* is when Participant 1 gets the ball and awaits Participant 2's readiness. When Participant 2 is ready, then event [B?;C!]* is begun, that is, the conjoined offering of the ball by Participant 1 and taking of it by Participant 2, followed by Participant 2 waiting for Participant 3 to be ready. When Participant 3 is ready, [C?;A!]* is begun, and so forth.

From these underpinnings, quite complex patterns can be created and monitored for the desired and found effects at the individual, small groups and whole class level. These patterns describe the relationship between individual behavior and group behavior in relationship to the tokens of coordination (the scribble sheets and boards) that are exchanged in the course of activity. The tokens can be used to monitor the degree and kind of success found in the implementation of different kinds of plans.

Alternative Versions of the Jigsaw Pattern

Here follow three variations of the jigsaw pattern of collaborative work. All involve the same global pattern, but each differs slightly in its execution.

Teacher leadership pattern. In a typical case of classroom enactment, the coordination pattern is centrally controlled – the teacher or other facilitator decides when the participants should switch roles. However, quite a bit of coordinative behavior (initiating or stalling, claiming materials or locations, passively tagging along) is likely to occur between the moment when the teacher calls out "time to switch roles" and the time that the actual transition is completed, none of which is either specified or captured in the plan view, and some of which may be very important to learning. (We may model and quantify this process loss.)

Student leadership pattern. Alternative distributions of responsibility have potentially different cognitive and affective properties for the participants. In one version of the jigsaw example above, we might assign a student an additional job, to initiate a benthic organism expert meeting, then conclude a site 1 meeting, and repeat the pattern to pattern, [B!;1?]*. This prescription means that that particular student is assigned responsibility for finishing the meeting, regardless of who starts it. Indeed, we might assign responsibilities in such a way as to deliberately distribute responsibility for meeting starting and ending to different people. This is the case if assignment is as follows:

- Student 1: [*D!;1!*]*
- Student 2: [*D?;2!*]*

– Student 3: [*B!;1?*]*
– Student 4: [*B?;2?*]*

Figure 5 shows the chronological ordering of two cycles of meetings consistent with playing the coordination game as described earlier. Note, particularly, that the meetings need not be synchronous (as might be implied from the static, plan view of the pattern). Even so, assuming that each of the meetings actually took place somewhere in the coloured band regions (that is to say between the time they were initiated and the time they were concluded), then the *experience* of each of the participants conforms to the intended pattern of interaction.

Student equity pattern. At the global level, it may not matter which students were responsible for starting meetings and which for ending meetings. However, it may matter a great deal to the individual students involved both affectively and in the learning. Trace theory helps us think about whether there is a more equitable (i.e., only one class of participants) distribution of responsibility that would result in the same overall interaction pattern. The following assignment of responsibility still leads to the overall pattern of the jigsaw. Yet, this may be a more successful implementation because each person starts one meeting and ends one:

– Student 1: [*D!;1?*]*
– Student 2: [*D?;2!*]*
– Student 3: [*B?;1!*]*
– Student 4: [*B!;2?*]*

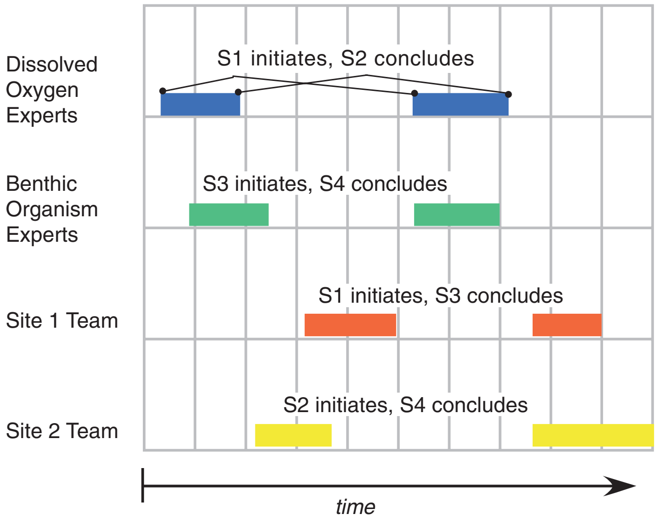

Fig. 5 Chronological ordering of two cycles of meetings in accordance with the lead students' pattern

Observing the actual exchange behaviors through and around Group Scribbles, in conjunction with trace theory modeling, allows us more traction over the effects and outcomes of our instruction.

Summary, Conclusions, and Future Research

In our explorations, the dynamic coordination as experienced through enacting such a specified coordination game is much richer and more nuanced than might be expected from the static view, even while the emergent pattern conforms to the static view. Since the put and take actions (and associated locations) are automatically logged on the server, it is a simple matter to implement a monitoring functionality that checks the emerging event pattern against the specification. Together, trace theory specifications, the canonical interpretation as coordination games, and Group Scribbles as a game board show considerable promise as a means of exploring the detailed dynamical role of coordination in learning.

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9.9

ONE-TO-ONE EDUCATIONAL COMPUTING: TEN LESSONS FOR SUCCESSFUL IMPLEMENTATION

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Introduction

When every student in an educational setting has a powerful computer to use as a learning tool, new options emerge and the benefits in terms of learning and preparation for the world outside of school can increase markedly (Roschelle et al., 2004; Livingston, 2006). However, this is not automatic. As Bielefeldt (2006) reported:

> High levels of access to technology are transforming schooling. The nature of that transformation is still evolving, but its outlines are emerging. The types of learning activities are different. Attitudes toward school are different. Relationships between school and the community change. There are also new tensions that arise, such as conflicts between new learning models and old policy models, and between new outcomes and old assessments. (p. 1)

As the ratio of benefits compared to cost continues to improve, as international competitiveness becomes a more pressing national priority (Friedman, 2005), and as higher-order skills are identified as important learning outcomes (Pink, 2005), more and more schools will turn to one-to-one computer to student ratios to boost educational productivity (Bonifaz and Zucker, 2004; Livingston, 2006). In fact, Livingston (2006) estimated that in the USA alone, by 2006, there would be more than 14,000 public schools and thousands more independent and parochial schools offering one-to-one learning environments. *America's Digital Schools 2006* (Greaves Group and Hayes Connection, 2006) substantiated the boom in one-to-one computing, estimating based on their research that 24% of US School districts are in the process of transitioning to one-to-one.

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But technologies are merely tools, and as such they have value only in the hands of thoughtful, well-prepared people, with a clear goal in mind and a supporting infrastructure that makes effective use possible. This chapter presents lessons learned from a review of literature on one-to-one computing and interviews with 14 pioneers in one-to-one educational computing (Peck and Sprenger, 2007). If we learn from the experience of pioneers in one-to-one computing we can increase the probability of successful implementation and new educational opportunities (Livingston, 2006). If, instead, we ignore these lessons, we will repeat the expensive failures of other naïve innovators (Cuban, 2001; Hu, 2007).

Lesson One: Focus on an Expanded Educational Vision

With all of the attention that is required by the technology infrastructure, budget, and other implementation issues, it is easy to lose sight of the fact that the primary purpose of adding technologies to educational settings is to enhance learning, and that enhancing learning involves teachers, students, parents, and others. Leaders of significant technology-based educational reform efforts must work hard to keep all involved focused on what students are doing with the technologies, and why.

As Fullan (2007) explains so well, the main problem in education is not the absence of innovation, but the presence of too many disconnected, fragmented, and "superficially adorned" projects. The one-to-one initiative must not be just another disconnected project, but instead must be a means of accomplishing a well thought out, integrated approach to effective teaching and learning.

Develop a coherent "vision statement" that describes what students, teachers, administrators, and parents will be doing with the technologies, and the benefits that will result from this use. Focus that vision on outcomes that go beyond the acquisition of knowledge. One-to-one access to technologies can be valuable in the development of higher-order skills such as collaboration, problem-solving, creativity, critical thinking, and advanced communication, but this only happens to the extent that activities students are assigned require them. Lowther et al. (2001) reported that strategies promoting learner activity, such as cooperative learning, inquiry, sustained writing, and computer uses, were more likely to be observed in one-to-one classrooms, but this occurred in a setting in which the goal was clear and a significant investment in goal-related professional development had been made.

Agree on a list of higher-order skills the one-to-one initiative is designed to develop, such as that created by the Partnership for 21st Century Skills (2005; see also Anderson (2008) in this Handbook), and require teachers list the activities that they have designed to cause students to develop those skills. Determine how to *assess student progress for each skill*, and use these assessments to guide the educational program.

Lesson Two: Expand Participation and Commitment

In *Leading in a Culture of Change*, Fullan (2004) describes the complex job of leading a group in an educational change effort, which includes establishing the moral purpose for the change, relationship-building efforts, coherence-making, and generating internal and external commitment to the change. The leader's job is often complicated by the fact that often the leaders of these change processes are not endowed with "positional power," but rather are, as Heifetz (1994) puts it, "leading without authority." While this may seem like a significant disadvantage, the nature of educational change makes authority insufficient for effective leadership, and other attributes compensate for the absence of authority.

One-to-one computing *involves and benefits from the support of all stakeholders in the educational process*. Upper level administrators and school board members must be committed to the vision, but this is not enough. Building-level administrators, principals, curriculum coordinators, and department heads must also understand both the purpose of the initiative and the struggles that lie ahead. Teachers, parents, and students as well must understand the purpose behind this very significant investment, and must work together to realize the vision. Staff members can also be crucial to the success, starting with the obvious roles of the technology coordinator and the tech support staff, but also including secretaries who will be involved in administrative processes (such as check-out paperwork, insurance claims, and acceptable use policy agreements) and custodians, whose work may also be impacted as students and others request longer hours of access to the school.

The leaders of the initiative must also work hard to develop an understanding throughout the citizens in the community, and may find it valuable to discuss the initiative and its benefits at meetings of local organizations and with members of the local press who write articles about education. The demands of leadership in changes of this scale are many, and it would be both arduous and risky to vest responsibility for this leadership in a single leader. For this reason it is wise to form a cohesive leadership team and to distribute responsibilities throughout the leadership team (Marzano et al., 2005).

Lesson Three: Think Software, THEN Hardware

When people think of computers in schools, they first think of the computers and then of the associated software. Computers and the devices that connect to them are necessary but not sufficient. *Because it is about what students do with the technologies, software is the key*. Buying a computer without the software that delivers the educational benefit is like buying a powerful electric saw, but no blades, or a drill with only one bit. Software costs money, but very significant discounts are available for site licenses for schools. Open source software and freeware may reduce costs, but small differences in functionality can make big differences in how students respond to an assignment and what they learn from it.

Assignments that appeal to students' creative side (such as producing videos and podcasts) can result in students devoting much more time to assignments, and to the development of higher-order skills. As you make decisions on hardware, make sure that a lower price does not result in a decision that prevents teachers from giving students compelling, higher-order tasks to perform.

Lesson Four: Embrace Professional Development

The key factor that determines the ultimate value of one-to-one computing in educational settings is what teachers ask students to do with the technologies. Unfortunately, most teachers have little experience learning with technologies. They know their content areas, and they tend to teach as they were taught (Goodlad, 1990). If we want them to do something different – to use a variety of strategies that engage students with the content and require them to use higher-order skills, we need to give teachers the time and opportunities to think deeply about what their classrooms will become. Professional development for one-to-one computing environments is not about telling teachers what they should be doing. As Creighton (2003) puts it, "The all-too-common practice of 'let's have a workshop' continues to make a bad situation worse. Workshops are often focused on one topic and not necessarily aligned with school objectives and goals" (p. 48).

Teachers should have more active roles in professional development (Penuel, 2006; Livingston, 2006). Professional development that prepares teachers for one-to-one teaching should allow them to see what one-to-one learning looks like in their subject areas, in the classroom of a teacher who is "living the vision," and should provide the time necessary to develop the skills and assignments that can move their classrooms in the desired direction. Consider the use of on-site "technology coaches," respected teachers from the existing faculty who are given dedicated time to think with teachers about their technology use and to model new, appropriate, effective instructional strategies (Lowther et al., 2006).

Just as we develop "individualized education plans" for students, each teacher should develop a "personalized professional development plan" clearly identifying the knowledge and skills they are to develop and a set of steps that will lead to that development.

Lesson Five: Re-assess Infrastructure Needs

No matter how well prepared a district or a building is to implement a one-to-one learning initiative, some basic infrastructure needs must first be addressed. Adding hundreds or thousands of computers to a school will increase the need for bandwidth and server capacity. For example, consider a typical large high school with computers for each staff member and perhaps 500 or so in laboratory settings. Then add 2,000 student laptops to the mix all going online, streaming video, and saving to the server. Will the bandwidth handle the new influx? According to The Greaves Group and the Hayes Connection (2006), "a bandwidth crisis is looming" (p. 16).

It is critical to look into bandwidth needs *before* the actual implementation. Experts have stated repeatedly that the key to a well-running one-to-one implementation is planning (Livingston, 2006) – researching the network bandwidth and hardware requirements in advance. Other issues to consider are whether the rooms have sufficient electrical power, locations for battery chargers for the laptops, and, if students will be accessing software or saving information to school servers, the processing capacity and storage space available.

Lesson Six: Focus on Functionality and an "Always Up" Learning Environment

Problems happen (Johnston and Cooley, 2001). But the educational mission is so important that we cannot let problems interfere with student learning. Successful one-to-one implementations come very close to an "always up" track record, not by accident, but by design. Many use "redundant" devices that mirror the primary devices and can be brought online quickly when a device fails. Most solid one-to-one implementations have "disaster recovery plans" that involve storing copies of all files in a remote location, so that they may be restored should a fire, earthquake, or other disaster wipe out the primary facility. (Educational institutions in the USA are increasingly providing these services to each other to reduce costs.) "Always up" should be the goal at the student level as well. Have a plan to get individual students up and running should their computer be damaged, lost, or stolen. This is relatively easy to accomplish when student data storage is server-based, by providing the student a "loaner" computer with the standard configuration and then downloading the student's folder from a server. Be ready to provide this level of support to teachers and administrators as well. Unreliable school networks have proven to be an important factor prohibiting the widespread use of technologies by teachers (Hill and Reeves, 2004).

Lesson Seven: Minimize the Number of Vendors

When selecting the hardware, software, networking, training, and other aspects of a one-to-one computing implementation, the choice of vendors can greatly affect the success of the implementation. Generally, the fewer the vendors involved, the easier it is to solve problems, because the presence of multiple vendors can lead to "finger pointing." Although this approach may hinder some smaller companies from getting involved, it may also enable a smoother, efficient transition and operation of a one-to-one initiative, which can lead to a much better experience for all involved.

Lesson Eight: Have an Insurance Plan

Because providing $800 – $1,500 laptops to children and making students and their families financially responsible can cause great concern to parents and because the computers must always be available if they are an integral part of the school day, extended warranties should be purchased and insurance plans should be required. Warranties only cover hardware failures that happen through normal use, and so an affordable way to insure the laptops should also be in place. Accidents happen. Computers (especially laptops) can be dropped, be damaged by liquids spilled on them, be lost, or be stolen. An insurance policy will soothe the concerns of both parents and school administrators about loss and accidental damage, but insurance policies do not cover intentional damage or negligence.

The Kutztown School District collaborated with the local Intermediate Unit (one of 29 educational service organizations set up by the state to provide specialized services to school districts that could not afford to provide the services internally) to develop a “self-funded” insurance program in which the cost per year to insure each laptop was $50. If the student was from a low-income family and received a reduced price lunch, the cost to the parents was $25 and if the need was great enough to warrant free lunches, the insurance fee was paid by the district. Plans like this will work well as long as the total cost of repairing and replacing the laptops that are destroyed, lost, or stolen does not exceed the funds collected from parents and the district, and this plan has worked well for more than 2 years now. Although some educators fear that insurance claims will be higher in schools in low-income neighbourhoods, the opposite actually seems to be the case. Students living in poverty seem to value deeply the computers in their care. The insurance claims and intentional damage to computers in these neighbourhoods are actually lower than those in wealthier suburban neighbourhoods.

Lesson Nine: Be Prepared to Add Technical Support Staff

The sudden influx of hundreds or thousands of laptops and the related addition of printers, scanners, servers, and other devices are sure to put a greater demand on the existing technical staff of a district. Even the most reliable computers have problems, whether they are in the hands of adults, children, or teenagers. Many districts have a minimal number of staff supporting the existing computer infrastructure. With the addition of student laptops, there is going to be a need for additional personnel to help support the influx of equipment. Any district planning on starting a one-to-one initiative should research the levels of support provided in other districts employing a similar computer platform and infrastructure, and should base staffing patterns on this research. People are expensive, but they protect the larger investment made in technologies and professional development, and when teachers perceive that technical support is inadequate it hinders their integration of technology (Penuel, 2006).

Lesson Ten: Assess Morale and Prepare for Turbulence

As Fullan (2007) reminds us, “Reform is not just putting into place the latest policy. It means changing the cultures of classrooms, schools, districts, universities, and so on. There is much more to educational reform than most people realize” (p. 7).

A one-to-one teaching initiative has the potential to markedly improve education, changing both what and how students are taught. Teachers are asked to “think outside the box,” to try new things, and to take risks by teaching in ways that replace the more comfortable practices they have been employing, some for 20–30 years or more. Ideally, people change because they feel dissatisfaction caused by a gap between what is and what could be, and they have a personal, internal desire to close that gap. If they feel dissatisfaction, but also confidence and trust, this support may sustain their efforts over what is bound to be a rocky road. Just as an airline pilot will often warn passengers in advance about anticipated turbulence ahead before turning on the seat belt sign, leaders of one-to-one initiatives should warn all constituents that this significant change will result in some turbulence as teachers change their practices and as students and parents, as well, adjust to their new roles. Help them understand that this turbulence is normal, that they can work through it, and the teachers who have made it report that the destination is worth the journey.

Because of the significant turmoil the move to one-to-one is likely to cause, a district with a history of conflict between administration and teachers and/or school board members or low morale among its teaching staff is probably not in a position to work through such a drastic change and get positive results. Morale and trust issues should be addressed first, before the environment will be conducive to change.

Conclusion

In conclusion we return to Fullan (2007), who reminds us, "There is an important distinction to be made between innovation and innovativeness. The former concerns the content of a given new program, while the latter involves the capacities of an organization to engage in continuous improvement" (p. 11).

We encourage you to make the move to one-to-one, but not as a "program" to be implemented, but as a new way of doing business, in which teachers and students work together in new ways, and in which those ways evolve as we learn more about the potential of technologies in redefined educational environments. This change will not be easy, but if we "work smart," based on the wisdom collected from intelligent, dedicated, hardworking pioneers and the scholars of educational and systemic change, we can use the power of one-to-one computing environments to transform education.

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9.10

MAKING THE MOST OF ONE-TO-ONE COMPUTING IN NETWORKED CLASSROOMS

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Potential of Classroom Networks

Examples of the promise of technology to improve learning outcomes abound in the research on computers in education. For example, drill-and-practice software has helped individual students master basic skills in reading and mathematics (Kulik, 1994; Murphy et al., 2001); adaptive tutoring software has proven effective in improving the achievement of algebra students (Morgan and Ritter, 2002); and technology-supported science curricula have raised test scores in science for urban students (Marx et al., 2004). Unfortunately, access to powerful technology-supported curricula is limited because most students are able to use technology only infrequently in school.

There is now a global movement to promote ubiquitous access to technology in education. This movement is driven in part by the ability to provide computers at a lower and lower cost and by wireless access to the Internet that is now available on even small, handheld computers. It is also driven by a recognition that to realize fully the benefits of educational technology, classrooms must transform from occasional, supplemental use of technology to more frequent, integral use (Roschelle and Pea, 2002). The movement is global in that the push for improving access to all is motivated by a belief that to participate fully in the economic, social, and political institutions of the future, there cannot be a class of people – young or old – who do not have access to the resources, information, and avenues of participation available on the Internet.

How can we make the most of new initiatives designed to bring ubiquitous, 24/7 access to students? Needed are comprehensive *innovations* that are more than just

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hardware and software. These innovations must be comprehensive in nature, focused on subject-matter learning in ways that ultimately can address the accountability demands of policymakers and parents, and usable to a wide range of teachers. These innovations need to include *images of teaching* that make it possible for teachers to contrast effective from ineffective uses of the technology. Fortunately, such innovations are already on the horizon, and their use by teachers provides some compelling (and not so compelling) images of teaching that can be articulated in a way to inform program design and professional development in the coming years.

This chapter presents two examples of exemplary teaching with technology in classrooms where all students have portable computers that are wirelessly connected to a classroom network. The scenarios presented here are based on current technology and reflect current practice, yet they also point the way to a possible path for educational technology to have a role in transforming not just individual or small group learning as in the past but also whole class learning. These scenarios in science and mathematics classrooms also illustrate three conditions necessary to *implement one-to-one access in a way that maximizes student learning*: (1) the technology is low-cost and readily learned by teachers; (2) the technology is part of a comprehensive innovation that informs but does not replace good teaching; and (3) the tasks students perform use the features of technology in ways that support student engagement and subject-matter learning.

Scenario 1: Peer Instruction with Student Response Systems in Science

Sarah teaches 8th grade Earth Science across the hall from her husband, who teaches the same subject and types of students. Their teaching styles are similar, but 2 years ago, Sarah began using a student response system in her classes. This system is a classroom network of handheld computers that can communicate to a laptop computer using infrared technology. Each student has a handheld computer, and the teacher controls the laptop. With the system, Sarah can pose a multiple-choice question such as, "What explains why there are seasons?" to her students. She can make the answer choices reflect both a scientific understanding (the tilt of the Earth's axis) and also common student conceptions (the distance of the Earth from the sun causes the seasons). The students can then use their handheld "clicker" to respond to Sarah's question. Sarah frequently displays students' responses to questions anonymously, in the form of a histogram that shows how many students gave a particular answer. She then has students turn to their neighbors and discuss their answer or try and convince their neighbor of their answer. Then, Sarah will ask students to vote again on the answer; often, many more students get the scientific answer to the question on the second try. After a year of using the system, Sarah's students have far outperformed the students in her husband's class on her district's end-of-year test in Earth Science. Both she and her husband attribute the gains to her use of the student response system.

The scenario illustrates a powerful way teachers can exploit connectivity in a classroom using a relatively simple technology that is inexpensive and relatively easy for teachers to learn to use. For the cost of a few desktop computers, a teacher can purchase a portable student response system for use in their classes that includes handheld clickers for all their students. On the surface, these clickers have limited functionality – many only allow students to input responses to multiple-choice questions – and seem to reinforce traditional teaching in which the teacher asks the questions and the student answers. But it is the simplicity that makes it relatively easy to learn (teachers report being able to adopt the technology after less than a day of professional development) and also easy for a broad range of teachers to adopt (Penuel et al., 2007). Furthermore, the technology does introduce new, if subtle, forms of teaching that have been documented already by a range of physics instructors in higher education, such as introducing paired student discussion into large lectures (Boyle and Nicol, 2002; Dufresne et al., 1996; Poulis et al., 1998).

Sarah is using a form of what Mazur (1997) has called *Peer Instruction*, an innovation that integrates student response systems into a framework for conceptual teaching in science. Peer instruction does rely on the teacher to pose questions, but it emphasizes that teachers need to ask particular kinds of questions, namely those that are conceptual in nature and that are able to elicit facets of student-thinking that might be different from scientific understanding of concepts. Student response system technology allows the teacher to ask the question of more than a few students, however. It allows the instructor to ask the question of *everyone*. In addition, peer instruction relies on small-group discussion – a powerful way to elicit student-thinking in science and transform it (Roschelle, 1992) – to achieve convergence on scientific conceptions of subject matter. Turning to one's neighbor – as Sarah has her students do – is a way to further engage students cognitively in the task of making sense of what they are learning.

Sarah's use of response system technology is not only consistent with the peer instruction approach; it also makes the most of the possibilities of the technology in class. A particularly powerful feature of the technology is the *shared display*. With the shared display, students can see that they are not the only ones who do not understand a concept or who share their point of view. The teacher can quickly discover whether many students do not understand a concept, well before she reviews a homework assignment or grades a chapter test. The display helps make students accountable for contributing: students often want to see their contribution depicted, even if it is anonymous (Davis, 2002). And it makes it far less likely that a teacher will simply "move on" because time has passed, when many students do not understand, providing an accountability for student understanding in the classroom.

Research on the effects of student response systems suggests that Sarah's use of her system is likely to produce achievement gains, but some other uses are less effective. The results for peer instruction are particularly positive; in a wide range of settings that have been studied, its use produces consistent gains in students' conceptual understanding of physics (Fagen et al., 2002). By contrast, when teachers use the system just for summative testing, hide the display from students, or fail to engage students in discussion, the results for teachers are often disappointing both from subjective and objective perspectives (Judson and Sawada, 2002; Penuel et al., 2007). Therefore, to make the most of student response systems, it is critical to design classroom activities that make the most of the technology and create multiple opportunities for students to participate, both by contributing responses to student questions and by discussing their thinking with peers and the class.

Scenario 2: Exploiting Classroom Connectivity in the Math Classroom

> *Alex teaches 9th grade algebra to a group of low-income students who in the past have struggled with mathematics. In his class, students regularly use a network of graphing calculators as part of a program called* SimCalc *developing tasks designed to exploit the power of networked graphing calculators. In a typical class, the students are discussing a set of mathematical representations they have made – in this case, in pairs – that are shown on a display the whole class can see. The task assigned, if performed correctly, would have resulted in the class producing a set of lines that converge on a point. One student argues that the lines are parallel, but Alex presses for evidence and for mathematical reasoning. Several students jump into the fray, trying to decompose the lines into "dots" or points associated with individual students. The class becomes animated as the group tries to deconstruct the problem and understand how each student's representation contributed to a mathematical whole, in this case, lines with different slopes that meet at a single point. The pitch of students' voices is high, as the whole class appears to be fully engaged in mathematical problem-solving and communication.*

The technology Alex is using in his class, similar to the student response system Sarah is using, is relatively inexpensive to implement and can be adopted by a wide range of teachers. The primary technologies in use here are graphing calculators, a laptop computer, and an LCD projector. Many students in algebra classes today already use graphing calculators, though few are connected through a classroom network in a way Alex's students' calculators are. The low cost of calculators – most cost less than $100 – and willingness of many parents to pay for them for students make them an affordable way for schools to implement one-to-one computing and still have room in the budget for other technology purchases. There also exists a large network of professional development available to teachers for making good use of graphing calculators in their classrooms. Texas Instruments, for example, has a national network of teacher leaders who present at national and regional conferences and who provide coaching and mentoring to individual teachers on a regular basis (http://education.ti.com/educationportal/sites/US/nonProductMulti/pd_tlc.html).

The developers of the software application for graphing calculators Alex is using have paid considerable attention to the kinds of *tasks* that are important to assign students such that the important mathematics is revealed in the ways reflected in the classroom discussion presented in the scenario. As part of the SimCalc project, researchers at the University of Massachusetts – Dartmouth (http://simcalc.umassd.edu) have developed a number of tasks designed to be used by the teacher to structure students' interaction with the software. For example, in the task Alex is facilitating, students work in small groups to devise a trajectory for their team that begins at a position two times their group number (1–6) and ends after 6 s in a tie in which all the teams end up at the 12 position. As part of the task, students not only set parameters with respect to speed and direction, they test out their trajectories using the software and write a narrative describing the path. In so doing, students gain fluency with mathematical representations of slope and with concepts related to the mathematics of change (Roschelle et al., 2000).

The technology Alex is using in his classrooms has different capabilities than the student response system that Sarah is using in her Earth Science class. This next-generation type of classroom technology enables students to input a variety of "answers" to teacher tasks, including open text and graphical images (Robinson, 2002). This technology also supports a much wider range of classroom interaction than question-and-answer; they enable teachers to use the specific subject matter to structure activity much more so than earlier systems (Kaput and Hegedus, 2002). In fact, much of the power of Alex's pedagogy rests on his ability to exploit connectivity to make visible fundamental concepts of algebra, especially with respect to developing a functional understanding of algebra. Even though this technology provides the same functionality as does the student response system Sarah is using, using only the student response system would represent a much less powerful aspect of the technology than Alex is actually using in his mathematics class. Making the most of newer classroom network technology, then, means designing subject-matter-specific tasks for students that do not require repeatable cycles of activities as is characteristic of peer instruction.

Although this technology is newer, there is already evidence of benefits to students from available research. In classrooms where students are using more advanced network technology, researchers often report that students identify with their responses in the shared display (Davis, 2003). They often refer to their position in the display in first-person terms, signifying their engagement and identification with the activity (Stroup et al., 2002). Even if the display is anonymous, researchers report that students sometimes seek to identify themselves and their peers in displays, especially if they are "outliers" in the space represented in the display (Hegedus and Kaput, 2004).

Which Way the Future?

Past innovations in educational technology have shown promise but have not been widely accessible to teachers and students. Improved access to technology and the Internet makes it possible that many more classrooms can benefit from technology. The scenarios presented earlier are not just for the privileged few; they can be implemented in suburban as well as urban areas, with students from diverse backgrounds.

For one-to-one access to improve teaching and learning, it is important to consider that what is important to promote is not just access to technology but access to learning opportunities with technology. The scenarios presented here point to the power of particular tasks – particularly ones that engage students actively with subject-matter learning – for improving learning opportunities for students. Technology enables students to "see themselves" in a graphical display, whether as one of several people who have a particular conception of a scientific concept or as a mathematical object in a graph. The tasks the teacher lays out for students engage students in scientific thinking, mathematical reasoning and communication, and self-reflection – all critical for learning in these subjects.

These scenarios are in a real sense the innovations that are needed to make the most of one-to-one access to computers. They describe not only a use of technology but a sequence of activities in which technology facilitates engagement, provides critical information to teachers about student understanding, and engages students in thinking about concepts. The scenarios can and should anchor program and professional developers, so that educators can see what is possible and understand how to make good use of technology. If this broader notion of a technology-supported innovation can be kept in mind, then a promise made in the past to a few can become a reality for many.

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Section 9

EMERGING TECHNOLOGIES FOR EDUCATION

9

EMERGING TECHNOLOGIES FOR EDUCATION

Cathleen Norris
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Section Editors

In the Emerging Technologies section of the Handbook we look at technologies on the horizon and explore the new opportunities for teaching and learning that they might well afford. Broadly speaking, there are four themes in this section:

Reducing the Digital Divide

– Universal access to computing is a goal that has been unreachable since computing first entered education. The reality has been that only those with resources were able to gain substantial access to technology. However, with the emergence of low-cost mobile computing devices – from cell phones to exciting new "laptops" – there is a real possibility that access will no longer be a problem for those with fewer resources.
– Brown (Chapter 9.2) explores the use of mobile technologies to support learning in Africa; he puts forth a hopeful, but cautious view that indeed m-learning can support Africa in educating its populace.
– van't Hooft (Chapter 9.3) is concerned with how culture, society, and learning need to be rethought in order for mobile technologies to truly realize their impact on teaching and learning.
– Ally (Chapter 9.4) explores the opportunities that mobile technologies can have in addressing the digital divide.
– Hsi (Chapter 9.5) explores the use of information technologies to support enhanced learning opportunities in museums. The availability of low-cost technologies may well help museums become highly popular, accessible, and productive learning environments.

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Increasing Collaboration Among Learners Using Augmented Reality

- When children talk to each other and to adults, learning occurs. While we have to be careful that there is some substance to the conversations – we are looking for more than social chit-chat, though it too can be a powerful form of learning.
- Educational theory has long known that collaboration encourages motivation and engagement, which in turn, leads to learning. The chapters in this group explore different, but complimentary strategies for supporting collaboration and substantive conversations.
- Clarke, Dede, and Dieterle (Chapter 9.6) focus on the use of multiuser environments where learners are “inside” a virtual world, exploring that world and engaging in conversations with others who are also exploring the virtual world. Clarke et al. argue that the computer can create a very rich context that is exciting and manageable, and that context can lead to enhanced collaboration.
- Jones and Warren (Chapter 9.7) also discuss the value-added of learners engaging with each other in a virtual world. Jones and Warren are keen on the use of three-dimensional and other visual issues to enhance the engagement of the learners.

Theory Meets Practice

- It is exciting when theory and practice work together, hand-in-hand to make each element better. There are two chapters in this section that explicitly link theory to practice – and vice versa.
- Patton, Tatar, and Dimitriadis (Chapter 9.8) explore the use of Trace Theory to inform the design and reflect back on the theory – of a collaboration tool for learners.
- Access does not guarantee effective use, however. Norris and Soloway in Chapter 9.1 describe how a popular instructional model – project-based learning – can provide the framework for effectively using mobile computing devices.

Lessons Learned: May We Take Heed!

- “Experience is a dear teacher, but a fool has no other.” Ben Franklin understood that we must learn from the past, lest we waste precious resources reinventing that which has come before. In this final group of chapters, the authors provide hard-learned lessons for trying to implement emerging technologies into real classrooms.
- Drawing on the experiences of schools around the country that have implemented one-to-one laptop programs, Peck and Sprenger in Chapter 9.9 identify ten key issues that must be addressed if such a one-to-one initiative is going to be successful.
- Penuel (Chapter 9.10) provides a more top-level piece of wisdom for those implementing one-to-one programs: make sure a comprehensive solution is being put forward – make sure all the pieces are in place and fit together. While a list is good, the pieces had better be integrated and complimentary.
- Roschelle and Singleton in Chapter 9.11 step back in time and describe how graphing calculators had a significant impact on the teaching and learning of math. Their chapter is full of wisdom that our community needs to heed.

9.11

GRAPHING CALCULATORS: ENHANCING MATH LEARNING FOR ALL STUDENTS

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Introduction

Educators and policy makers want to improve students' mathematics achievement, particularly in middle and high schools. A consistent association between frequent calculator use and higher average scores on the well-respected National Assessment of Educational Progress calls attention to calculators as a basis for interventions at these grade levels. It is rare for educational research to identify a tool for improving achievement that is inexpensive, ready for large-scale classroom use, and backed by strong research evidence. A closer look at the scientific evidence shows that graphing calculators are just such a tool.

A robust and consistent body of research shows that graphing calculators can effectively support mathematics learning and democratize access to complex mathematical concepts. Further, the story of the graphing calculator provides valuable information to guide the development and implementation of new educational technologies.

First and foremost, technologies that enhance learning for all students do so by changing *how* and *what* students learn (Roschelle et al., 2001). Graphing calculators change what students learn by making graphing a readily available representation. Graphing calculators change how students learn by reducing cognitive load, increasing opportunities for complex and multistep problem-solving, and enabling teachers to emphasize mathematical reasoning, not just calculation. To successfully transform learning in this way, educators must be able to transition from occasional, supplemental

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use of computers, to frequent and integral use of portable computational technology (Soloway and Norris, 2001; Tinker and Krajcik, 2001). Further, technologies must be integrated into the social practices of schools – a difficult but important challenge that requires integration with teaching practices, curricula, assessments, and school leadership.

Graphing calculators have become one of the most widely adopted technologies in education because they are an affordable handheld device that has proven effect, with direct linkages to curricula. Indeed, graphing calculators have reached far more K-12 mathematics learners than computers have. Approximately 40% of high school mathematics classrooms use graphing calculators, whereas only 11% of mathematics classrooms use computers (National Center for Educational Statistics, 2001). Graphing products are now integrated with national and state standards (e.g., National Council of Teachers of Mathematics, 2000) and they are embedded in some curricula. Furthermore, research has identified best practices for instruction (Burrill and Allison, 2002; Seeley, 2006) and teacher professional development offerings are widely available to further support the successful integration of graphing technology into classroom teaching and learning.

Features of Graphing Calculators

The consumer market for graphing calculators started with the introduction of the Casio graphing calculator in 1985. Other companies, including Texas Instruments, Hewlett Packard, and Sharp, quickly joined in, bringing a variety of new capabilities to the market. Unlike earlier four-function calculators, graphing calculators could solve equations symbolically and use named variables; by the 1990s they could also perform symbolic algebra and do some calculus. Calculators with full "Computer Algebra System" capabilities now cost less than $200; strikingly just 25 years ago, these capabilities were only available in massive research computers.

Importantly, graphing calculators also added display and visualization capabilities. In particular, standard models now provide three linked, canonical views of mathematical constructs: numeric views (using tables and lists), symbolic views (using algebraic expressions and function definitions), and graphical views (function graphs, charts, and scatter plots). Modern graphing calculators not only do calculations and create graphs, but can also display geometric figures and integrative diagrams, opening the door for further innovations in classroom use.

Cutting edge research is exploring the latest new advance – graphing calculators that are connected via a wireless network. In simple uses, the wireless network can enable teachers to engage in formative assessment. For example, a teacher can take a quick poll of students' responses to a conceptual question and display the results instantly. Teachers can use this capability to give students feedback and to adjust instruction. Wireless networks can also be used to rapidly distribute teacher assignments and share student work. In some research studies, advanced use of these features increases student participation in classroom discussions by displaying student work in projected view at the front of the classroom (Dufresne et al., 1996; Roschelle et al., 2004).

For example, the classroom can use the network to engage in a participatory simulation, such that each student plays a unique role in an emergent mathematical phenomenon (Stroup et al., 2005). In another example, each student can be asked to create a slightly different algebraic function, such that a family of functions emerges when the functions are aggregated and displayed (Hegedus and Kaput, 2004). In designing these advanced uses, researchers aim to create classroom environments in which students learn through participation in a shared, social, mathematical space (Stroup et al., 2002; see also Penuel (2008) in this Handbook).

Alignment of Graphing Calculators with Standards and Practices

There is a growing consensus among state and national agencies that graphing calculators are a valuable tool for enhancing math learning for all students. The US National Council of Teachers of Mathematics (NCTM) has advocated for the integration of calculators in mathematics education since the publication of their landmark Standards (aka *Curriculum and Evaluations Standards for School Mathematics*) in 1989. A recent scan of state education policies reveals that more than half of the states address appropriate calculator use as part of their mathematics standards. Indeed, a handful of states now *require* the use of calculators on high stakes accountability examinations. In Texas, for example, the use of graphing calculators is required in high school mathematics courses and on statewide assessments:

> The Texas Essential Knowledge and Skills (TEKS) mathematics curriculum implemented in 1996 requires the use of graphing calculators in high school mathematics courses. As a result, graphing calculators will be used on the statewide mathematics assessments for students in Grades 9, 10, and 11, providing alignment among curriculum, instruction, and assessment. In May 2001 a letter was sent to districts stating that "a sufficient supply of calculators must be available so that each student in Grades 9, 10, and 11 has ready access to a graphing calculator, not only on the day of [TAKS] testing, but also for routine class work and practice. (Texas Education Agency, n.d.)

While the NCTM and state agencies advocate the use of graphing calculators, they also recognize that calculators do not obviate the need for students to learn certain fundamental math skills. Educators and researchers alike firmly believe that non-calculator-based skills – such as number sense, skill in estimation, and mental arithmetic – are important for both the workplace and further mathematics learning. Indeed, no one argues that calculators should be used to supplant learning of basic arithmetic, fractions, or other core aspects of mathematical fluency.

Nonetheless, calculators can both support students' basic mathematical understanding and facilitate their success with more advanced mathematical concepts. In the early grades, calculators can be used in some creative ways to strengthen basic arithmetic skills, as with the classic "broken calculator" exercise (see, for example, Collison et al., 2006). In the later grades, where most calculator use actually occurs, calculators can enable students to move beyond basic calculations toward a deeper understanding of math concepts. Accordingly, the NCTM recognizes the need for balance between manual computation and other problem-solving techniques:

> [S]tudents no longer have the same need to perform these procedures with large numbers or lengthy expressions that they might have had in the past without ready access to technology…The teacher should help students learn when to use a calculator and when not to, when to use pencil and paper, and when to do something in their heads. Students should become fluent in making decisions about which approach to use for different situations and proficient in using their chosen method to solve a wide range of problems. (NCTM, 2005)

A number of countries in Europe, including Austria and the Netherlands, as well as progressive states such as Ontario, Canada, and Victoria, Australia, are moving to a new level of the calculator debate. By incorporating calculators with computer algebra systems that can automatically transform symbolic expressions, they are raising the question of how much effort students should devote to manipulating algebraic expressions versus focusing on meaning and problem-solving with algebraic expressions.

Pedagogical Affordances of Graphing Calculators

Graphing calculators have a powerful potential to help students master important concepts in mathematics because they provide specific functionalities that are valuable for math learning. They realize this potential well because they are inexpensive, portable, and readily adaptable to existing classroom practices. Employed as an instructional technology, graphing calculators can enable teachers to foster a problem-solving approach to mathematics and help students to reason mathematically. The contributions of graphing calculators to problem-solving and reasoning can include the following:

– Increasing attention to conceptual understanding and problem-solving strategies by offloading laborious computations.
– Enabling students to hone their understanding by tackling more than “textbook examples” (those that can be completed in less than 5 min with paper and pencil).
– Examining the related meanings of a concept through the display of multiple representations, such as exploring rate of change (i.e., slope) in a function definition, a corresponding graph and a table of values.
– Engaging students with interactive explorations, real world data collection, and more authentic data sets.
– Giving students more responsibility for checking their work and justifying their solutions.
– Providing a supportive context for productive mathematical thinking.

Underlying these pedagogical affordances, we see several basic cognitive contributions of calculators to student learning. One prominent factor involves reducing cognitive load and allowing students to focus more attention on high-level thinking (Sweller, 1988). Students with calculators can take on traditional tasks in new ways and also tackle new topics that would otherwise be inaccessible. Rather than laboring over tedious calculations, classes that use calculators can devote more time to developing students' mathematical understanding, their number sense, and their ability to evaluate the reasonableness of proposed solutions. Students can also use calculators to explore concepts and data sets that would otherwise be too complex or cumbersome. For example, students can easily investigate, graphically, numerically, and symbolically, the effects of changing a, b, and c on the graph of $ax^2 + bx + c$, which can be quite tedious using paper and pencil graphing techniques.

A second basic cognitive factor is the complementarity of textual/linguistic, tabular, and graphical representations. According to many recent studies, students can often reason best when they experience mathematics through related representations, such as equations, tables, and graphs (Ellington, 2003; Khoju et al., 2005). Graphing calculators can make constructing and using multiple representations easier, allowing students to spend more of their time and intellectual energy exploring the underlying concepts. In addition, technology can link the representations, enabling students to make conceptual connections, such as understanding how a change in an equation links to a change in a graph. Standard mathematical representations can also be linked to other visualization aids, fostering further conceptual understanding.

A third cognitive factor is that calculators appear to enable students to engage in higher order mathematical reasoning. For example, because problem-solving with a calculator saves time, students are more able to explore multiple solution strategies. Research has also shown that students using graphing calculators change their approaches to problem-solving: they explore more and their attempted solution strategies are more flexible (Ellington, 2003; Khoju et al., 2005). In general, students who use calculators better understand variables and functions and are better able to solve algebra problems in applied contexts than do students who do not use calculators (Schwarz and Hershkowitz, 1999). Similarly, students who use calculators use graphs more often and interpret graphs better than students who do not regularly use the technology (Hollar and Norwood, 1999). Finally, students who use calculators are better able to move among varied representations – that is, from graphs to table to equations – than can students who do not have access to the technology (Ruthven, 1990). Clearly, students who regularly use calculators have an advantage over those who do not.

Research on Graphing Calculators

A strong body of literature provides evidence that graphing calculators can effectively improve mathematics achievement for a wide variety of students. Importantly, graphing calculator research also illuminates effective instructional practices and conditions of successful implementation. This research provides educators and policy makers with concrete guidance on how to achieve an effective implementation and confidence that large-scale implementations will also be successful. (*Note:* Some of the research cited below does not discriminate between calculators and graphing calculators. We use the term *calculator* to include any form of calculator and reserve *graphing calculator* for those calculators that include graphing features.)

In the United States, the National Assessment of Education Progress (NAEP) samples both 4th and 8th graders throughout the country and measures how many students perform at proficient and advanced levels in mathematics. This research has consistently shown that *frequent use* of calculators at the 8th grade level (but not at the 4th grade level) is associated with greater mathematics achievement, stating as follows:

> Eighth-graders whose teachers reported that calculators were used almost every day scored highest. Weekly use was also associated with higher average scores than less frequent use. In addition, teachers who permitted unrestricted use of calculators and those who permitted calculator use on tests had eighth-graders with higher average scores than did teachers who did not indicate such use of calculators in their classrooms. The association between frequent graphing calculator use and high achievement holds for both richer and poorer students, for both girls and boys, for varied students with varied race and ethnicity, and across states with varied policies and curricula. (National Center for Education Statistics, 2001, p. 144)

A study by Heller (2005) corroborates the NAEP findings. Heller examined a model implementation for high school students, which included a new textbook, teacher professional development, and assessment tools – all aligned with the graphing technology by the theme of *Dynamic Algebra*. This study shows that daily use of graphing calculators is generally more effective than infrequent use, and establishes that the teachers and students who used graphing calculators most frequently learned the most.

Researchers in different settings have investigated the effectiveness of graphing calculators in relation to students, teachers, and schools with diverse characteristics. Graham and Thomas (2000), for example, examined the effectiveness of graphing calculators in algebra classrooms in New Zealand. The study compared pretest and posttest scores for year 9 and year 10 students in treatment and control group classrooms in two schools. In all the classrooms, the regular classroom teacher taught the "Tapping into Algebra" curriculum module. In treatment group classrooms, each student received a graphing calculator to use throughout the module; in control group classrooms, students did not use graphing calculators. Students in all classrooms had similar background characteristics and math abilities. Graham and Thomas found that students in the treatment groups performed significantly better than students in the control groups on the posttest examination.

Meta-Analyses Show the Effectiveness of Graphing Calculators

A meta-analysis by Ellington (2003) summarized 54 classroom experiments, of which 80% employed some form of random assignment of students to experimental groups (using calculators) and control groups (not using calculators). Ellington's analysis shows a positive effect of graphing-calculator-based interventions on student achievement. The effects are substantial, often increasing an average student's achievement by 10–20 percentile points (Ellington, 2003). In addition, the studies suggest that when graphing calculators are allowed on tests, gains extend from calculations and operations to conceptual understanding and problem-solving. Ellington's summary includes a wide variety of grade levels, socioeconomic backgrounds, geographic locations, and mathematical topics, suggesting that the effectiveness of calculators holds true in a variety of contexts.

A second meta-analysis looked specifically at algebra. Khoju et al. (2005) screened available research using stringent quality-control criteria published by the US Department of Education's What Works Clearinghouse. They found four suitable studies that examined the impact of graphing calculators on algebra learning. Across a wide variety of student populations and teaching conditions, use of graphing calculators with aligned instructional materials was shown to have a strong, positive effect on algebra achievement.

Why Have Calculators Been So Successful?

A number of key features contribute to the success of calculators in bolstering math learning. Calculators and graphing calculators are relatively simple, robust, and cheap; they are also remarkably free of much of the complexity that accompanies full-featured computers. More important, there is a deep scientific linkage between the capabilities of the technology and how people learn. Students learn more when cognitive load is focused on the most important learning challenges (Sweller, 1988), when linked multiple representations make different features of a mathematical object available to students perception (Kaput, 1992), and when students have more time to focus on the strategic and problem-solving aspects of mathematics (Ellington, 2003).

Two less readily obvious factors also contribute to the success of graphing calculators. First, the adoption of the technology has been led by practicing teachers, who function as the key champions and influencers in a professional community (Ferrio, 2004). Second, efforts to integrate graphing calculators into classrooms did not begin with the expectation of a rapidly transformed classroom, but rather provided a context to support a long, steady trajectory of continuous improvement (Demana and Waits, 1997). In this way, teachers can begin with one or two relatively simple applications of the technology, and gradually increase the depth and breadth of their calculator integration as they grow more comfortable with the technology. At each stage, graphing calculators can provide concrete enhancements for teaching and learning math.

Discussion and Conclusion

Graphing calculators are an important case of successful large-scale adoption of information technology in education, with a robust and consistent research base that links technology use to increased student achievement. Further, new technological capabilities, including multiple, dynamic representations and connectivity, offer additional opportunities to transform teaching and learning in mathematics, making critical math concepts accessible to all students. If educators and policy makers want to improve students' mathematics achievement, graphing calculators – in conjunction with aligned curricula, instructional practices, and professional development – can provide an inexpensive and effective solution that is feasible and ready for large-scale implementation. Moreover, if members of the educational technology community want to provide new technologies that will have a real impact on learning, they would do well to heed the lessons and successes of the graphing calculator.

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Section 10

RESEARCHING IT IN EDUCATION

10

RESEARCHING IT IN EDUCATION

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Section Editors

This section focuses on the priorities, methods, and effectiveness of research relating to IT in primary and secondary schools. In comparison with other innovations in education and research, IT in education has been a very high priority for most governments because of the pervasion of IT into all aspects of society (Kouzelis et al., 2005). These priorities have changed from early investigations focusing on measuring the impact of educational computer programs on pupils' learning to measuring the effects of diverse types of IT on the curriculum, the ways in which schools and teachers adopt and use IT, the different types of human–computer interactions and the communication opportunities provided by online teaching and learning.

Once the cost of IT technologies became affordable for schools, local, national and international research studies were set up to investigate the numbers of computers in schools, the numbers of teachers using them and how frequently they were used, amongst many other factors relating to IT technology in education. Large-scale quantitative studies have been used to make comparisons between the provisions and uses of IT in different countries (Pelgrum and Plomp, 1993) and to measure changes over time in teachers' uses of IT; meta-analyses to measure changes in pupils' learning (Liao, 1999) as well as small qualitative studies to measure in-depth changes in teaching, learning and collaboration have also been used. New technologies are changing the emphasis and the balance in terms of the production, content, knowledge representation and meaning of IT, necessitating a change in the methods needed to measure their impact on education.

This section presents evidence of the diversity and complexity of researching IT in education, considering the strengths and weaknesses of different designs and methods.

Chapter 10.1 gives an overview of the different techniques and methods that have been used to measure the impact of IT on education, drawing on the history of researching IT in education over the last 50 years. It draws together the issues identified from previous research studies, concluding with guidelines for improving research into IT in the future.

Chapter 10.2 reviews a range of research results to show the strengths and weaknesses of different research designs and approaches, comparing formative and

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summative research designs and considering the educational theories about teaching and learning methods which should underpin the research. It also reviews the relationship between specific research goals and the methods that have been used to meet these goals.

Chapter 10.3 focuses on the impact of IT on students' learning and discusses the ways in which it has been measured taking account of a range of perspectives. These include methods that have been linked to specific IT resources and tools, techniques that have matched more traditional methods of assessing learning, techniques that need to take account of new modes of representations and new literacies for the users and learners in different educational settings.

Chapter 10.4 discusses the strengths and weaknesses of meta-analyses of a large number of studies investigating the impact of IT in education. It considers the aspects that can be reliable in such studies in relation to large-scale individual studies such as those using experimental and control groups, identifying the benefits and limitations of this meta-analytical approach for different educational settings.

Chapter 10.5 discusses and analyses previous techniques used for evaluating educational software and how evaluation should be an integral part of the design and development of IT tools in education for different educational uses and sectors. Examples of the effectiveness of software evaluation methods are presented and analysed, explaining the limitations and scope of software development and evaluations.

Chapter 10.6 reviews the different large-scale international comparative studies that have been conducted over the last two decades to consider the range of techniques and their usefulness and reliability. These studies are analysed in relation to various national and international policies and programmes in order to determine the indicators that are likely to be reliable on a large international scale.

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10.1

RESEARCHING IT IN EDUCATION

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Introduction

During the growth of IT in education, research has diversified and improved our understanding of the impact of the wider educational experiences, teachers' pedagogical practices and the learning contexts on students' learning. Researching the effects of IT on students' learning now includes measuring the consequences of collaborative learning, the increasing autonomy of the learner, the relationship between the immediate learning experience and the wider learning context, the role of the teacher and many other influences (Salomon et al., 1989; Crook, 1992, 2000). Including these factors in educational research has resulted in a diversification in the research methods used to investigate the impact of IT on learning and in education, controversies about what is actually being researched and the reliability of the results (Cox and Marshall, 2007; Marshall and Cox, 2008). The explosion of IT tools and resources has spawned new literacies based on changing perceptions and understandings and linked to new modes of presentation and representations. These new literacies and knowledge representations are changing the emphasis and the balance in terms of the production, content and meaning of IT and therefore a change in the methods needed to measure its impact on learning (Liao, 1999; Ravenscroft and Pilkington, 2000), which is often not understood by teachers or even some researchers.

Research into the uptake, use and impact of IT in education can be done from a growing number of perspectives. These perspectives have increased in number as the technology has diversified and are influenced by the way in which IT has pervaded society and education (Kouzelis et al., 2005). In the 1960s, research into IT in education was initially focused on the effects on students' learning, because the main purpose for using IT was to enhance existing teaching and learning practices or to present the existing curriculum in different ways (see also Voogt, 2008 in this handbook). During this period, there were two main thrusts for IT in education. Firstly, universities and national governments recognized the need to provide a growing number of IT experts to work in the IT industry, and secondly, pioneering educators

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saw the potential for new technologies to enhance teaching and learning in other subjects. The research and development of IT in educational settings was therefore intertwined with the design of the IT tools themselves and the focus was on the impact which these had on students' learning and the consequent improvement of the design (Reeves, 2008). Alongside these developments were evaluations of the effects of using IT on students' IT skills and abilities. Therefore, researching IT in education needs to acknowledge the ways in which IT is used in and out of schools, on-line and in many different contexts. It needs to take account of the uptake of IT in different settings, the role of the teacher in the teaching and learning process, the influence of the curriculum and the complexity of the IT environments. If we consider the wider field of educational research in general, then there is no other educational innovation which is so complex to research because of its relentless evolution which changes the very nature of what is taught and how knowledge is accessed and presented. Table 1 shows some of the important changes in IT systems, their consequent uptake in education and the development of research agendas and foci which have evolved.

Evolution of IT Resources

The ways in which IT technologies have evolved have influenced the focus and scope of research. In the early days of IT use in education, as is shown in Table 1, the main types of software available on the mainframe computers were linked to graphics terminals and then on small stand-alone microcomputers. The research focus on evaluating software, which had specifically been developed for use in education, raised specific research questions such as "what effects does this mathematics program have on the pupils' understanding of fractions?" and "how does this simulation improve pupils' understanding of satellite motion?". The scope of IT educational software was bounded by the types of programming languages available at the time such as Fortran and Algol (Suppes, 1966). However, by the early 1980s, there were more programming languages, e.g. Basic, C-plus and higher-level languages such as Logo and much more powerful computers with more memory and powerful graphical interfaces which broadened the range of educational software enabling pupils to build models, react more extensively with the software environment and experience more sophisticated human–computer interactions. Researchers were measuring the effects on pupils' learning of microworlds such as Logo (Papert, 1980), intelligent tutoring systems (Sleeman and Brown, 1982) and simulations and modelling (O'Shea and Self, 1983). There was relatively little research at that time into how teachers might be using these systems in relation to their own pedagogies. The learning measures were mostly based on using traditional pre- and post-tests or through analysing pupils' performances through the completion of IT-based tasks such as the models they built using Logo, or the choices they made for variables entered into a computer simulation.

The early researchers were also those often involved in developing and disseminating educational software as well as measuring its impact on pupils' learning. A good example of this is shown in Table 2, which lists a range of research papers published

Table 1 Technological developments leading to IT in education and research agendas

Dates/era	Technological developments	Development of IT in education and topics for research
1950–1967	Large-scale mainframe valve-based analogue computers	Subject-based drill and practice programs for use with small groups of pupils
	Miniaturization of electronic components (transistors and diodes) and circuitry leading to the large-scale digital computer	The impact on learning and evaluating educational software
	Increase in memory and processing capacity	
1968–1970	The introduction of the Internet–ARPANET–JANET and International networks of computers	Remote access to universities and further education colleges to use IT
1970–1977	Real-time interactive computers	Remote access to educational software programs from universities to schools and colleges
	User graphics on-line computer terminals	
	Internet connections for some schools	
	Remote access to computers from different locations	
	Forerunners of desktop computers: e.g. Hewlett Packard, Horizon	The impact on learning and evaluating educational software
1977–1980	Miniaturization of computers. Production of small desktop computers with 32 k of memory and graphics	Educational graphic simulations, expanding range of educational software
	Move from tape-based storage to disk-based storage of large computer programs	Changes in the IT subject curricula
	Prestel/teletext: commercial and educational information provided on-line	The impact on learning and the requirements for teacher training
1980–1984	Fibre optics facilitating fast and large-scale communication modems in schools providing wider remote access	Large range of drill and practice and simulation software available to schools
	Range of input and output devices for education, e.g. concept keyboard/graphics tablets, touch screens, speech input and output	The impact on pupils' learning, attitudes and uptake by teachers and schools
		Effectiveness of teacher training
1985–1987	Microsoft windows launched	More diverse range of educational software, including modelling software and some access to the Internet and WWW
	More powerful cheaper personal microcomputers	International school collaborations
	Invention of the World Wide Web by Tim Berners-Lee (http://www.en.wikipedia.org/wiki/Tim_Berners-Lee)	The impact on learning, uptake by teachers and schools, and collaboration amongst learners

(continued)

Table 1 (cotinued)

Dates/era	Technological developments	Development of IT in education and topics for research
1987–1990	New external storage devices: CD-ROM: interactive video; plug-in memory cards	Uptake by schools, teachers; international comparisons
1990–1995	Laptop computers	School/home uses of IT
	Spread of wireless computer technologies: networks; air-mouse; video-conferencing; mobile phones	Pressure on IT resources for teaching IT as a subject and teaching with IT
		Organisation of learning with IT and on-line
		School priorities and level of integration
		Theories underpinning educational change
1996–1999	Interactive whiteboard	Whole class teaching with IT
	Personal digital assistants (PDAs)	Individualised learning; informal education
2000–2004	Further increases in processing and storage of personal computers	More powerful educational software
	Wide cheap access to the Internet and the World Wide Web, virtual learning environments (VLEs)	Conflict between office software and educational bespoke software On-line courses and assessment
2004–2007	Web2, Wikis, VLEs. Thin clients	Digital literacies and agendas, relative benefits of different IT resources in school and home

Table 2 Range of IT Japanese and British educational research in the early 1980s

Authors	Title of paper	Research goal
M.J. Cox	Evaluation and Dissemination of Science Software	To evaluate the effects of using science software on pupils' understanding of science and how software can be disseminated to other users
J.R. Hartley	Software Tools for Teaching and Learning in the Sciences	Designing and evaluating software tools and their use and impact in science teaching
H. Nishinosono	Transportability of Software for Microcomputers	Measuring how software can be transported from one type of microcomputer to another (across platforms)
T. Sakamoto	Present State of the Use of Microcomputer in Education	Measuring the level of availability and use of IT (microcomputers) in Japanese schools
J.T. Shimozawa and Y. Kuroishi	Recent Development of the Use of Microcomputer in Chemical Education	Evaluating the use of IT in chemistry teaching in Japanese secondary schools
R.A. Sparkes	Microcomputers in the Science Laboratory	Designing and evaluating the uses of measurement and control devices in the science teaching laboratories in the UK

Source: Journal of Science Education in Japan, 1984, *8*, 2

in the Journal of Science Education in Japan in 1984 as the output from a Japanese–British Seminar on computers in science education and assessment.

In the early 1980s, there were still few computers in schools and mostly they were stand-alone or in small clusters. The teaching and learning contexts being researched during this period included individual pupils working on his/her own through an educational program, pairs or small groups working around a computer collaborating on the problems and inputs presented to them through the software, and whole class teaching involving a teacher demonstrating an educational software program and eliciting answers to problems on the screen from the class. Then, in the late 1980s, four major changes took place which changed the whole educational research agenda for IT in education (Cox, 2005):

1. The cost of computing reduced sufficiently for schools in many countries to be able to afford networks of computers and display monitors.
2. The computer manufacturers provided bundled "educational" generic software when the networks were purchased, mainly chosen for the wider software market in commerce and industry; i.e. word processing, spreadsheets, database software and graphics applications, which mostly displaced the educational software being used.
3. The complex design of the "new" software environments required much more understanding of human–computer interfaces, curriculum potential and the wider learning context.

4. It was recognised that schools and teachers needed to have much more training to take up the use of IT in their teaching.

IT in education was no longer seen by governments as an optional extra, it was a very large investment which required ongoing justification and substantial research to show what impact IT was having across all sectors of education, especially schools. National policies on IT in education became closely linked to government-led research agendas (Pelgrum and Plomp, 1993; Plomp et al., 2008) and a large element of this was to measure the uptake of IT in schools by teachers, pupils, types of computers and so on, which is discussed in the next section of this chapter.

Uptake of IT in Education

As can be seen in Table 1, access to IT resources has expanded with the reductions in cost and the diversification of types of IT technologies. As a result of national government IT in education policies, there have been many national and international studies investigating and comparing the uptake of IT in education (mostly at the school level) (e.g. see DfES, 2003; Pelgrum and Plomp, 1993, 2008), which have provided evidence of the factors which promote or inhibit the uses of IT in education. The methods used in these large-scale studies include school and teacher questionnaire surveys across countries, specialised IT tests and standardised tools for analysing the results. However, the data provided by each country will be influenced by the national interpretations, the political priorities and the local methods for collecting the data. For example, answers to questions about how much training teachers have had to improve their uses of IT in teaching in one country which does not have the professional development of teachers as a national entitlement would list the number of attendances at occasional workshops and other training sessions (providing all the training information), whereas another country which does provide regular days of training for all practising teachers may not include these in their responses because the training on these days varies significantly between individual schools and does not always include IT. Furthermore, many of these large-scale studies do not always specify what is meant by IT and what is understood nationally. For example, in the comparative international studies, does IT mean a wide range of educational software plus different IT hardware (desktop computers, laptops, measurement and control devices, etc.) or does it mean regular use of office type software such as word processing, spreadsheets, e-mail and Web sites or possibly both? Although great care may be taken in the design of questionnaires for example to cover this diversity of IT resources, schools and teachers themselves have been seen to differ significantly in their interpretation of the meaning of IT which therefore influences their responses to such questionnaire surveys (Watson, 1993).

In a questionnaire survey of 100 British IT teachers whose main responsibility was to teach the IT curriculum, conducted by Preston et al. (2000), the frequency of use of IT, as reported by these teachers, was for every lesson and everyday of the week. However, in response to questions about the frequency of specific *types* of IT resources used, i.e. word processing, spreadsheets, educational simulations, modelling, etc., 96% of the teachers were only using *word processing* more than once a month. All the other software resources they were expected to use were actually only being used very infrequently. This shows that had the researchers relied on questions which only asked about use of IT without specifying what types of IT, then the results would have been very misleading. There still remain ambiguities across such results because of these factors and more work needs to be done to identify how to monitor specific IT types being used and which data collection methods can provide the most reliable and robust results.

In spite of many nationally funded research programmes, there is some evidence that the relationship between robust research results and subsequent government policies is sometimes thin to non-existent. There is, however, evidence from government strategies that the IT industry is driving policies for IT in education rather than the educational research evidence, in case education gets left behind. See, for example, the study by Moss et al. (2007) which was commissioned to evaluate the effectiveness of interactive whiteboards (IWBs) in London schools which had received £25 m from the government to purchase and install IWBs prior to the research study. Although the British government had commissioned a small literature review previously into the usefulness of IWBs (Becta, 2003), it is often the case in the UK that the government will commission substantial research studies *after* large programmes of IT investment in schools (Watson, 1993). This investment is often linked to innovative developments in the IT industry, such as PDAs, video-conferencing, virtual environments, IWBs and so on, so there is an ongoing debate about how much research should be conducted in which the innovation is made available to educators and institutions *before* its educational value is known.

Measuring Learning and Motivation

Since the early research, which focused on measuring the changes in learning as a consequence of an educational IT program intervention, the design of research instruments has also been influenced by the types of educational theories and practices used by the researchers. For example, the early measures used to assess pupils' learning of science or mathematics concepts were based upon similar tests used for more traditional learning environments. Even though these studies might involve pupils exploring graphical representations on a computer screen, the research into pupils' learning was often using paper-based pre- and post-tests based on standard subject tests to measure pupils' achievements in solving problems, solving simple equations and completing prescribed tasks. It was some time before researchers realised that measuring the impact of IT on learning and motivation was much more complex (Laurillard, 1978; Somekh, 1995) and that the learning gains of the pupils may be more related to being able to interpret graphical representations than solve equations representing factorial relationships (Cox, 1983).

Researchers in the last two decades have also recognised the need to investigate the effects of IT on pupils' generic and specific skills and knowledge, the effects of group and collaborative learning, taking account of human–computer interfaces, the changing nature of knowledge presented and the role of the teacher. Taking many of these factors into account, numerous results of studies researching the impact of IT on students' learning have provided convincing evidence of its positive impact on learning gains (cf. Cox and Abbott, 2004; Bliss, 1994; Liao, 1999; Watson, 1993) and students' motivation (cf. Cox, 1997; Gardner et al., 1993; Sakamoto et al., 1993). Even then, many of these studies have involved using different research methods and learning contexts, thereby limiting the generalisability of the results for the wider IT using community.

Large-scale international studies, such as those conducted by Pelgrum and Plomp (1993) and Malkeen (2003), which use the same instruments for all country participants and meta-studies (e.g. Liao, 1999; Liao and Hao, 2008), therefore involve methods which provide results which can be generalised for the common variables being investigated. However, such studies cannot always take account of the local and national variables such as whether or not the country's national curriculum requires the teachers to use IT and therefore the uptake might be higher than where it is an optional extra, or how teachers and schools and the national researchers interpret the meaning of IT. The results of large-scale studies or meta-studies comparing the uptake and use of IT by different countries or large numbers of schools need to take account of these limitations.

The term *IT* implies an all embracing generic term covering all aspects of IT resources. However, the way in which a specific IT resource is used in education may or may not have a positive impact on learning (Cox and Abbott, 2004) and how that resource is used will also depend upon its design and implementation. For example, if we consider computer-based modelling using different modelling environments (Mellar et al., 1994), the educational potential will be determined by the relevance of the design to the modelling skills of the learner. It will also depend upon the human–computer interface and its transparency for use in education, and the design of the environment in relation to how the subject material is represented and how the interaction is split between manipulating the software and engaging with the deeper learning activity. Therefore, an important component of researching IT in education is to evaluate the design and development of IT tools through an iterative process of design, use in education and redesign as explained by Reeves (2008) in this handbook. This diverse area of research ranges from evaluation studies which aim to measure the usability of the tools with teachers and learners (Reeves, 2000; Squires and McDougall, 1994), to more in-depth evaluations of the way in which the learner interprets knowledge through engaging with new presentations and various human–computer interactions (Cheng et al., 2001; Mellar et al., 1994; Ravenscroft and Pilkington, 2000). Therefore as explained by Pilkington (2008), research in this area requires detailed knowledge by the educational researchers of the nature of IT tools, their different representations and the ways in which they may contribute to learning and knowledge to design appropriate research methods to measure their impact.

Teachers' Beliefs and Practices

The funding and research between the 1970s and 1990s into the effects of teachers' professional development on their uses of IT were mostly based on the assumption that the IT training of teachers only required developing their competence in using the technology and knowledge of suitable hardware and software in order for them to be able to make the transition to become regular IT users in their subject (Cox and Rhodes, 1988; Rhodes, 1999). Therefore, research studies in many countries into the impact of teachers' professional development on IT use in schools were focused on measuring the teachers' reported frequency of IT use in their subjects and lessons and whether they felt competent and confident to use IT with pupils (DfES, 2003; Pelgrum and Plomp, 1993). However, these research results often also showed a disappointingly low level of uptake of IT by teachers in spite of encouraging research evidence about the previous amount of training which teachers had received. In those earlier days, little use was made by governments and many researchers into the theories already known about how to change teachers' practices (Desforges, 1995) and how influential the school staff and context would be on their ability to take up the use of IT in their lessons (Fullan, 1991; Somekh, 2008). It is now known that this was a too simplistic and unrealistic view of how to train teachers effectively to use IT in their teaching and how to measure the real effectiveness of this training on practice (see also Knezek and Christenson, 2008).

Substantial previous research into teachers' use of innovations has shown that a change in pedagogical practice not only depends upon the teachers' beliefs and theories of teaching (Shulman, 1987; Watkins and Mortimer, 1999; Webb and Cox, 2004), and a willingness of the individual teacher to adopt the use of IT but also depends on the policies and practices of the institution as a whole, and of the culture within that institution (Fullan, 1991; Rhodes, 1999; Williams, 2005). Research into the impact of teacher training (Leach and Moon, 2000; Leaton-Gray, 2005; Rhodes, 1999) and the pedagogical practices in the classroom (Cox and Webb, 2004; Harrison et al., 2002; Higgins, 2003) needed to take account of and measure the many factors which need addressing through professional development. These include the need to measure: the attitude of the head teacher (principal) (Rhodes, 1999; Koutromanos, 2005), the attitude of the teachers to IT (Katz and Offir, 1993; Koutromanos, 2005; Preston et al., 2000), teachers' expectations of the learning impact of the technology (Cox and Webb, 2004; Pajares, 1992), the responses of the pupils' and teachers' willingness to further their professional development (Desforges, 1995; Williams, 2005) and the teachers' beliefs and understanding of the role of IT within the subject being taught (Cox, 1997; Cox and Webb, 2004; Webb, 2002). Research into teachers' beliefs about IT and their teaching practices therefore requires understanding and taking account of a complex framework of factors which influence the ability and willingness of teachers and principals to take up the regular use of IT in their teaching.

Based on a much deeper understanding of the complexities of researching teachers' IT beliefs and practices, there is now a growing area of educational research into how IT affects the ways in which we teach using IT (e.g. Cox and Webb, 2004; Law and Plomp, 2003). This research includes methods to evaluate the pedagogical beliefs and practices of teachers (Webb, 2002; Cox and Webb, 2004), research into the enablers and barriers to the use of IT in education (Jones, 2004; Scrimshaw, 2004) and the impact on practice of the professional development of teachers (Desforges, 1995; Sparks and Loucks-Horsley, 1990). Therefore to understand how IT might contribute to students' learning, we also need to investigate what influences on this process are attributable to the professional development of the teacher and the consequent uses made of IT by the teacher and pupils.

National and International Contexts

The ways in which IT is used in different nations will set the priorities for researching IT in education. There are many factors identified by researchers which have been shown to differ between countries and country states and school districts. Here, examples of local and national differences are considered which underpin the research priorities.

The Teaching and Using of IT in the Curriculum

Ever since the 1960s, pupils in many countries have had the opportunity to learn computer science in secondary schools as a specific subject (Beauchamp, 2003). When the use of computers to enhance learning started to move into schools (Bork, 1980, 1985; Cox, 1983; Sakamoto, 1984), then this computer science curriculum became influenced by and in conflict with the uses of IT to enhance the teaching of other subjects (Cox, 2005). Cross-national policy and practice research (Pelgrum and Plomp, 1993; Plomp et al., 2008) has shown that the balance and priorities between these two uses affect the relative level of IT resourcing, the number of staff available to teach IT compared to those who can help other teachers use IT in their teaching and how these might affect research into the impact on pupils' learning and the uptake by schools and teachers. For example, in England and Wales, IT as a subject is a compulsory part of the national curriculum whereas in many other countries it is not (Perraton and Creed, 2000). Consequently, research into the uptake of IT by different subject teachers will vary from country to country because of these different priorities. This has implications for using previous research results to inform new research projects, conducting meta-analyses of many individual studies which involve different national priorities and large-scale comparative studies which do not take these differences into account.

Level of IT Resources in Schools

Large-scale international studies and cross-national comparisons have shown that the level of IT resources available to teachers and schools vary significantly from state to state and country to country (e.g. see Pelgrum and Plomp, 1993; Perraton and Creed, 2000). Researching the impact of IT on pupils' learning will depend upon the regular availability of IT in subject teaching and the range of IT resources which the teachers and pupils use. Even if the measurement instruments are similar, there will be significant differences in learning outcomes attributable to pupils using for example computer-based modelling with one computer per pupil compared with pupils who only have access to IT use once per month in a class which has only two computers shared between 30 and 40 pupils.

There is also a rapid growth especially in many of the developed countries in using the Internet for on-line collaborations, whole courses, remote working, blending home and school learning and individualised learning of pupils. Research into the potential contribution to teachers' strategies and pupils' learning brought about by these IT uses needs mixed methods to measure these influences effectively and a recognition of the imbalances between countries for access to this wider IT environment and educational opportunities.

National and Regional Priorities

Although most countries are now engaged in promoting the uses of IT in education (see also Perraton and Creed, 2000; Plomp et al., 2008), it is not the only priority for improving education. In Mexico, IT is being used to help provide regular education to remote villages and poor districts, while in the US the level of IT resources is very high but it is used differently in schools from state to state. Since 2006 in the UK, the government agenda for education has become "every child matters" similar to the US' policy of "no child left behind". The UK policy has resulted in the research agenda focusing on individualisation of pupils' learning with IT and furthermore a programme to rebuild all secondary schools by 2010 with a strong emphasis on IT resources (Cox, 2008). Therefore, the ways in which IT is used as a result of national and regional priorities will affect the types of research which can be conducted and limit the comparisons possible between studies in different countries.

Cultural and Language Differences

Each country has its own educational curriculum and practices for teachers and learners which will impact upon the effects of IT in education. For example, in the UK, teachers can stay in a specific school for the whole of their teaching career if they choose, whereas in Japan teachers are required to move schools every 2 years. Researching the uptake of IT by teachers in schools will be affected by this difference. Previous research shows that it takes a long time for teachers and schools to adopt innovations (Rhodes, 1999) so on the one hand, teachers remaining in schools for a long time will have time to develop networks of colleagues in the school to help them take up IT use, strengthening the IT use within the school. On the other hand, in Japan, where teachers move schools frequently then IT experienced teachers will take this experience to the next school and help disseminate expertise from school to school.

Significant cultural differences between different religious states will affect the types of IT resources available to pupils and therefore the learning scope and potential for the pupils. In Kuwait, for example, there are strict guidelines applied to the design of all educational resources including IT environments to honour the practices of Islam (Sadeq, 2003). In secular states, such guidelines do not apply so that the types of IT resources regardless of the different languages will differ from some countries to others. Comparative studies of the impact of IT on learning across different countries need to take account of these differences.

Since the growth of the Internet started in the English language, there are many more Web sites in English than in any other language. Research into on-line learning investigations will consequently differ across countries due to this variation in range and types of on-line resources for teachers and learners.

Complexity of Researching IT in Education

Educational research draws on many disciplines to inform the methods which should be used which have to take account of the ever-changing IT environment.

Theories Underpinning Researching IT in Education

If the focus of the research is on the learning of the pupils, then the research should be underpinned by psychological theories relating to learning, attitudes, human–computer interactions and conceptual understanding and development (Marshall and Cox, 2008). At the other end of this spectrum when researching the ways in which schools adopt IT and how the teachers are able to use IT, then educational research should be based upon sociological theories about educational change, drivers in education and educational policies. The interrelated perspectives of IT in education identified above require a plethora of methods to research IT in education effectively.

Suitability and Reliability of the Methods

The assumptions often made by researchers about the reliability of their instruments and the significance of their results are not limited to those finding positive effects of IT in education. A critical review published by Cuban et al. (2001) of a study of the effects of IT on students' learning of mathematics concluded that using IT had a negative effect. On examining the original research in detail, it was clear that the mathematical tests were not measuring the mathematical tasks and outcomes which the IT tools were actually providing. Neither was the role of the teacher examined, nor the specific actions of the pupils, so it is impossible to conclude that the IT resources had a negligible or negative impact on the students' learning. Another example of misleading outcomes is the research results of the first UK Impact Study (Watson, 1993), in which it was claimed by critics of the research that IT had a negative impact on children's learning of science. This conclusion was incorrect because the reviewers had only considered the original grouping of the high-IT (experimental) and low-IT (control group) comparative results. As the research progressed, it became clear to the researchers that the original non-IT using science classrooms overtook the "high-IT" classes in their uses of IT and therefore the results of the experimental and control classes should have been reversed (Cox, 1993).

The Complexity of the IT Environments

As mentioned above, the growth and range of IT resources have led to an expanding range of representational systems and different modes of human–computer interfaces which has extended the specification of knowledge and knowledge domains (see Marshall and Cox, 2008). IT technologies in education now include sensors and switches and the use of haptics (virtual physical environments using touch devices) for teaching and learning which introduce contexts, in which the learner is immersed in a virtual reality which will affect the learner's cognitive development according to the learner's ability to move between different states of reality. As a consequence of these wide ranges of IT environments, the impact on the pupils' learning is extremely complex and research into this impact needs to take account of such variables as, level of presence, stages in the learning process, levels of immersion and the transfer between the virtual and real worlds.

These complexities, changes in theories, anomalies and misunderstandings about research results imply that there needs to be a much clearer identification and classification of what constitutes researching IT in education and what can be relied upon to inform other researchers, practitioners and policy makers.

Conclusions

The issues identified in this chapter show the complexity and dynamic nature of educational research caused by the scope and potential of the IT environments and the demands this places on the educational community to understand them. Without a deep understanding of the potential for IT resources for teaching and learning, it is very difficult for researchers to design studies which will measure the actual relationships between specific IT resources and teaching and learning. Regardless of the level of IT use in any one country, researchers can benefit from including the following in their investigations:

1. Any investigation should be clear about what types of IT are going to be used and design measures to match the specific IT type to the teaching and learning outcomes.
2. Research studies should take account of the nature of the knowledge representations likely to be experienced and not limit the research to assumptions about traditional subject material knowledge representation.
3. Research into the impact of IT resource types on learning needs to take account of the pedagogical beliefs and practices of the teachers involved.
4. In-depth case study investigations are required to measure the quality and extent of the teaching and learning experience.
5. The ways of measuring the impact of IT on education need to take account of the different factors which may need measuring in addition to attainment and learning gains.
6. Large-scale national and international studies should include case studies to find out the level and depth of IT use and experience to inform the quantitative data.

Finally, as we all know, the IT industry is bringing out new products all the time, many of which will enter education. In referring back to Table 2, the research agenda has changed in many countries to focus on investigating the uses and impact of on-line learning. What previous research has shown us, however, is that innovations in IT may reach schools but are often not taken up as extensively as expected and often not used to their full potential. It is therefore necessary to take into account the relevance of these innovations to the curriculum, the time teachers actually have to learn how to use new IT devices effectively and whether schools and current curricula can keep up with the impact of IT on society as a whole. It is often said that research conducted a few years ago is no longer relevant because the IT environments are changing so rapidly. However, all the evidence to date shows that schools and teachers do not change so rapidly and there are valuable lessons which can be learnt from past research findings. Had governments paid more attention to these findings when they were first produced they would have avoided many inadequate studies which followed.

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10.2

RESEARCH METHODS: THEIR DESIGN, APPLICABILITY AND RELIABILITY

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Introduction

This chapter reviews the strengths and weaknesses of different research methods used to measure the impact of IT in education. It includes reviewing the designs and approaches, and the relevance and applicability of quantitative and qualitative methods drawing on previous research evidence. Many previous research studies have relied upon methods which measure changes in education due to innovations, generally resulting in many cases of a limited applicability of the methods to the research goals. Such studies could have been linked more specifically to the learning activities promoted by specific IT tools and the relative emphases required to take account of different factors influencing the integration of IT in education. A basic premise of this chapter and of research into IT in education is that important questions are generated, and strategies that are appropriate and rigorous are deployed to answer those questions as unambiguously as possible. A major goal of research and evaluation is to advance knowledge.

"Evaluation" is often considered a more pragmatic aspect of educational research than the techniques employed in "classic" research studies. Evaluation has usually been conducted to answer questions of interest to funding agencies, education authorities and other stakeholders who demand answers to questions of "How?" and "Why?" and "Of what influence?" Evaluation results, for better or for worse, have often been influential amongst policy makers in determining the effectiveness of IT in teaching and learning. We therefore include some discussion about evaluation design and approaches, and the consequent results in this chapter in addition to the often more rigorous research techniques which have been used. Design and evaluation of IT tools are discussed in more detail by Reeves (2008) in this handbook.

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Research Goals

Before considering the effectiveness and relevance of different methods which have been used to research IT in education, we review the different goals of researchers, which have been influenced by technological developments, national priorities, expectations of educators, the types of IT tools available and so on. The major research goals have changed as a result of the growth and uptake of IT in education as discussed by Cox (2008) in this handbook. The research goals reported on most extensively are listed in Table 1 below showing the types of research methods most often used to address these goals.

Table 1 Research goals and relevant research methods

Research goals	Quantitative	Qualitative
To measure the impact of IT on pupils' learning	Large experimental and control groups Pre- and post-tests of learning gains Meta-analyses of quantitative data Large-scale (on-line) surveys	Small groups of learners using specific IT tools as either an intervention or part of the natural class activities Observations, specific task performance, focus groups Interviews of learners Pre- and post-tests
Uptake of IT by schools and teachers	Large-scale surveys Questionnaires of many teachers and schools	Questionnaire surveys of teachers in schools Observations of classes
Effects of IT on learning strategies and processes	Pre- and post-tests of specific subject processes	Assessment of prescribed tasks Observations of pupil–computer interactions
Effects of IT on collaboration, contextual effects, etc.		Class observations, teacher interviews, questionnaires, documentation
Attitudes towards computers in education	Attitude tests of pupils and teachers	Interviews and focus group discussions
Effects of IT on pedagogies and practices of the teachers	Large-scale surveys of frequency of use, types of IT use, etc.	Class observations, teacher interviews, questionnaires, documentation
Computer use by girls vs. boys	Large-scale questionnaire surveys of computer use	Class observations, pupil interviews, questionnaires
Contribution of IT to enhancing access and learning for special needs	Large-scale surveys Questionnaires of many teachers and schools	Small groups of learners using specific IT tools as either an intervention or part of the natural class activities
Total operating costs and cost effectiveness	On-line surveys of all school staff, large-scale surveys	Teacher interviews, school records, staff questionnaires

As explained by Cox (2008), in the late 1970s and 1980s, the major emphasis of researching IT in education was on investigating the specific impacts which an IT intervention might have on students' learning outcomes, their motivation and the impact on understanding specific concepts and skills. The methods used were mostly methods of subject-based assessment which had been used to measure impacts of other educational innovations and interventions. This focus on the impact of IT on learning changed as more factors were identified. The types of interventions were dependent upon the priorities of the educational establishment, the way the curriculum was delivered and the types of IT tools developed at the time. These changing goals shown in Table 1 and discussed below were as a consequence of the growth of IT in education and the outcomes of previous research studies.

To Measure the Impact of IT on Learning

Since the mid-1960s, one of the major goals of researching IT in education has been to examine an intervention ("What was the treatment?") and examine the impact ("What was the impact?"). Explaining the variance between what occurred (or what did not occur) and the consequent impact should be part of any educational research project. As discussed by Pilkington (2008) and Reeves (2008), the original design for measuring the effects of an intervention was to expose a select group of pupils to using IT tools specifically designed for educational purposes, sometimes in a school setting, sometimes in a laboratory and to measure improvements in learning through pre- and post-testing. For examples of this type of research, see the early editions of *Computers and Education* and similar journals. The various limitations of this type of research design included the researchers often assuming that the tests could be based on those which measured traditional learning gains. The intervention was often an additional extra to the pupils' learning programme and the results could not be generalized to other schools and settings.

Uptake of IT by Schools and Teachers

Once IT resources became cheap enough to be able to be purchased in large numbers, schools purchased networks of computers, clusters of stand-alone ones and some for administrative purposes. The increase in provision resulted in governments and local districts wanting to find out what the uptake was by individual schools and teachers. Many governments commissioned large-scale surveys of their schools to find out how IT resources were being used. A good example of the range of research instruments used for national surveys is given by Pelgrum and Plomp (1993, 2008). They coordinated several international surveys of the uptake of IT by schools, teachers, head teachers, etc. There have been many large-scale studies since the 1980s which have focused on measuring this level of resource use (e.g. Watson, 1993; Harrison et al., 2002).

Effects of IT on Learning Strategies and Processes

Once there were sufficient IT resources in many schools and classrooms, there was an increase in research projects to measure in more detail how specific IT uses impacted upon learning strategies and processes, requiring different research methods as shown in Table 1 including audio–visual recordings of pupils' IT uses, human–computer interactions, and the devising of specific tasks which pupils had to complete relating to specific IT uses. The most reliable evidence of a positive impact of IT tools on learning strategies and processes as explained later was with this research approach where the pupils were assessed in great depth and detail regarding specific identified uses of IT (Cox and Abbott, 2004).

Effects of IT on Collaboration and the Learning Context

As a consequence of a large number of studies of pupils using computers in different class settings and the growing awareness of researchers about the importance of teamwork amongst pupils, research in IT in education expanded to include the goal of measuring what effects pupils' collaborating had on their learning and teamwork skills when using IT and conversely what effects the use of IT environments had on those collaborative skills. Since the rapid growth in the use of on-line learning, then more sophisticated research tools have been developed, including on-line monitoring of pupils' computer use, on-line assessment techniques and the need to take account of the different knowledge representations which such complex environments provide (Cheng et al., 2001).

Attitudes Towards Computers in Education

In spite of a large increase in IT resources in schools and informal educational settings, the research into uptake by teachers and pupils still showed that this was disappointingly low. It became apparent that the attitudes of teachers and learners significantly affected their willingness and abilities to use IT tools and thereby the level of benefit which could be achieved. As a consequence, there are now a large number of research studies into attitudinal and personality factors towards IT in education (Katz and Offir, 1988, 1993; Sakamoto et al., 1993; Gardner et al., 1993; Koutromanos, 2004), in which attitude tests, consisting of many questions about fear of computers, liking of technology, liking using them in schools, etc., have shown strong links between pupils' and teachers' attitudes and the effects on IT use and learning (see Knezek and Christensen, 2008 for more details about this research). Many researchers also claimed to measure attitudes of pupils by simply asking a few questions about whether they liked using computers or not, a strategy which does provide some useful evidence but is not so robust as using tried and tested attitude tests which try to measure the underlying feelings about IT.

Effects of IT on Pedagogies and Practices of the Teachers

Even though there was a gradual growth in IT use by teachers and pupils reported in many countries, the research evidence showed that the ways in which IT was used were very dependent upon the teachers themselves, what they believed to be important, how they selected the IT tools for their curriculum, how they organized the lessons and so on. Therefore, many researchers focused on measuring those factors, mostly either through questionnaire surveys which only obtained evidence about level of use and types of IT use in different curriculum subjects (see for example Pilkington, 2008; Pelgrum and Plomp, 2008). To understand the effects of teachers' beliefs and their consequent practices, it was necessary to conduct interviews with individual teachers, observe their behaviour in lessons and follow their practices over a period of time (Somekh, 1995; Castillo, 2006; Cox and Webb, 2004).

Computer Use by Girls vs. Boys

In the early days of IT in schools, many researchers reported that especially with teaching IT or Computer Science as a subject, many more boys were making regular use of IT compared with girls, resulting in a range of studies into the rate of access to IT by girls and boys and types of IT use, etc. The studies involved both large-scale questionnaire surveys as well as actual class observations, pupils' interviews and focused questionnaires. These more detailed methods are able to find out whether girls use IT in different ways to boys and how the design and development of IT tools should take into account these differences (Hoyles, 1989). See also Meelissen (2008) in this handbook.

Contribution of IT to Enhancing Access and Learning for Special Needs

One important goal, which is sometimes overlooked by governments, is to measure the important contribution which IT use can make to pupils with special needs (Abbott, 1999, 2002). This is a very complex research area because of the contribution which IT can make to both physically and mentally disadvantaged pupils. Some IT devices may consist of hand-held manipulative toys which provide sound feedback when a task is performed correctly; others may involve sound output for blind pupils typing e-mail messages on a computer; and others may involve providing safe IT environments for pupils who emotionally find it difficult to relate directly to humans. Measuring the effects of IT tools on pupils' learning requires specifically designed measures to determine the specific characteristics of the IT device and how the device contributes to changes in skills and competencies.

Total Operating Costs and Cost Effectiveness

A final goal, which dominates many large-scale nationally funded research projects, is to answer the questions: "Does IT provide a more cost-effective solution to improve teachers' and pupils' performances?" and "What are the total operating costs of IT in schools?" It is very difficult to provide clear irrefutable answers to the first question although some projects have tried to measure this by extrapolating financial benefits from the improvement in pupils' learning (e.g. Watson, 1993). However, national bodies and researchers are developing tools to answer the second question but they have to rely on teacher interviews, the accuracy of school records and questionnaire surveys of all staff (Becta, 2006a,b). See also Moyle (2008) in this handbook. It is well known that it is very difficult to estimate the total operating costs of IT systems in educational establishments because account must be taken not only of the purchases of IT tools, systems, repairs, upgrades, on-line subscriptions and so on, but also the costs of training the staff, mis-use, inappropriate uses of IT tools, etc., while the IT environment and its role in education are constantly changing.

Epistemological Theories and Research Design

A fundamental influence on the research designs to measure the impact of IT in education since computers were first introduced into schools in the late 1960s and early 1970s has been the beliefs of researchers, educators and policy makers into how pupils learn (epistemologies). *The Structure of Scientific Revolutions* (Kuhn, 1970) contributed to an acceptance of different beliefs about how knowledge was organized and how investigations into the nature of all manner of things could be conducted. Thus, theorists began to re-examine traditional theories and methods in a wide range of disciplines. For example, Reese and Overton (1970) said that the epistemological foundations of researchers in the field of child development (i.e. how learning occurred and was organized) result in different and mutually exclusive strategies for research design and analysis. Dede (2008) in this handbook elaborates how different theoretical perspectives influence the use of IT in teaching and learning. Briefly stated, behaviourists believe that knowledge is a copy of reality, that learning occurs from the outside in, occurs in incremental bits and is facilitated by repetition and reward. According to this philosophy, instructional design including that using IT should be organized in pre-ordained steps.

Researchers working in the tradition of Comenius (Kalas and Blaho, 1998), Piaget (Sigel and Hooper, 1968), Bruner (1966) and Papert (1980) believe that pupils do not photocopy reality. Instead, a mismatch between levels of mental maturity and instruction will result in "deformations" of what has been taught. Similarly, their research is based on the belief that pupils' interactions, either physical or mental, are crucial components of learning, which, in turn, results in a partial or total re-organization of knowledge. Intrinsic needs, not reward and repetition, drive learning and instruction which should proceed in "spirals" (Bruner, 1966), or in the presentation of fully organized blocks of material. Serendipity (Duckworth, 1972), capitalizing on a spontaneous event that engages pupils' interest and motivation, is also recognized as a viable foundation for instruction. The different beliefs about learning have had major influences on the educational design of IT environments and researching IT in education.

Some IT researchers design and conduct experiments based on a behaviourist epistemology. The early work of Bork (1980, 1985), Nishinosono (1989), Katz and Offir (1993) and many of the studies reviewed in the large-scale meta-analysis by Niemiec and Walburg (1992) for example, report on investigations into the impact of IT on specific tasks through the analysis of test performances. Descriptions of the research might include resources, including costs associated with a "treatment" (Moonen, 2001), types of IT tools used but pedagogical methods are often only described very briefly. Pre- and post-tests are used to assess the extent to which changes (number of items correctly answered, for example), if any, occurred. Time, how much time pupils need to solve specific questions, is often an important variable. The methodology ignores questions about the conditions promoting changes in cognitive structuring because researchers worked within "the mind is a black box" framework. An example of such an approach is shown by the early work with pupils conducted by Katz and Offir (1988, 1993). The problem with this type of investigation is that we do not know whether the pupils understood all or part of the material used, or participated in the instructional activities, nor do we know if they understood directions or had the mental maturity needed to engage fully with the task. We do not know if teachers' instructional practices were geared to all pupils nor if the time allowed for instruction was sufficient for all pupils to understand the tasks. Finally, we do not know what cognitive processes pupils used to solve the problems. Did all pupils use the same strategies? Did some pupils understand the problems but make simple mistakes? Could some pupils have solved the problems if more time were available?

Many of these questions could be answered if researchers working within a behaviourist framework adhered to standards for conducting and reporting educational research. So, while research conducted in a behaviourist tradition answers important questions, many other important questions are unanswered by the research, questions which are equally important if we are to answer the question, "What impact does IT make and does the impact make a difference in terms of cost, effort and aims?" Equally important for the reliability of researching IT in education is the need for the researchers to understand the theories which might underpin the factorial relationships in the learning environment and the wider context. Schoenfeld (2004) comments on the "sterility" of experimental/quantitative research. Often, the research has been based on no theoretical framework as was the case with studies of human problem solving, an important topic in mathematics. But models exist for conducting experimental and quasi-experimental research that allow for the examination of complex thinking and of the impacts of competing theories of educational practices, attitudes and personalities and contexts and their impact on pupils' learning (e.g. see Webb and Cox, 2004). Stallings' (1975) research on the effects of Follow Through, a U.S. federally funded program based on several different theories of learning, was a rich, robust attempt to demonstrate the differential impacts of models based on theories. An educational research programme, comparing the effects of different learning theories and instructional programmes (curricula) involving writing, mathematical problem solving, computing skills, etc., could provide needed answers to perplexing questions about the depth and breadth of IT's impact on a wide spectrum of pupils.

Research conducted within a "constructivist" epistemological perspective examines changes in the way learning takes place, or how knowledge and practice are re-organized in the mind as a result of an intervention. Research in that theoretical tradition asks "What was learned?" and "What does the learning tell us about teaching methods?" and the answers provided by pupils are viewed as indices of the effectiveness of curricular design as an instructional tool and/or the impact of that design on learners.

A classic example of the problem of failing to understand how learners think is a body of studies examining the impact of Logo on young children (Cox and Marshall, 2007). Many of the studies were designed and conducted within a social reality framework, which assumed that children were essentially passive receptors who could be manipulated by external agents and events (Pea and Kurland, 1994). Their research was based on the hypothesis that young children's ability to plan could be enhanced by instruction in Logo. But earlier research summarized by Ginsburg and Opper (1979) has shown us that young children's information processing systems are different from adults' systems. Hence, a lack of improvement in children's planning skills using Logo need not be an indictment of Logo but a further manifestation of developmental issues that frame hypotheses and need to be considered in the design of studies.

The work of Bottino and Furinghetti (1994, 1995) on teachers' understandings and actions as well as studies of children and classrooms conducted by Cox and Nikolopoulou (1997), Yokochi (1996), Yokochi et al. (1997) and Chen and Zhang (2000) provides examples of the research based on the theory that *changes* in learning occur as the result of planned interventions. Traditional educational research methods rely on interviews with pupils or teachers, analysis of video- or audio-taped sessions or direct observation of behaviour. While inferences can be made about the level of understanding, based on responses, we do not know if all share the same understandings. The research strategy is dependent on the extent to which the instructor (or the software used) presents the problems in a way that can be understood without providing *all* the scaffolding needed to solve the problem, a situation which results in trivial learning. Carefully designed investigations, where measurements provide data on *how* pupils perform and what instructional strategies were employed, especially across a wide range of settings, would provide more definitive answers than are currently available to consumers of research.

If we are working in IT settings, we must be especially conscious of the fact that IT is not the only independent variable (e.g. see Katz and Offir, 1988; Kalas and Blaho, 1998). If we want to know if using computers improves writing skills, an analysis of pupils' writing via computer is necessary but not sufficient. We must also know the structure of the writing curriculum, the ways that the curriculum is implemented in classrooms, the facility with which the IT tool can be used, the attitudes and skills that pupils bring to the tasks, and their understandings and intentions as they engage in writing. So, interviews with pupils before and after a course of IT-based writing are necessary but it is also essential for the researcher to describe as many components of the design and delivery as possible, so the question "What was learned?" can be directly or indirectly tied to pupils' learning, teaching methods, instructional design and even the IT tool used. Researchers working in a "constructivist" tradition bear no less responsibility for following standards for acceptable and unambiguous research.

A further complication here as elaborated by Pilkington (2008) is that the nature of the IT tool or environment itself will influence the effectiveness of different research designs and measures (Laurillard, 1978, 1992; Sakonidis, 1994; Triona and Klahr, 2005). The growth and range of IT resources had led to an expanding range of representational systems and different modes of human–computer interfaces, which has extended the specification of knowledge and knowledge domains that learners now meet in education (Klahr and Dunbar, 1988; Merrill, 1994; Mellar et al., 1994; Klahr and Chen, 2003). Research into pupils' understanding of different representations produced by IT environments has shown that the learners may have a different understanding of the metaphors and symbolisms which are presented to them on a computer screen, for example, and consequently interpret the subject knowledge included in the learning task differently to that expected by the researchers (Mellar et al., 1994; Cheng et al., 2001; Cox and Marshall, 2007). The way in which new technologies have changed the representation and codifying of knowledge and how this relates to learners' mental models has shown that learners develop new ways of reasoning and hypothesizing their own and new knowledge (Bliss, 1994; Cox, 2005). Therefore, measuring the effect of IT on pupils' learning needs to address the literacy of the pupils in the IT medium as well as the specific learning outcomes relating to the aims of the teacher or the IT designer.

How learners think about the problem or task will be influenced by their familiarity with the IT medium and with the type of IT environment with which they are working. For example, the use of on-line IT environments for teaching and learning introduces contexts, in which the learner is immersed in a virtual reality which will affect the learner's cognitive development according to the learner's ability to move between different states of reality (Sakonidis, 1994; Kim and Shin, 2001). Furthermore, research by Ijsselstein et al. (2001) showed that the extent to which the learner moves between these different states of reality will change continuously. Therefore, research into the impact of IT on pupils' learning and within different learning contexts needs to include measuring the transition between reality states to delve more deeply into the potential impact of IT on learning.

There are theories which apply to many other areas of educational research relevant to the goals discussed earlier, such as attitudinal and pedagogical theories about teachers' pedagogical beliefs (Webb and Cox, 2004), sociological theories about educational change and institutional innovations (e.g. Fullan, 1991), system theories relating to IT in schools such as activity theory (Engestrom, 1999), and psychological theories relating to human–computer interactions and knowledge representations (Cheng et al., 2001), all of which can underpin different educational research studies to provide more reliable and robust methods of investigation.

Standards for Research

The American Educational Research Association (AERA, 2006) provides a set of standards for educational research and the standards are used widely to judge the acceptability of research and evaluation studies. Two principles are the basis of the standards:

1. "Adequate evidence should be provided to justify the results and conclusions".
2. "The logic of inquiry" resulting from the topic/problem choice and all subsequent data analysis and reporting should be understandable by readers.

Problem formulation should be descriptive and clear, and should make a contribution to knowledge. The design of the study should be shaped by the intellectual traditions of the authors. Clear descriptions of the site characteristics, number of participants, roles of researchers, methods for obtaining participant consent, data on key actors (teachers, etc.), when the research was conducted, what "treatment" was used, data collection and analysis procedures, and types of data collection devices should be reported. The standards also call for complete descriptions of measure development, descriptions of any classification scheme used, coding descriptions and procedures, complete description of statistics (including data on the reliability and validity of instruments), a statement of the relevance of the measures used and the rationale for one or another data collection procedure, especially as those procedures are relevant to the site or participants. Analysis and interpretation of the data are regarded as essential and "disconfirming evidence, counter examples, or viable alternative explanations" should be addressed. The standards further call for discussions of intended or unintended consequences of significance and statements of "how claims and interpretation support, elaborate or challenge conclusions in earlier scholarship".

The AERA standards recognize two types of research designs: quantitative and qualitative. Typically, research conducted within a behaviourist perspective will use quantitative methods and many surveys, designed to provide evidence at a point in time of programme practices, features and outcomes. Examples of such work can be found by examining many of the studies analysed by Niemiec and Walburg (1992) which rely primarily on statistics. To collect a large set of data of many variables to be able to make comparisons, large-scale international studies follow the standards described above to be able to make generalisabilities (see Pelgrum and Plomp, 1993, 2008; Malkeen, 2003). Similarly, meta-studies (see also Liao and Hao, 2008) involve methods which provide results which can also be generalized but which do not always take account of the interpretation which is made of the results in relation to specific national contexts, many local variables for the individual studies forming part of the meta-analysis and the assumptions made of many research studies of the standardization of knowledge representations explained above.

In all cases, the statistical analyses, data collection and analysis and reporting of the results must follow the logic of the question, i.e. Is the statistical variance of the evidence caused by the variables being investigated or are there other local and contextual factors which have caused this variation? For example, some of the earlier large-scale studies which have shown a statistically significant positive effect of IT on pupils' learning, e.g. the Impact1 (Watson, 1993) and Impact2 studies (Harrison et al., 2002), were only able to determine the impact of specific IT tools by conducting mini-studies and qualitative analysis of the use of IT in specific educational settings. In many cases, it has not been possible to identify the actual types of IT use which have contributed to these learning gains. Therefore, although the outcome of such research may be that IT has had a positive effect on pupils' learning, it is not known in such large-scale studies if this was due for example to using simulations, or problem-solving software or accessing additional relevant information over the Internet.

The very complex nature of IT makes it more difficult to conduct research as compared with more confined educational innovations. So, according to Fendler (2006) and the discussion above, "more recent literature on research theory is indicating the emergence of scientific approaches to studies that are not focused on generalisability" and "one of the effects of an overweening belief in the generalisability of research findings has been to narrow the scope of intellectual and scientific inquiry" (p. 447).

To address such questions, many investigations conducted from a constructivist perspective tend to be based on qualitative methods: local education authority, school, classroom or individual pupil observations, interviews, etc. The standards for qualitative research are no less rigorous than those of quantitative studies. In fact, the plethora and complexity of data may place greater burdens on researchers if the standards are followed. For example, "…it is important that researchers fully characterize the processes used so others can trace their logic of inquiry" (AERA, 2006). Researchers must look for alternative explanations of their data, seek confirming evidence, provide direct evidence supporting claims, ask participants for corroboration of claims, especially where evidence and conclusions are not shared by participants. Upon examining qualitative studies, we find that many in the IT field often fail to follow the standards established for qualitative research. For example, there is evidence that teachers' ideas, beliefs and values may also influence their uses of IT (Fang, 1996; Moseley et al., 1999; Webb and Cox, 2004) yet research papers which claim to measure the pedagogical practices of teachers by interview and observation when using IT in the classroom sometimes fail to measure the teachers' beliefs which might be the main influence on the IT-related educational experiences of the pupils and therefore a more significant variable than the range of IT tools which might contribute to the pupils' knowledge. Frequently, one finds published reports of the impact of IT on pupils' learning without even specifying what IT tools were being used. The research conducted by Noss and Hoyles (1992), however, provides a useful model for conducting large-scale studies of how and why children learn.

A literature review of IT and attainment by Cox and Abbott (2004) showed that the most robust evidence of IT use enhancing pupils' learning was from studies which focused on specific uses of IT. Where the research aim has been to investigate the effects of IT on attainment without clearly identifying the range and type of IT use, then unclear results were obtained making it difficult to conclude any repeatable impact of a type of IT use on pupils' learning. Also, missing from many previous research publications are methodologically robust studies that might be based on large and varied samples, that are conducted over several years and that provide unambiguous answers to questions such as:

- "What impact have specific IT uses had on pupils?"
- "Does the way IT is implemented have a major/minor impact on pupils' learning?"
- "Does the impact affect the surface or deep structure of pupils' thinking and acting?"

Failing to account for such situations raises an issue for educational research because although research into specific IT uses provides less ambiguous results as explained above, it is also clear from the evidence discussed above that adhering to standards would improve the quality of researching IT in education and to date these standards have been more rigorously addressed for large-scale quantitative studies, as is explained in Chapters 10.4 and 10.6 than for the large number of small-scale qualitative studies.

Formative and Summative Studies

Formative and summative studies are typically conducted at a meta-level, i.e. an analysis of what occurred in several classrooms, schools or education authorities. Each type of research plays a major role in effectively answering questions about the impact of IT and the formative stage is no less important than the summative stage. In fact, without formative studies ("What were the initial conditions?" and "What critical factors delayed, impeded or deformed the intended plan?"), data collected in a summative study will miss key factors in the transformations of programmes of instruction that resulted in success or contributed to the failure of a project. Furthermore, formative studies play a very important part in the development and evaluation of IT tools through trials with pupils in schools, providing feedback on the effectiveness of such tools on pupils' learning, the design of the IT environment and how it can be used in a range of curriculum settings (Reeves, 2008).

The formative phase often involves a set of pilot studies to refine instruments and ensure validity and reliability (Cox, 1989; Squires and McDougall, 1994; Provus, 1971; Fendler, 2006). Collecting many different types of baseline data (type of school organization, roles of staff, teacher credentials, types of equipment, etc.) is essential, so that changes over time can be assessed. Refining methods, ensuring the right questions are asked, providing information on problematic or promising situations, and analysing variables that may later be used to explain the variance in outcomes, choosing the appropriate measures or designing instruments in the absence of measures that will yield information to ensure unambiguous data are key steps in the formative process (Walberg, 1974). It may be the case that examples provided via evaluations designed within a behaviourist framework and intended to assess impacts on pupils do not reflect the types of questions/measures considered necessary to answer questions raised in the "constructivist" tradition. Resources (Wolf, 1991; Ridgway and Passey, 1993; Ridgway, 1998) are available to assist evaluators in choosing or designing rich and robust measures that provide insights into pupils' thinking.

It is often the case that researchers do not report the results of their pilot tests even though these are an important part of the formative stages of the research, but use them instead to refine and edit tests, interview questions and survey questions. For example, a large study by the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2005), investigating the indicators of IT application in secondary education of South-Eastern European countries, devised a large questionnaire to gather evidence about the resourcing and use of IT in schools. The evidence was derived from the use of 68 indicators such as the total number of schools with computer classrooms and whether IT was taught as a separate subject or across the curriculum, for example, with the purpose of developing recommendations to stimulate national educational policies, strategies and their implementation. However, there was no explanation for the final range of questions selected and whether any preliminary research was conducted at a formative stage to determine which types of indicators would provide the most reliable comparative data. There are many other examples in IT in education academic journals where the formative stages of research go unreported. However, in other cases where formative data are provided, these serve as "guideposts" for evaluators working with experimental curriculum projects. For example, the evaluation of the Comprehensive School Mathematics Program (CSMP) included a formative phase for each level of curriculum development and teacher professional development activities (Marshall and Herbert, 1983). The formative period allowed evaluators to construct and re-tool measures of impact that were not biased towards either the CSMP or the "traditional" mathematics curricula and allowed for rigorous reliability and validity checks over a course of several years.

Where formative evaluation reports describe only a few variables, they fail to address issues such as the impact of the planned programme on staff, pupils and school/community culture as in the case of the first few years' evaluations of the programme Star Schools (2005). The evaluators of this programme failed to provide data that can inform the wider IT community about problems and prospects. To the degree that the reports document each stage of the programmatic change process, describe measures, their reliability, validity and results, they broaden the knowledge base of the IT community.

A major reason to conduct formative evaluation is to avoid what Charters and Jones (1973) call "the risk of appraising non-events" when reviewing the impact of a planned educational change. If sufficient data have not been collected during the formative stages, evaluators run the risk of attributing any changes to planning or implementation that did not occur during the course of the project. Ridgway (1997) comments on the same problem when he discusses the differences between the intended, implemented and attained curricula.

The summative phase of evaluation is designed to collect and analyse data at the conclusion of an intervention. Several early primers with guidelines and suggestions for conducting summative evaluation are worth a second look (Wittrock and Wiley, 1970; Guba and Lincoln, 1981). Since then IT researchers have conducted studies on the impact of a variety of IT-based approaches to instruction. For example, Azinian (2001) describes changes in two schools' cultures as a result of the IT use. Midoro (2001) describes collaborative teacher development conducted on-line. Both studies are abbreviated descriptions of actual conditions, events, ongoing practices and comprehensive change but they highlight key factors that other researchers may reflect on and compare with their own experiences. Lee (2001) reports that in building capacity for IT use in the developing countries of Asia, the role of human capacity development is critical, a facet of IT-based change that is often neglected in the change process. Attention in the IT community is more often paid to the hardware, and the tools and procedures of IT than is paid to issues of who can/should use IT and how IT use can be best introduced and utilized.

More extensive reports of research (e.g. Somekh, 1995; Scrimshaw, 2004; Watson, 1993; Collis et al., 1996) elaborate to a greater or lesser degree on conditions, events and outcomes in efforts to transform classrooms and schools via IT. Many of these are discussed elsewhere in this handbook and show that increasingly there is a greater understanding of the plethora of key factors which need to be taken into account when measuring the impact of IT in education. So, questions such as "What changes occurred?" and (less frequently asked) "What contributed to the change?" are requiring more complex and in-depth measurements compared with the earlier superficial reporting of the IT tools used and the changes in test performance before and after the intervention.

More troubling is the criticism Berman and McLaughlin (1974) pointed out in their discussion of "change" studies during the period of educational ferment in the 1950s, 1960s and 1970s. Few, if any, theories of implementation and institutionalisation of change processes guide the design and execution of summative studies. Of the many studies of school, local education authority or country plans for IT-based change, few start from questions based on a theory or theories of implementation nor the mix of components referred to above, conditions, critical elements and facilitating factors. The result is a melange of this and that, descriptions of what occurred in one or more places at one or more times in situations that may or may not mirror conditions occurring in other places.

More recently, action research (Ziegler, 2001; Somekh, 1995) has gained currency as an evaluation strategy to document within and across school changes in practice. Originally envisioned as a way to collect both information about a social system and, simultaneously work to change the system, action research is viewed as a way for educators to study what they do, how they can affect change and look for the impact on themselves and their pupils (Calhoun, 2002).

Action research often ignores many of the input/output and cognitive change methods employed by summative studies conducted. Instead, action research documents the activities associated with implementation, usually from multiple points of view and multiple foci on "reality", and those data form the basis of the discussions of within classroom/school activities or across classroom/school activities related to IT-based initiatives.

While action research studies play an important role in describing conditions in a classroom, school or local education authority, few attempts have been made to analyse the data to explain the *systematic* conditions that yield variances in implementation and impact. Perhaps, the greatest challenge for action researchers is fulfilling the standard of "searching for confirming or disconfirming evidence, and (trying) out alternative interpretations" (AERA, 2006, p. 38).

Most summative evaluations, regardless of what evaluation strategy is used, often fail to provide a complete and coherent description of the practices, measures, changes and interpretations of results that generate a fuller understanding of the challenges posed by the introduction of IT into schools. Passey (1999) has written an exposition of the importance of systematic studies and has provided an analysis of the differences in contexts in two different schools, and the resulting differences in implementation outcomes. Future action research studies would do well to study the issues and models provided by Passey.

Critical Factors

Two hallmarks of researching IT in education are attention to reliability: "How likely are we to obtain the same result over several iterations?" and validity: "How important/universal/long term is the phenomenon?" and "Does the subject or another researcher/observer interpret the questions in the same way?" Unfortunately, few educational research studies of the impact of IT report on the reliability and validity of their instruments and even fewer attain the high standards set by the Follow Through and CSMP evaluations. The meta-analysis studies attempt to use systematic selection and analysis measures and can address the reliability factor but it is much more difficult to reach a robust standard of validity because of all the factors discussed in this chapter which are constantly changing due to the emerging nature of IT.

Conclusions

Compared with other disciplines like physics and medicine, educational research is still in a great state of flux and none more so than researching IT in education. As we have shown in this chapter, there are many limitations to the research methods much in use and there is a lack of theory underpinning many of the previous research studies. The expanding goals for researching IT in education and the driving forces for more answers to questions about the impact of IT in education from politicians, IT companies and educators alike highlight the need for more systematic and rigorous research across the different educational settings, in which pupils find themselves using IT.

To achieve greater reliability of research findings which can inform important decisions about the role and place of IT in education, we need the following:

- Realistic goals which take account of the complexity of IT environments and the multiplicity of factors which influence their impact
- More experimental and quasi-experimental research that adheres to AERA and other standards; i.e. provides *complete* data on what was done
- More appropriate measures with convincing reliability and validity, especially with larger samples and greater variance of samples
- Qualitative research must also adhere more closely to AERA standards and encompass larger and more representative samples and provide data on measure development, reliability and validity

– Systematic use of appropriate theories and models to underpin research investigations
– More information on the intended, implemented and evaluated curricula must be provided
– More information on alternative explanations (lack of "ceiling" of measures, for example) should be provided
– A recognition of the effects of IT environments on knowledge representation and therefore on the design of research instruments to capture such knowledge understanding
– More funding targeted at long-term studies where time and money can be allocated for the proper development of measures that adequately assess what the IT-based programmes intend to accomplish
– More researchers/evaluators with different theoretical/practical foci to form teams to conduct research in the mode of Stallings
– More information on the "goodness of fit" within and across countries on various uses of tools, etc.

Although there are many reliable research studies which already comply with many of these recommendations, by having international standards which both researchers and funders recognize and follow, we shall possibly achieve much greater commonality of research reliability and outcomes across the international field which, in the field of IT in education, has been elusive up until now.

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10.3

MEASURING THE IMPACT OF INFORMATION TECHNOLOGY ON STUDENTS' LEARNING

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Introduction

Many governments have continued to fund rapid expansion in the use of information technology (IT) in schools and, not unreasonably, want to know whether the positive impact of IT on learning is commensurate with investment (Tolmie, 2001). Politicians want research evidence to address the question "was it worth it?" (Pittard, 2004). However, to pose the question is much easier than to answer it. This has to do with the potential and limitations of available research approaches as well as with measuring "learning".

The aim of this chapter is to provide an overview of progress in researching the impact of IT on students' learning. When considering the last two decades of research in this area, a number of recurring issues emerge. These issues have led many to call for a paradigm shift in our approach to educational research. However, the nature of the shift called for is, itself, controversial, as it relates to alternative perspectives on how educational research should be conducted, how learning should be measured, and how we should approach teaching and learning if we are to maximise potential. In addition, the ways in which different authors view the role of IT within learning and teaching processes also affects how they evaluate the impact of IT on learning.

In presenting this review I discuss some of these alternative perspectives and, in doing so, suggest what is known about the impact of IT on learning, gaps in our understanding and future directions for research.

Impact of IT on Learning – Experimental Research Designs

There is a debate as to the best research approach to take when measuring the impact of IT on learning. Those advocating experimental methods often regard randomised controlled trials (RCTs) as the "gold standard". The aim in experimental methods is

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to compare the performance of students assigned to an intervention group using IT with the performance of students exposed to more traditional methods. In these studies "learning" is often reduced to student performance on a test.

Ainsworth and Grimshaw (2004) point out that evaluations show that computer-based Intelligent Tutoring Systems have achieved effect sizes between 0.4 and 1, compared to classroom teaching (whilst one-to-one tutoring by expert tutors produces on average an effect size of 2 according to Bloom, 1984). However, such effects are not consistently gained. Ainsworth and Grimshaw (2004) found, when evaluating the REDEEM Intelligent Tutoring Authoring System, that the effect size was highly variable from 0.1 to 1.33 (mean, 0.51). Effect sizes for other computer-aided instruction software are often reported to be even more variable or negative (Andrews, 2004; Eng, 2005). Moreover, experimental control is easier to achieve for self-contained computer-based learning software used by individuals than it is for more open social learning in classroom environments where activity at the computer is just one activity amongst many. REDEEM worked best when teachers used the flexibility of the design to add additional interactivity and when students took advantage of this extra interactivity by answering questions or writing notes whilst learning (Ainsworth and Fleming, 2006).

This study illustrates a number of important issues affecting the value of comparative experimental and quasi-experimental studies, one of the principal points being that the local conditions of use are of central importance. Comparative research designs that use different groups of students and/or tutors can be confounded by individual differences in the characteristics of student and tutor. Local contextual variables associated with the implementation of instructional strategies can also impact on success. As Ringstaff and Kelley (2002) point out, classrooms are not experimental laboratories where scientists can compare the effectiveness of technology to traditional instructional methods whilst holding all other variables constant. Therefore, whilst the RCTs may still be regarded as the gold standard by many, the difficulty of isolating the role of the computer-based element in the learning context can undermine the value of conclusions drawn (Tolmie, 2001; Pittard, 2004; Cook, 2006).

Joy and Garcia (2000) argue that inability to control such variables can make it *less* likely that researchers will find significant differences between computer-based treatment groups and no-treatment groups. Similarly, Tolmie (2001) argues that it is unlikely, given the complexity of the research context, that the addition of *any* new element into the classroom environment could have a straightforward impact on learning.

In adopting the quasi-experimental comparative approach, there are often also ethical issues concerned with the ways students may access resources at particular times. Indeed, setting up these kinds of study in schools and colleges is notoriously difficult because educational practitioners are concerned that the research should not interfere with day-to-day classroom practice. In particular, research should not burden or disadvantage some students more than others. These problems account, in part, for the scarcity of well-controlled comparative studies that measure the impact of IT on learning.

Joy and Garcia (2000) conclude that the outlook for comparative studies is bleak and we should instead investigate particular combinations of instructional strategies, media and activities that produce desired learning outcomes. Robust measurement of impact is important but RCTs should perhaps be supplemented with richer "added value" methods (Pittard, 2004). Tolmie (2001) also suggests that more context-sensitive approaches are needed which consider the interplay of technology with existing practice.

However, alternatives to the quasi-experimental approach are not without their own difficulties. Rogers and Finlayson (2004) agree that interpreting quantitative data from comparative studies and large-scale surveys is often problematic, yet qualitative studies have also been criticized for the small number of students they involve and the special conditions which make drawing general conclusions difficult.

Researchers on the ImpaCT2 project (Harrison et al., 2002) proposed a socially contextualised model of research that recognises that IT experience is only part of a larger picture of pupils' interaction with computer-based technologies. Consequently, they looked at the overlap between out-of-school learning and school-based learning and attempted to assess the impact of some of these additional influences through collection of qualitative data. Kennewell (2003) similarly argues that IT should be studied alongside other variables in natural pedagogic settings using both quantitative and qualitative research methods. Later in this chapter we explore further what large-scale surveys and meta-analysis of case-based research can tell us about the impact of IT on learning.

Measuring the Impact of Learning

An associated problem in drawing general conclusions concerning the impact of IT on learning relates to how we measure learning. Thus, one of the first casualties of introducing ITs into the curriculum is this original alignment of aims and objectives with delivery and assessment strategies (Noss and Pachler, 1999; Ellaway, 2006). In short, the delivery method has an effect on what is learned and how it can reasonably be assessed. This means that it is difficult to prepare a common form of assessment that can fairly compare the traditional course with the computer-based course. This problem was of particular concern to those involved with the ImpaCT2 project (Harrison et al., 2002) discussed further later in this chapter.

Further, several authors have argued that knowledge gained through IT may be different in nature from that gained through other methods (Laurillard, 1978; Cheng, 1999). This is not to say that one or the other is necessarily better but that they are different. Thus Cheng (1999) notes that the representations used for learning in science and mathematics can substantially determine what is learnt and how easily this occurs. Clements (2000) argues that representations used with computational media offer unique opportunities for problem- and project-oriented pedagogical approaches that can catalyse pedagogic innovation. Hammond (1994) concludes that this kind of innovation makes it difficult to compare "with" and "without" IT conditions since introducing IT changes the nature of the learning activity. As McCormick (2004) points out, research in assessment has not kept up, for example, with the new learning opportunities offered by IT through collaborative construction of multimedia or Web-based products. Such products may employ different purposes, skills and audiences from those of traditional handwritten essay.

When taking a quasi-experimental approach to research, many studies have addressed this problem by devising their own assessments that more validly reflect the skills and knowledge to be compared. However, the point remains that the introduction of IT very often changes the nature of the learning tasks and outcomes for good or ill, and we need to be sure that we are sensitive both to evaluating what is actually learned (in both conditions) and to whether what has been learnt is equally valuable relative to our educational aims.

Impact on Learning – Survey-Based Approaches

In this section the aim is to examine what is known about the impact of IT on learning from survey-based approaches. A number of large-scale surveys have been commissioned to evaluate the impact of funding on learning (Harrison et al., 2002; Conlon and Simpson, 2003; Thomas et al., 2003, 2004; Burns and Ungerleider, 2003; Hennessey and Deaney, 2004; Underwood et al., 2005). Such surveys often seek to discover the impact of IT by comparing a number of case schools. This enables researchers to study authentic use of IT by teachers and learners without the need for experimental manipulation and yet still make more general claims than can be provided by a single local case study.

The ImpaCT2 project (Harrison et al., 2002) involved a large-scale survey of IT use in UK primary and secondary schools to see what effect this investment was having. Strand 1 of the study looked at baseline tests administered at the beginning and end of each key stage (standard national attainment tests) alongside performance on GCSEs (qualifications at 16 years) to try to determine evidence of the value added to the education of children. Data related to use of IT at home and at school were further analysed in relation to gender, ethnicity and socioeconomic factors. Overall, the project found a small positive relationship between GSCE performance and IT use with no cases where there was a significant negative relationship, i.e., no case where there was a statistically significant advantage for lower IT use. However, there was no consistent advantage for higher IT use in all subjects or at all key stages.

The quantitative data alone raised many questions. However, the authors concluded that the most likely reasons for lack of consistency were lack of constructive alignment between assessment and learning and effective teaching; i.e., the factor most likely to impact on learning remained the quality of the teaching (with or without IT). Because the results of quantitative survey-based research are often confusing in relation to the impact of IT on learning, there is a need to study a range of other variables that may be implicated through survey design. *Use of* and *access to IT* in schools are perhaps the two related variables that have been studied most.

The Transforming the School Workforce (TSW) Pathfinder project in the UK (Thomas et al., 2004) was not designed to look at the impact of IT on learning per se but rather the ways in which IT was being *used* in schools. The survey did record through questionnaires and interviews the use of IT in school and at home. What this survey principally revealed was that despite a push toward integrating IT into the classroom, use of computers for learning and teaching remained relatively modest. With notable exceptions, teachers were mainly using IT to support basic literacy, numeracy and IT skills. There were many fewer examples of using IT to support teaching in other subjects, for collaborative work, extended project work and discussion. The main computer applications used were word-processing, presentation software and the Internet. These applications were used mostly to support teachers in lesson preparation rather than by children in the classroom.

The IT test beds baseline project (Thomas et al., 2003) found similar results. Both studies suggested from a quantitative perspective a disappointing range of IT resources being used in schools. From quantitative data it was difficult to tell why this was the case, although staff recognised a need for additional training in using IT for pedagogic purposes. However, in both surveys there were outstanding examples such as the use of specialist multimedia software (e.g., CAD and data-logging) to improve and extend the curriculum in art and design and in science classes. There were also examples of use of the Interactive Whiteboard, Desktop Publishing and PowerPoint software for extended project work and presentations of children's work in a range of subject classes.

Similar findings emerge from international studies: Conlon and Simpson (2003) compared the introduction of IT in Scottish classrooms with introduction of IT in schools in Silicon Valley and found similarities in access to resources at home and at school and in the main uses of the technology for word-processing, e-mail and searching the Internet. They also showed (as in IT test beds baseline study and TSW Pathfinder studies) that teachers were not inherently resistant to the use of the technology. Around half of teachers regularly used the computer for report writing and preparing lessons, but use of computers by pupils in schools was much more limited. The computer was seldom used in class unless the subject studied was technology-intensive. Students in secondary schools used computers in class only once or twice a week, and the majority of teachers use technology to reinforce existing patterns of teaching rather than to innovate.

McMullan's (2002) report in the UK looked at whether schools had *access* to the necessary IT infrastructure to integrate IT in schools and concluded that whilst 99% of schools had Internet access and there had been good progress on meeting targets of computer to pupil ratios of 1:11 in primary and 1:7 in secondary schools, most schools did not have broadband; links were slow and bandwidth was often below that which was required to deliver a digital curriculum. Underwood et al. (2005) surveyed the impact of the roll-out of broadband on UK schools and found that whilst variations in connectivity persisted, barriers to the use of IT were shifting away from basic "access" problems toward providing resources for technical support, sustainable maintenance of equipment, training teachers and pedagogic strategies to exploit the technology. McMullan (2002) noted that less than 10% of schools were covered by a managed service contract. The issue of sustainability, particularly IT technical support and maintenance of equipment, emerged as barriers affecting teachers' computer use in the IT test bed baseline study (Thomas et al., 2003; Pilkington, 2007) and TSW Pathfinder study (Thomas et al., 2004; Pilkington, 2007). Similarly, in these studies a high percentage of teachers felt the need for more training in the instructional use of IT.

Burns and Ungerleider (2003), in discussing the Pan-Canadian Education Indicators Program, reported that 88% of primary and 97% of secondary schools had Internet access but 70% of the teachers still reported poor or limited access to computers due either to low computer–pupil ratio or to other barriers to incorporating IT into their teaching such as the need to book a computer laboratory down the hall (see also Watson, 2001). However, no relationship between the presence of a computer in Ontario classrooms and achievement was found for third grade students. Similarly, Burns and Ungerleider (2003) report that in the USA children using computers at least once a week did not perform better than children using computers less than once a week on National Assessment of Education Progress tests for reading.

Although Burns and Ungerleider (2003) did not find a relationship between computer presence and achievement, they found many examples of innovative programmes where access to technology was combined with instruction designed to complement its use. For these programmes, learning gains could be demonstrated in reading and spelling and in science.

The results of large-scale surveys generally present a mixed picture that is hard to interpret. The reasons for differences in outcome from such studies often relate not only to differences in access to IT resources but to the location or nature of the space for learning, the ways in which resources are employed (and the teachers' and pupils' ownership or control over them), differences in media, activity, interactivity and feedback, instructional presentation, the wider cultural setting of the school or college, other less formal learning with peers and the degree to which teaching staff, parents or other authority figures engage with IT. These factors can all impact on the way IT is used by students.

A major problem in large-scale, survey-based research is that often detailed contextual information from rich qualitative data is lacking. The above-mentioned surveys drew on a wide range of data, including free text boxes in questionnaires and interview data from teachers and other staff; however, large-scale studies often involve little opportunity or resource for follow-up questioning to decipher interconnections between data, generate more holistic impressions or uncover the precise reasons for local successes or failures. Pelgrum and Plomp (2008) in this Handbook discuss the potential and limitations of large-scale survey research in more detail.

Taken together, findings from large-scale surveys would seem therefore to suggest, perhaps unsurprisingly, that providing computers is no guarantee of their effective use but that not providing enough computers with adequate speed and bandwidth is a barrier to use (Conlon and Simpson, 2003; Thomas et al., 2004; Underwood et al., 2005; Burns and Ungerleider, 2003). Moreover, large-scale studies have told us that IT in schools can impact positively on children's attainment and motivation (Pittard, 2004), but it does not always do so; it can even have a negative effect (Andrews, 2004). The alignment of particular types of IT to particular educational objectives and assessment methods, together with tutor-planned, structured and guided activity, is likely to be what makes the difference. We still need much richer contextual data to support these conclusions (Cox et al., 2003; Pilkington, 2007).

Impact on Learning – Case Studies and Meta-Analyses

One response to the appreciation that neither large-scale surveys nor quasi-experimental laboratory studies can easily provide us with straightforward answers concerning the impact of IT on learning is to either abandon the attempt to conduct studies aimed at evaluating the impact of IT or adopt alternative approaches such as rich contextual case studies that aim to answer more modest questions concerning the impact of factors in particular contexts.

There are many examples in the literature of this case-based approach. The hope of such research is to gather sufficient volume of cases to enable the generation of some more general principles or guidelines for pedagogic design and implementation: the *how*, *when* and *why* of using computer-based learning (Cook, 2006). There are, therefore, a number of studies that attempt to compare and contrast more than one "case study" based on a range of selection criteria. Case studies can therefore represent a single context or multiple contexts and may use a range of methodologies, including quantitative and qualitative data collection involving outcome, process and attitudinal data on learning and related variables. I will refer here to research studies that present data collected by the researchers as "case studies", including those that compare more than one case. I will refer to research that reviews or independently re-evaluates and compares the results of different studies as meta-analyses. Many of these review case studies but some do not always make clear methodological distinctions between the types of study reviewed.

Strand 2 of the UK ImpaCT2 project involved researchers looking at six representative or "case" schools and included more qualitative data such as log books/diaries and peer-interviewing to gain insights into pupil and teacher perceptions. Concept mapping was also used as a tool to access students' conceptualisation of the role computers played in their lives, particularly the purposes of IT and locations of use. Strand 3 extended the use of qualitative techniques to 15 schools using video diaries and electronic journals. One of the results from this qualitative data was that the majority of pupils had very rich IT experiences at home mainly using the Internet and playing computer games, and that pupils were frustrated by the IT curriculum at school. The skills focused in class were often basic, not challenging and only infrequently involved thinking or reasoning. Other studies have reached similar conclusions in exploring the relationship between using computers and motivating pupils in school (Passey et al., 2003).

Overall, as reported in the previous section, the UK ImpaCT2 study found a positive statistically significant association between IT and higher achievement in National Tests for English at key stage 2, which stands in contrast to some reviews that have looked at the impact of computers on literacy (Andrews, 2004; Eng, 2005). As discussed earlier, surveys of IT use for learning in UK schools have suggested that one of the most frequently reported uses of software is for basic literacy. A range of software is available that is aimed at helping pupils learn to spell. Torgerson and Elbourne's (2002) meta-analysis based on pooling data from six RCT studies of IT and spelling concluded no demonstrably better effect size for computer-based teaching. Andrews (2004) looked at the impact of IT on literacy based on a review of 188 international research studies and found small positive effects for spelling software but overall negative results for computer-aided instruction software on literacy. In contrast, software that provides audio accompaniment to text can help some children. Andrews (2004) found positive effects for speech synthesis. Thus, another reason for mixed results may be failure to personalise learning to individual needs.

As students progress through the curriculum, basic literacy skills receive less emphasis and greater emphasis is placed on compositional and critical-thinking skills and the ability to write in different styles for different audiences (Walker, 2003). In the ImpaCT2 study (Harrison et al., 2002), when pupils used IT in English and achieved higher mean scores at key stage 3, teachers identified factors leading to success, which included high-quality multimedia outcomes from using the word-processor, which motivated commitment to writing together with the use of e-mail to support collaborative writing. Collaborative writing can increase reflection on writing products. Similarly, Walker's (2003) case study using text-based discussion to develop critical argument skills amongst children at this key stage suggested that computer-mediated communication can impact positively on debating skills (Walker, 2003; Walker and Pilkington, 2005). Further evidence of the potential impact of IT on higher order critical discussion and writing skills comes from case studies on online discussion in higher education (Pilkington et al., 2000). Positive results are reported for some groups of students, notably those learning in a second language.

Passey (1999) analysed the learning objectives of the National Curriculum for IT in England against Bloom's taxonomy and concluded that there were too many lower-order learning objectives with little use of IT to support higher-order thinking. Moreover, Burns and Ungerleider (2003) suggest that whilst many studies show computer-based learning can improve motivation, there are few controlled studies and the effect may be higher for boys than for girls. Mumtaz (2001) found that the most frequent activity at the school computer was word-processing, which many pupils considered boring. Moreover, Burns and Ungerleider (2003) note that when a motivational effect is found for computer use in education this effect may be associated more with accompanying changes in instruction toward collaborative or social learning rather than use of the technology per se. Mumtaz (2001) concludes that teachers need to ask whether the tasks they are setting using word-processors are challenging or interesting for children and whether they involve higher-level skills.

Clements (2000), on the basis of a review of studies in mathematics education, suggests that one of the unique contributions computers can make to learning is through the support of problem-based learning and extended project work. Collaborative activities also resulted in enhanced achievement. Voogt and Pelgrum's (2005) evaluation of case studies in 28 countries found that those innovating with IT in the curriculum did evidence elements of an emerging pedagogy of learning with IT that emphasised collaborative and meta-cognitive skills that are considered important for deeper learning.

Waxman and Huang (1996) in a case study of middle school mathematics found significant differences in instruction in the classroom depending on the amount of technology used. Whole-class approaches where pupils generally listened to or watched the teacher tended to be used in classrooms where technology was not often used. When technology was used moderately there was much less whole-class instruction and more independent work, suggesting using technology may help shift teachers' activity toward a more pupil-centred approach at least in some instances.

IT is also said to have some unique properties with respect to being able to provide richer multimedia resources that engage additional perceptual channels to encode and retrieve information. Najjar (1996) in reviewing a range of studies, including work by Mayer and Anderson (1991), concludes that for understanding particular kinds of processes the dynamic qualities of video and animation with explanatory narration can improve learning. Cox et al. (2003) in their review of the literature and a number of case studies conclude that simulation and modelling software may have similar advantages and, in addition to helping students envision abstract, complex and/or dynamic relationships, may also help them develop critical-thinking skills through hypothesis-testing. However, they suggest that the effective exploitation of the potential of IT depends on the way in which the teacher selects and organises IT resources and how these are integrated with classroom activities.

Another use of multimedia to help students envision relationships in science is data logging. Rogers and Finlayson (2004), on the basis of a study of teacher-evaluations of lessons, report positive effects from the use of real-time data logging of temperature to offer simultaneous presentation of graphs. They suggest that this adds value to learning in the science lesson by making results instantly visible. Other examples of teacher-rated effective lessons were recorded in UK IT test beds baseline and TSW Pathfinder studies discussed earlier, including "through the bell" projects conducted over several lessons in different subjects using Desktop Publishing or video editing to create presentations on cross-curricula themes.

The over-riding difficulty with case studies, when read in isolation as opposed to within the context of more comprehensive reviews or surveys, is the "starry nights" effect (Ellaway, 2006). Case-based research often seeks out "good" examples of practice, focusing on these interesting "stars" in detail and ignoring the darkness of the night around them. There are examples of researchers addressing this selectivity problem and comparing and contrasting different cases, e.g., case schools at different stages of development in their progression toward integrating IT in the curriculum (Pilkington, 2007). However, there is potential for distortion in seeking and reporting examples, demonstrating the positive impact of ICTs on learning particularly in the absence of similar reporting of negative cases.

Wang et al. (1993) researched factors impacting on education more generally (regardless of the use of IT) through a meta-analysis based on comparing the results of nine previous literature reviews and 179 research studies. The aim was to try to find out which of the many factors affecting attainment seemed to be most significant. They found that the following "proximal variables" have the most effect: meta-cognitive and cognitive activities; classroom instruction and management; pupil–teacher social and academic interactions; the home environment; students' prior knowledge and level of understanding; instructional strategies such as reciprocal teaching (see Rosenshine and Meister, 1994, for a review of this method). One of the principal conclusions was that students benefit from academic interactions with tutors and positive social interactions with students and that the actions of students, teachers and parents matter more than policies at the program, school-district, state or national level. Wang et al. conclude that the limited effect of the latter more "distal variables", when compared with the day-to-day efforts of the people most involved in students lives, should help educators and policymakers be mindful of where they can make the biggest difference. This resonates with Cox et al.'s (2003) conclusion that the nature of the local classroom interaction and activity with computers are critical in determining the impact on learning.

Ringstaff and Kelley (2002), on the basis of a US Department of Education funded review of findings from several studies, sum up for many when they say that there is now a substantial body of research suggesting that technology can have a positive effect on student achievement under the right conditions. However, there is as yet no “magic formula” that educators and policymakers can use to determine whether the return is worth the investment. Eng (2005), also on the basis of a meta-analytic review of several studies mainly from the UK, USA and Australia, noted that the relationship between IT use and attainment was overall positive though weak. Eng concludes that results were likely to be better when IT was used as a supplement for individual learning, and teacher-led programmes were more effective than commercial software because they linked more closely to educational objectives. Some consensus thus seems to be building around the notion that applications need to be tailored to contexts of use and the needs of individual learners for full potential to be realised.

Moreover, based on recent survey approaches presented in the previous section the barriers to effective use of IT are shifting away from basic provision of resource toward more complex access issues (such as the location and control of resource within organisations and the reliability and speed of machines and their connections). There is an identified need to invest in professional development for staff, to provide teachers with technical support and to resource the maintenance and upgrading of equipment (Thomas et al., 2003; Thomas et al., 2004; Burns and Ungerleider, 2003; Underwood et al., 2005; Pilkington, 2007).

Part of the answer to the dilemma in finding a suitable approach to research therefore almost certainly lies with recognising the complex nature of the ways different variables interact in authentic situations and in seeking more holistic approaches to investigation and data-gathering techniques.

Future Schools: Making Progress and Managing Change

In this section the vision of the IT-supported “future school” is revisited looking at emerging barriers and enablers to effective use of IT in schools and colleges.

Results from surveys and meta-analyses reviewed so far suggest that from a quantitative perspective there is a disappointing range of IT resources being used in schools. Moreover, there are some emerging common barriers to IT use. The Fischer Family Trust (2002), on the basis of an expert consensus-building exercise, sums up many of these barriers: lack of access (including remote computer rooms), lack of time to prepare, cost of software, lack of technical support, resources for maintenance and upgrades, low teacher confidence. Similarly, Mumtaz (2000) suggests that factors affecting teachers’ decisions to use technology include access to resources, quality of software and hardware, ease of use, incentive to change, support from the school, commitment to professional development and familiarity with IT.

Many of these issues are difficult for individual teachers or schools to address in isolation, particularly infrastructure issues. The state of repair of computers can be a "hidden" access problem limiting the usable machines in a class. Another hidden access problem that emerged was the need to book a classroom down the hall. The disruption of moving is a major disincentive to integrating IT in subject teaching (Watson, 2001; Thomas et al., 2003; Burns and Ungerleider, 2003; Underwood et al., 2005).

Mumtaz (2000) in a review of the literature suggests that personal factors outweigh institutional factors in affecting decisions to use technology, specifically that teachers' theories about IT use are central and that even with up-to-date resources they may not be enthusiastic if technology is imposed from outside. Watson (2001) also suggests that teachers are not impressed by the imposition of change that appears to focus on what the technology can do rather than on the learning. Rogers and Finlayson (2004) argue that teacher rejection of IT is more likely to be the inevitable result of lack of teacher time to learn how to use the technology. Conlon and Simpson (2003) also suggest that teachers are not inherently resistant to IT. Several surveys suggest that teachers' belief in the potential of IT to support learning is positive (Thomas et al., 2003, 2004). However, such surveys have repeatedly highlighted that teachers feel the need for more professional development, particularly in pedagogic applications of technology (Cox et al., 2003; Kennewell, 2003).

Flecknoe (2002), in discussing a UK Teacher Training Agency funded programme for professional development of teachers, notes the difficulty in demonstrating that such training has a direct impact on pupils' learning. As explained in Chapter 10.2, early research evidence from Canada, England, the Netherlands and Spain (Watson and Tinsley, 1995) suggested that teachers using IT tended to be those who could relate the use of technology to their own subject. However, those electing for courses may also be early adopters not reflecting the majority of teachers.

Ideally, students' activity at the computer holds students' attention, releasing the teacher for individual facilitation. However, this requires considerable skill. As Barrows (1992) suggests, there is nothing automatic about becoming a good facilitator. Coutts et al. (2001) describe the teacher hovering in the background uncertain of what to do as pupils engage with computer software. Moreover, some technologies, e.g., PowerPoint projected on the Whiteboard, can support teachers in traditional methods (Pilkington, 2007).

Hennessey and Deaney (2004), on the basis of interviews with teachers engaging in IT projects in five case study secondary schools, illustrate how once barriers of access are overcome, teachers do continue to develop and evolve their practice so that their use of the technology becomes increasingly integrated with their subject teaching and more innovative. The Fischer Family Trust (2002) in summing up the common enablers that affect teachers' use of IT include creativity, ownership of resources, sharing good practice, strategic leadership and subject specific knowledge of IT.

Revisiting Learning Theory: Issues for Design

In this section we revisit learning theory looking at what we have found out concerning the contribution of IT to instructional design and how we should approach teaching and learning with IT to maximise potential.

As we develop and become adults, we need increasingly to be able to take responsibility for our own learning, to be involved in planning, negotiating and personalising our learning and ensuring its relevance to our aptitudes, vocation and interests. Approaches that are thought to scaffold this kind of autonomy emphasise sharing experiences through collaborative inquiry and authentic problems or tasks. Most important, such approaches give plenty of opportunity for discussion and reflection on experience in social and constructive contexts (Knowles, 1970; Scardamalia and Bereiter, 1991; Savery and Duffy, 1996; Organisation for Economic Cooperation and Development, 2004).

Many believe a positive aspect of IT is that it encourages a shift in pedagogy toward more facilitative teaching approaches better suited to social and constructive models of learning. Use of IT has been associated with a decrease in direction by and exposition from the teacher as students work individually or in pairs and groups around computers. There are reports of corresponding increases in self-regulation and constructive dialogue (Crook, 1997; Wegerif and Dawes, 1998; Voogt and Pelgrum, 2005). However, in moving to a facilitator role teachers still need to lead through the planning, preparation and follow-up of lessons. Where little planning occurs, class work can be unfocused and outcomes poor. When teachers use their knowledge of both the subject and the way pupils understand the subject, their use of IT has a more direct effect on attainment (Cox et al., 2003).

However, as Rogers and Finlayson (2004) report in relation to science teachers' use of IT, perceptions of success are largely expressed in terms of achievement of subject learning objectives with criteria strongly rooted in existing pedagogy and assessment methods developed using conventional resources. IT can, therefore, both challenge and change practice but it is not automatic. Pedagogical practices using IT range from only small enhancements of existing practice underpinned by traditional methods to more fundamental changes in approach (Cox et al., 2003; Pilkington, 2007).

Similarly, it has emerged from the surveys reviewed here that as teachers begin to use IT they may do so at first in ways that reinforce traditional practice. Later they may use IT to make modest enhancements, e.g., exploiting properties of multi-media to improve resources in ways that impact on the understanding of concepts. Later, as they continue to integrate their subject knowledge with the use of IT, they may include more subject-specific software to improve and extend the curriculum. As they continue to evolve their practice, perhaps adopting more social and collaborative ways of working, they may also use IT for extended collaborative projects (Pelgrum and Anderson, 1999; Cox et al., 2003; Voogt and Pelgrum, 2005; Passey, 2006; Pilkington, 2007).

Voogt and Pelgrum (2005) argue that improving the quality of teaching and learning with IT should now focus on setting new goals, including the design of resources for comprehension through effective use of multiple modalities and improving students' critical engagement, independent and collaborative learning skills (particularly including a focus on learning how to learn). Perhaps most controversially, curriculum content should be offered in a school-wide, cross-curricula way and embedded in authentic contexts.

Conclusions

Reynolds et al. (2003) describe claims for the effectiveness of IT as "optimistic rhetoric" that has led successive British governments to spend billions of pounds without first establishing through research whether IT improves learning.

The inherent difficulties in conducting comparative studies in educational settings have made it difficult to obtain robust and conclusive evidence regarding the impact of IT on learning. This has led many to suggest that although robust measurement of impact is important, RCTs should perhaps be supplemented with richer added value methods (Pittard, 2004). Tolmie (2001) also suggests that more context-sensitive approaches are needed if we are to consider the interplay of technology with existing practice. Moreover, there is a need to readdress the constructive alignment of assessment methods in evaluating learning from IT.

On the basis of data at that time, Pittard (2004) concluded that despite progress in putting resources into British classrooms, including roll-out of broadband technology, the delivery of education happens in many of the same ways it did before. Conlon and Simpson (2003) and Voogt and Pelgrum (2005) looking at the international scene seemed to conclude similarly, though more positively. There is evidence that activities for students using IT in classrooms are often not challenging and tend to involve low-level or basic skills development with little of the reasoning or critical thinking needed to develop deep learning. These activities can frustrate pupils (Passey, 1999, 2006; Mumtaz, 2001; Passey et al., 2003). This has led many to argue that we need to refocus educational goals when using IT to include more collaborative, cross-curricula, problem-based or project work (Clements, 2000; Voogt and Pelgrum, 2005). However, perhaps we should not be too quick to say that the investment has not worked. More recently, Webb and Vulliamy (2006) revisited 50 primary schools previously studied in the early 1990s, despite criticisms of initiatives. Teachers were reported to believe that teaching methods had been enhanced by IT and that new technologies had enabled innovation. We have also seen evidence that so far only the initial barriers to teachers using IT in classrooms have been overcome. Whilst basic access problems are largely overcome for schools in developed countries, this has simply shifted the focus from the barriers of access to barriers of technical support and maintenance, teacher time and professional development. There is evidence from more recent studies that practice is continuing to evolve as teachers extend their familiarity with technologies. For example, on the basis of more recent observation of lessons in 2005, Passey (2006) concludes that although there was still limited use of IT to directly support critical and collaborative discourse or hypothesis testing, IT resources were being used directly to support concept formation through video resources.

We know from educational research more widely that however important educational policy is, the factors that impact most on learning are the local ones, such as classroom instructional strategies and management, student–teacher social and academic interactions, the home environment and students' prior knowledge (Wang et al., 1993). Watson (2001) suggests that technology today holds a major symbolic function in society associated with the imagery of the new, positive change, renewal and economic revival but argues for the need to reframe intervention away from the technological model. What is needed is an intervention of educational philosophy and debate. Teachers may then be inspired to integrate IT into their existing practice in ways that make a less conservative impact on subject learning. There are plenty of examples of early adopters leading the way. However, a lot more rigorous research is needed if we are to discover precisely how particular combinations of IT, instructional strategies and activities produce desired learning outcomes.

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10.4

LARGE-SCALE STUDIES AND QUANTITATIVE METHODS

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The Meta-analysis Research Method

A study, even a well-designed one with a large sample size, will become more useful if its results are examined in the context of others in the field. Integration of research findings across studies, either qualitative or quantitative, has its merits and plays an important role in any area of research. Quantitative reviews of large-scale studies have a long past, and since the early 1930s, reviewers have used special statistical tools for combining results from a series of empirical studies. The work carried out before Glass's development of meta-analytic methodology in 1976 is still exerting an influence on research reviews (Kulik and Kulik, 1989).

Definition of Meta-analysis

Research syntheses using meta-analytic methods have made the 1980s an extraordinary time in the history of research into teaching and learning. Cooper (1984), Glass (1977), Glass et al. (1981), Hedges and Olkin (1983, 1985), Hunter et al. (1982), Jackson (1980), Light and Pillemer (1982), and Rosenthal (1976), among others, provide excellent examples and insights into the use of meta-analysis for measuring research outcomes into teaching and learning. The primary purpose of meta-analysis, which was first advocated by Glass (1976), is "the statistical analysis of a large collection of analysis results from individual studies for the purpose of integrating the findings" (p. 3). Since 1976, literally thousands of reviews have been conducted using meta-analysis methods; a title-word search using the term "meta-analysis" performed on ERIC through FirstSearch resulted in 3,357 studies. The applications

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of this method are not only in education but in many other areas such as sports and exercise (Doherty and Smith, 2005; Martyn-St James and Carroll, 2006), medical research (Aertgeerts et al., 2004; Bischoff-Ferrari et al., 2004), economics (Rubb, 2003), and politics (Roscoe and Jenkins, 2005).

For years, there have been different views regarding what exactly constitutes a meta-analysis. Hunter and Schmidt (2004) modified Bangert-Drowns's classification (1986) and categorized five forms of meta-analytic methods: Glassian meta-analysis; study effect meta-analysis; homogeneity test-based meta-analysis; the Schmidt-Hunter meta-analysis; and validity generalization, psychometric meta-analysis. These meta-analytic methods differ in terms of the purpose of review, unit of analysis, treatment of study variations, and outcome of analysis. However, all of the techniques apply statistical methods to the treatment of quantitative representations of study outcomes. This distinguishes meta-analysis from traditional and more informal narrative forms of review such as "vote counting" or "box-score" reviews (Liao and Bright, 1993).

Procedures for Conducting a Meta-analysis

There have been variations on the basic meta-analysis procedures, depending on the data given. However, the following seven steps were usually included (Roblyer et al., 1988):

- Step 1: Set criteria for studies to be included.
- Step 2: Identify variables that contribute to effect size (ES).
- Step 3: Find studies meeting criteria.
- Step 4: Calculate individual study effect size.
- Step 5: Correct individual study effect size for sampling error.
- Step 6: Combine individual studies to determine overall effect size.
- Step 7: Identify relationship of effect size to study variables.

Wolf (1986), in addition, highlighted 13 guidelines for the practice of a meta-analysis.

- Define and report criteria for the inclusion and exclusion of studies.
- Search for unpublished studies in order to test type I error.
- Develop coding categories to accommodate the largest proportion of the identified literature.
- Examine multiple independent and dependent variables separately through blocking mediating effects.
- Examine and graph the distribution of results and look for outliers to examine more closely.
- Check the reliability of raters who code study characteristics.
- Always accompany combined tests of significance with estimates of effect size.
- Calculate both raw (unadjusted) and weighted combined tests and effect sizes to empirically examine the impact of sample size on results.
- Consider whether it is important and/or practical to calculate nonparametric as well as parametric effect size estimates.
- Consult the literature on meta-analysis for guidance when in doubt.
- Combine qualitative reviewing with quantitative reviewing.

– Describe the limitations of your review and provide guidelines for future research concerning relationship reviewed.
– Remember Green and Hall's (1984, p. 52) dictum: "Data analysis is an aid to thought, not a substitute."

For years statistical formulae and procedures of meta-analysis have been modified in an effort to reduce errors which may arise from the variation of individual studies and make effect size a true estimate of the impact of a given treatment.

Advantages of Meta-analysis

There are a number of potential problems with a traditional literature review. These include (a) selective inclusion of studies often based on the reviewer's own impressionistic view of the quality of the study, (b) differential subjective weighting of studies in the interpretation of a set of findings, (c) misleading interpretations of study findings, (d) failure to examine characteristics of the studies as potential explanations for disparate or consistent results across studies, and (e) failure to examine moderating variables in the relationship under examination (Wolf, 1986).

In contrast, meta-analysis has been viewed as an efficient way to summarize the findings of many studies (Green and Hall, 1984), while providing several distinct advantages over traditional methods of synthesis (Hauser-Cram, 1983; Jackson, 1980). Abrami and Bernard (2006) listed nine advantages of meta-analysis: (a) it answers questions about effect size; (b) it systematically explores the source of variability in effect size; (c) it allows for control over internal validity by focusing on comparison studies vs. one-shot case studies; (d) it maximizes external validity or generalizability by addressing a large collection of studies; (e) it improves statistical power when a large collection of studies is analyzed; (f) the effect size is weighted by sample size; large sample studies have greater weight; (g) when a review is updated, it allows new studies to be added as they become available or studies to be deleted as they are judged to be anomalous; (h) it allows new study features and outcomes to be added to future analyses as new directions in primary research emerge; (i) it allows analysis and reanalysis of parts of the data-set for special purposes (e.g., military studies, synchronous vs. asynchronous instruction, Web-based instruction); and (j) it allows comment on what we know, what is new, and what we need to know.

Other researchers (Green and Hall, 1984; Light and Pillemer, 1982; Wolf, 1986) have suggested that meta-analysis is helpful in highlighting gaps in the literature, providing insight into new directions for research, and finding mediating or interactional relationships or trends either too subtle to see or that cannot be hypothesized and tested in individual studies. In general, meta-analysis offers reviewers advantages over other methods of synthesis that are similar to the advantages gained by primary researchers who have the opportunity to move from a small pilot study to a large-scale investigation in which there is large sample and a wide range of subjects and measures (Hauser-Cram, 1983). Meta-analysis "is an important contribution to social science methodology. It is not a panacea, but it will often prove to be quite valuable when applied and interpreted with care" (Jackson, 1980, p. 455).

Criticisms of Meta-analysis

Just like any other research method, meta-analysis has not been free from criticism. Critics of meta-analysis have found fault with techniques and features that are characteristics of this approach. For example, meta-analysis can only assess relatively direct evidence on a given topic, and it is perhaps difficult to achieve valid and reliable coding of the characteristics of the primary studies to be analyzed. In addition, when the available studies for a given topic are few in number and their results are relatively heterogeneous, the findings of a meta-analysis may mislead our understanding of the given topic. These same concerns, however, could be addressed to traditional forms of reviews. More substantial concerns that have been raised can be grouped into four categories (Cook and Campbell, 1979; Glass et al., 1981; Hunter and Schmidt, 2004; Jackson, 1983; Wolf, 1986; Wortman, 1983):

1. One of the most frequent criticisms against meta-analysis is that it mixes apples and oranges; that is, meta-analysis combines studies that are so different that they are not comparable.
2. The inclusion of methodologically poor studies in the review can result in misleading results in meta-analysis.
3. The representation of individual studies by multiple effect sizes can result in nonindependent data points, and misleadingly large samples.
4. The selection bias in reported research can lead to biased meta-analysis results, particularly when published studies, which often show more statistically significant results and have larger effect sizes than unpublished studies, have a greater possibility of being included in a meta-analysis.

Improvements in meta-analysis techniques by some researchers (e.g., Kulik et al., 1985; Hedges and Olkin, 1985; Hunter and Schmidt, 2004; Lipsey and Wilson, 2000; Rosenthal and Rubin, 1982) have answered some of these criticisms, but it remains up to the researcher preparing a synthesis to determine whether the advantages of the meta-analysis technique outweigh the disadvantages for the particular area under investigation. In general, our view is that meta-analysis techniques add considerably to our understanding of phenomena related to teaching and learning. As noted by Abrami and Bernard (2006), “It goes far beyond what a single study might ever hope to contribute about a phenomenon and provides a greater case for the generalizability of results across populations, materials, and methods.”

Review of Studies of Meta-analysis on Information Technology in Education

The Period from 1972 to 1986

Owing to the widespread adoption of information technologies into the processes of teaching and learning, the number of research studies into the impact of IT in education and more recently, with the growing use of the Internet, on distance education (DE) and online learning, has been proliferating in recent decades. These large numbers of published studies have enabled educational researchers to conduct studies of meta-analysis. Walberg (1983) introduced and illustrated the methods of research synthesis, summarized the substantive findings regarding teaching, and evaluated methods of the reviews. These syntheses included the studies before 1983, summarizing findings on general teaching and areas of instructional technology (IT in education). There were a few types of reviews introduced: a review of reviews of teaching effects (Waxman and Walberg, 1982), the 16 research syntheses that Walberg (1983) did, the University of Michigan group's team approach to 11 syntheses, synthesis of bivariate productivity studies completed by the group at the University of Illinois at Chicago (Walberg, 1984; Walberg et al., 1979), synthesis of multivariate studies also completed by the same group (Walberg et al., 1982), syntheses of open-education research (Giaconia and Hedges, 1982; Hedges et al., 1981; Horwitz, 1979; Peterson, 1979), and syntheses of instructional theories (Haertel et al., 1983).

Another large-scale synthesis on instructional technology was completed by Roblyer et al. (1988), who assessed the impact of computer-based instruction (CBI) by reviewing 26 research studies between 1972 and 1986. The reviews from this period did not reach similar conclusions, and only few clear agreements were found among the findings of the review. However, nearly all the reviews seemed to yield evidence that computer-based treatments offered some benefits over other instructional methods (Roblyer et al., 1988). While Walberg (1983) and Roblyer et al. (1988) established their syntheses by 1988, this chapter in the Handbook intends to continue the work, and includes the studies published since 1988 till 2006. The compiled data were based on 44 studies utilizing meta-analysis techniques.

The Period from 1988 to 2006

The studies included in this research met the following predetermined criteria:

1. They included quantitative results. In the results, cognitive, affective, social, or psychomotor performance/skills were the dependent variables. Computer-assisted instruction (CAI), computer-based instruction (CBI), distance education, or Internet technologies were the treatment.
2. They had experimental, quasi-experimental, or correlational research designs.
3. A few key-word searches (computer-aided instruction (CAI), CBI, DE, online learning, computer-mediated communication) were performed on ERIC through First Search, and was limited for the publication year from 1988 to 2006. Because the *Dissertations Abstracts International* was unavailable to the authors, dissertations were not included in the study.

The 44 studies were grouped into two categories. (1) Computer-assisted instruction (CAI): CBI, CAI, information and communication technologies (ICT), teaching or learning with multimedia, and all kinds of tools related to educational technology; CAI is used as a general term here. (2) DE and Internet technologies: Tele-courses, online learning (synchronous or asynchronous), and courses utilizing the media of online computer-mediated communication belong to this category; DE is used as a general term here. When combining the effect sizes of both CAI and DE together, the

Table 1 Overall effect sizes for 30 meta-analyses of CAI vs. conventional instruction

Author	Number of studies	Effect size	Method applied[a]	Subject	Grade level
Azevedo and Bernard (1995)	Immediate = 22 Delayed = 9	Immediate = 0.8 Delayed = 0.35	Hedges and Olkin Hunter and Schmidt; Rosenthal	NA	NA
Bayraktar (2001)	42	O = 0.27	Hunter and Schmidt	General science	Secondary and college
Bangert-Drowns (1993)	32	C = 0.27 A = 0.12	Glass et al.	Writing	All
Bergstrom (1992)	15	Computer adaptive testing = −0.002	Hedges and Olkin	All	All
Blanchard, Stock, and Marshall (1999)	10	O = 0.16	Hedges and Olkin	Math, Reading and language arts	Elementary
Christmann and Badgett (2000)	26	O = 0.13	Glass et al.	All	Higher education
Christmann et al. (1997a,b)	27	O = 0.21	Glass	All	Secondary
Christmann and Badgett (1997)	26	O = 0.19	Glass et al.	All	All
Christmann et al. (1997a,b)	28	O = 0.17	Kulik	NA	Secondary
Cohen and Dacanay (1992)	37	O = 0.41	Glass et al.	Health profession education	Adults
Dacanay and Cohen (1992)	30	O = 0.37	Glass	Dental education	College or above
Dwight and Feigelson (2000)	30	S (impression management) = −0.08 S (self-deceptive enhancement = 0.04	Hedges and Olkin	NA	All
Fletcher-Flinn and Gravatt (1995)	120	O = 0.24	Kulik	All	All
Khalili and Shashaani (1994)	36	O = 0.38	Glass et al.	All	All
Kulik and Kulik (1991)	254	O = 0.3	Glass et al. Cohen	All	All
Lee (1999)	19	C = 0.41 A = −0.04	Glass	All	All
Liao (1992)	31	O = 0.48	Glass et al.	Problem-solving ability	All

(continued)

Table 1 (continued)

Author	Number of studies	Effect size	Method applied[a]	Subject	Grade level
Liao (1998)	35	O = 0.48	Kulik and Bangert-Drowns	All	All
Liao (1999)	46	O = 0.41	Kulik and Bangert-Drowns	All	All
Liao (2007)	52	O = 0.55	Kulik and Bangert-Drowns	All	All
Liao and Bright (1991)	65	O = 0.41	Glass et al.	Problem-solving ability	All
Lou (2004)	71	C = 0.36 A = 0.07	Hedges and Olkin	NA	All
McNeil and Nelson (1991)	60	O = 0.53	Hedges and Olkin	All	NA
Pearson et al. (2005)	20	O = 0.49	Hedges Lipsey and Wilson	Reading	K7-9
Ryan (1991)	40	O = 0.3	Glass et al. Hedges	NA	K-6
Schmidt et al. (1986)	18	O = 0.67	Glass et al.	Special Education	K-12
Soe et al. (2000)	17	O = 0.13	Rosenthal	Reading	K-12
Timmerman & Kruepke (2006)	118	O = 0.12	Hunter and Schmidt	All	Higher education
Torgerson and Elbourne (2002)	7	O = 0.37	DerSimonian & Laird	Spelling	K-6
Waxman et al. (2003)	42	O = 0.41 C = 0.48 A = 0.46 S = −0.091	Glass et al. Hunter, Schmidt, and Jackson	All	All

The overall effect size of the cognitive aspect is 0.41 (K-12 = 0.32; non-K-12 = 0.31)
The overall effect size of the affective aspect is 0.15 (same for K-12 and non-K-12)
The overall effect size of the social skill aspect is −0.02 (same for K-12 and non-K-12)
NA data not available, *O* overall, *C* cognitive achievement, *A* affective achievement, *S* social skill
[a]The meta-analysis procedures used

overall effect sizes were 0.29 and 0.06 for the cognitive and affective aspects, respectively. The overall effect sizes for CAI were 0.41, 0.15, and −0.02 for the cognitive, affective, and social skill aspects, likewise. Tables 1 and 2 list the meta-analyses, included in the present chapter, for CAI vs. conventional instruction and DE vs. conventional instruction, separately; the overall effect sizes are given as a footnote to each table.

Further analysis was to compare the different effects between K-12 and other students for both CAI and DE meta-analyses. For CAI, the effect sizes were almost identical for K-12 and non-K-12 students on every aspect. However, for DE, the results

Table 2 Overall effect sizes for14 meta-analyses of distance education and Internet technologies vs. conventional instruction

Author	Number of studies	Effect size	Method applied[a]	Subject	Grade level
Allen et al. (2004)	39	O = 0.05	Hunter and Schmidt	All	Higher education and adults
Allen et al. (2002)	24	A = 0.09	Hunter and Schmidt	NA	Higher education
Bernard et al. (2004b)	232	C = −0.04	Glass et al.	NA	All
		A = −0.1	Hedges, Shymansky, and Woodworth		
		S = −0.09			
Bernard et al. (2004a)	232	C = 0.013	Hedges and Olkin	All	All
		A = −0.081			
		Delayed = −0.057			
Cavanaugh et al. (2004)	14	O = −0.03	Hedges and Olkin	All	K-12
Cavanaugh (2001)	19	O = 0.15	Cohen and Hedges	All	K-12
Cavanaugh (1999)	19	O = 0.15	Cohen	All except foreign language	K-12
			Hedges, Shymansky, and Woodworth		
Lou et al. (2006)	103	O = 0.02	Hedges and Olkin	All	Undergraduate
Machtmes and Asher (2000)	19	O = −0.009	Hedges and Olkin	All	Higher education and adults
Shachar and Neumann (2003)	86	O = 0.37	Glass Hunter and Schmidt	NA	Higher education
Sitzmann et al. (2006)	96	O = 0.14	Hedges and Olkin	All	Adults
Williams (2006)	25	O = 0.15	Glass et al.	Allied health profession	Higher education and adults
Zhao et al. (2005)	51	O = 0.1	Cooper and Hedges	All	All
Zhao (2003)	9	O = 1.12	Hedges and Olkin	Second language education	Adults

The overall effect size of the cognitive aspect is 0.17 (K-12, 0.06; non-K-12, 0.19)
The overall effect size of the affective aspect is −0.03 (K-12, −0.09; non-K-12, −0.03)
O overall, *A* affective achievement, *NA* data not available, *C* cognitive achievement, *S* social skill
[a]The meta-analysis procedures used

showed that the effect sizes of non-K-12 were slightly higher than those of K-12 for the cognitive and affective aspects.

In total there are 30 studies comparing CAI with conventional instruction in terms of students' cognitive achievement. Ninety percent (27) of the studies indicated that students whose teaching was supplemented with CAI performed better than students without CAI. One study indicated that there was no significant difference between the effects of the two modes of teaching on students' learning, and one study's results showed that in all cases where the mean differences were statistically different, the mean ability measures were higher for a paper-and-pencil test than for the computer adaptive test. Among the 30 studies on CAI, five investigated the affective variable, attitude. Two of the five studies indicated that students using CAI had a better attitude toward learning than did students without CAI, and two studies indicated that there was no significant difference between the two modes. One study concluded that students preferred traditional instruction methods to CAI. Only one study compared students' social skills when using computerized testing with those when using paper-and-pencil tests. This study by Dwight and Feigelson (2000) identified the extent to which collecting data by computers influences socially desirable responding, compared to collecting data by traditional paper-and-pencil questionnaires. The authors investigated socially desirable responding, which consisted of two components, impression management and self-deceptive enhancement. Impression management was the deliberate tendency to overreport desirable behaviors or underreport undesirable behaviors. Self-deceptive enhancement referred to the deliberate tendency to provide an honest but overly positive representation of oneself (Dwight and Feigelson, 2000). The results indicated that a slight reduction in impression management happened because of computerized testing and a slight increase in self-deceptive enhancement happened because of computerized testing, when comparing computerized testing with paper-and-pencil or face-to-face administration. Liao (1992) and Liao and Bright (1991) studied the effects of CAI and computer programming on students' cognitive outcomes, focusing on problem-solving. Conceptual transfer, conditional-thinking skills, critical-thinking skills, and metacognitive skills were all included. There was a medium positive effect of CAI and computer programming on students' cognitive outcomes, with mean effect sizes of 0.48 for the CAI, 0.41 for computer programming, and 0.44 for combined CAI and programming. These two meta-analyses of Liao, and Liao and Bright suggest that teaching and learning with CAI and computer programming have some learning benefits on students' problem-solving abilities.

In total, there were 14 studies comparing DE with traditional face-to-face instruction. Fifty-seven percent (8) of the studies indicated that DE students slightly outperformed traditional students on examinations. Thirty-six percent (5) of the studies concluded that there was no significant difference between the two modes, and 7% (1) of the studies summarized that traditional students had better achievement than remote distance learning students. Among the 14 studies on DE, three studies investigated the affective variable, attitude. All the three studies indicated that either (67%) traditional students had better attitude toward instruction than did remote students or (33%) students had no significant preference to any mode of instruction.

Evidence Outcomes Achieved Through Meta-analysis on Information Technology in Education

When both CAI and DE were combined, the effect size for the cognitive achievement was 0.29, and 0.06 for the affective aspect. According to Cohen (1977), an effect is said to be small when effect size is 0.2, medium when effect size is 0.5, and large when effect size 0.8. The result suggests that students with technology integrated in learning slightly outperformed those without using technology for learning. With regard to the affective aspect, technology seems to have trivial impact on student learning. In addition, when comparing K-12 and non-K-12 settings, CAI and DE appear to be equally effective for both K-12 and non-K-12 students' performance. Since this Handbook focused primarily on the K-12 education, meta-analyses specifically on this level were briefly reviewed as following.

Christmann et al. (1997a,b) investigated through 42 effect sizes from 28 studies on whether there was any difference among the responses of secondary urban, rural, and suburban students to CAI. The overall mean effect size was 0.17. While it could be interpreted as small effect, whatsoever, the results concluded that CAI was more effective than traditional instruction, and CAI was more effective in urban areas, followed by suburban, and then rural areas. Ryan (1991) synthesized 40 studies and analyzed whether use of computers as an instructional tool can help K-6 students achieve better academic results, compared with the instruction without computer for use. An effect size of 0.3 indicated that the amount of training provided to the teachers who integrated computers into their instruction was significantly related to academic achievement on the part of the experimental students. Torgerson and Elbourne (2002) examined six studies on whether ICT made children spell better in English. The overall effect size was 0.37, suggesting a small difference: The teaching of spelling by using ICT tools was as effective as traditional instruction of spelling. Thus, the difference was not statistically significant.

To investigate whether use of digital tools in instruction can help middle-school students achieve better reading performance, Pearson et al. (2005) analyzed 20 studies and had a positive result, a robust effect size of 0.49. They concluded that digital technologies enhanced the reading performance of the students, as evidenced by the robust overall effect size obtained in the study. Schmidt et al. (1986) used 18 studies to calculate effect sizes so as to find whether CAI achieved better educational achievement than did traditional instruction for special education in the K-12 setting. The result showed that CAI appeared to positively affect the educational achievement of exceptional children. The language-disordered and mentally retarded students (those at lower levels of learning) benefited most from CAI.

The performance benefits of CAI were greater in studies published from 1985 to1994 than from 1995 to 2004 (Timmerman and Kruepke, 2006). In terms of how CAI should be effectively used in facilitating the process of learning and teaching, the results of a few studies shed light on the question. First of all, the learners in the immediate feedback group perform better than the group without feedback (ES = 0.8), and the learners in the delayed feedback group perform better than the group without feedback (ES = 0.35). One can conclude that the immediate feedback can provide better instructional advantage to the students than the delayed feedback can. Especially, the diagnostic and prescriptive management strategies of computer-based adaptive instructional systems can provide the most effective feedback (Azevedo and Bernard, 1995). Moreover, CAI delivered with an audio channel is associated with the highest performance gains (ES = 0.26), followed by text (ES = 0.14), text with graphics (ES = 0.12), video (ES = 0.07), and physical apparatus (ES = −0.05) (Timmerman and Kruepke, 2006). The hybrid technology (simulation with both the presentation mode and the practice mode) is more effective than pure technology (simulation only with the practice mode) in improving students' cognitive outcomes (ES = 0.41) (Lee, 1999).

Research evidence has also shown that technologies that were created by a research team had a much larger effect size than those technologies either adapted from the commercial market or that merely used the technology as a delivery system (Pearson et al., 2005). CAI designed for a specific class would increase learning outcomes to a higher degree than the CAI produced by general publishers (ES = 0.14) (Timmerman and Kruepke, 2006). As for which subject area has better effects with the integration of CAI, the results have not been consistent in studies (Blanchard, Stock, and Marshall, 1999; Christmann and Badgett, 2000; Khalili and Shashaani, 1994; Timmerman and Kruepke, 2006). On the other hand, Zhao (2003) concluded that the application of technologies can be effective in almost all areas of language education. In all, results for language-disordered and mentally handicapped students (those students at lower levels of learning) appear consistently to show that they benefit the most from the use of CAI (Schmidt et al., 1986).

Studies in which CAI was used repeatedly had higher average effects (ES = 0.16) than did studies in which CAI was used only once (Timmerman and Kruepke, 2006). According to Khalili and Shashaani (1994), the optimal frequency of using CAI is suggested to be a period of 4–7 weeks (ES = 0.94). When Logo programming language is integrated into class use, high school students achieve better academic results than do other K-12 students (ES = 0.62) (Khalili and Shashaani, 1994). However, other reviews have shown that such evidence about optimal frequency and Logo programming is dependent upon the input of the teachers and is not consistently positive in other educational settings (Cox and Marshall, 2007). Furthermore, the performance gains of CAI have been shown by some studies to be greater for undergraduates than for graduate students (ES = 0.14) (Timmerman and Kruepke, 2006), and the CAI program has been shown to be most effective in grades 2, 3, and 5, and less so in grades 1 and 4 (Blanchard, Stock, and Marshall, 1999). As explained earlier, other studies, including qualitative ones, provide results contrary to these and there is still uncertainty about when, where, and how IT has a positive impact on teaching and learning (see also Cox, 2008; Marshall and Cox, 2008; Pilkington, 2008).

In comparing DE with traditional classroom instruction, in general, DE students have similar gains in achievement outcomes but have less positive attitudes toward instruction at a distance than students who are being taught traditionally. For K-12 students, the results of meta-analyses conducted by Cavanaugh and her colleagues (Cavanaugh, 1999, 2001; Cavanaugh et al., 2004) showed that the overall effect sizes were either under 0.2 or a negative value, suggesting that DE was only slightly better than the traditional instruction for these students' cognitive achievement. No factors (content areas, duration of use, grade levels of students, role of the instructor, type of school, timing of interactions, pacing of the learning) were found to be related to significant positive or negative effects (Cavanaugh et al., 2004). Two-way interaction was found to be the best method of interaction between learners and the instructor (Machtmes and Asher, 2000).

When DE is operated through the Internet, namely Web-based, DE is more effective than classroom instruction in teaching declarative knowledge. However, when DE (Web-based) is used as a supplement to classroom instruction, DE is more effective than classroom instruction only in teaching declarative and procedural knowledge (Sitzmann et al., 2006). Media and pedagogy that can support interaction with the instructor and other students are more important than media and pedagogy that are used to establish individual student interactions with content only (Lou et al., 2006). Distance education, combined with an individualized approach and traditional classroom instruction via tools of telecommunications, enhancement of classroom learning, short duration, and small groups, can yield better student achievement than DE using videoconferencing, primary instruction via distance, long duration, and large groups (Cavanaugh, 1999). Sitzmann et al. (2006) compared Web-based instruction (WBI) (totally online) and WBI-supplemented instruction with face-to-face instruction in both K-12 and non-K-12 settings. Across all the studies they selected, the results indicated that WBI (totally online and supplemented WBI) was 6% more effective than traditional instruction for teaching declarative knowledge. WBI and traditional instruction were equally effective for teaching procedural knowledge. Trainees were equally satisfied with the two delivery media. Besides, across all the studies their results indicated that WBI-supplemented instruction was 13% more effective than traditional instruction for teaching declarative knowledge and 20% more effective for teaching procedural knowledge. Trainees were more satisfied with traditional instruction than with WBI-supplemented instruction. As to whether or not Web-supplemented instruction can achieve more effectiveness in teaching declarative knowledge than can WBI, further research needs to be done to answer this question.

Bernard et al. (2004b) meta-analyzed studies of DE in all education settings and reached some conclusions. In comparing the traditional classroom with **s***ynchronous* DE, students' achievement (ES = −0.102) and attitudes toward instruction (ES = −0.185) were found to be better in the classroom setting than through synchronous DE. The classroom and synchronous DE conditions had equal retention (ES = 0.005). However, in comparing the traditional classroom and *asynchronous* DE, asynchronous DE improved the students' achievements more than the traditional class setting (ES = 0.053), but the students' attitudes toward instruction were the same for both settings (ES = −0.003). The classroom condition had better retention outcomes than the asynchronous DE (ES = −0.093) (Bernard et al., 2004b). In asynchronous DE, independent DE pedagogy was generally found to be less effective than DE that supports collaborative discussion among students (Lou et al., 2006).

In this meta-analysis a small negative but significant effect in favor of classroom instruction on overall attitude (ES = −0.0812) as well as for retention outcomes (ES = −0.0573) was shown, on comparing classroom instruction and DE (Bernard et al., 2004a).

On the other hand, Allen et al. (2002) concluded that students viewed distance learning as satisfactory as traditional instruction. Therefore, regarding students' achievement and attitude, whether face-to-face and synchronous or asynchronous DE has significant differences from each other, no conclusion has yet been arrived, since the results have not been consistent (Allen et al., 2002; Bernard et al., 2004b; Lou et al., 2006).

Meta-Analysis on Information Technology in Education: To Use, or Not to Use?

Meta-analyses have been criticized for being established in low-quality studies, for only depending on published results, for mixing apples and oranges, and for covering multiple results derived from the same studies, as mentioned earlier in this chapter. These and other criticisms are not new, and Glass et al. (1981), Kulik and Kulik (1989), and other meta-analysts described the criticisms before. To overcome choosing low-quality studies and only investigating their published results, it is necessary to have a list of valid criteria for the selection of studies to synthesize. To overcome the criticism of combining "apples and oranges," meta-analysts use standardized mean differences to transform outcomes from disparate studies. To avoid inflating the sample size by covering multiple results derived from the same studies, one does not lump together nonindependent results. After overcoming the pitfalls, one can expect meta-analyses to help contribute to the evidence on the effectiveness of technology on student performance. However, the meta-analytic method is not a panacea. A few defects that meta-analysis was borne to have are never avoidable. Although meta-analysis quantifies studies in a so-called objective way, it may lack what a good qualitative study (i.e., a good descriptive review) can achieve, because meta-analysis only synthesizes quantitative studies. Moreover, this method may produce solid data (i.e., effect size) to answer the research questions of "what," but it can never be able to answer the research questions of "why." To get to know the reasons behind some investigated phenomena, meta-analyses are not a good choice.

Nevertheless, meta-analyses quantify different study results and consequently produce more summarized results. By using meta-analysis, one can synthesize the findings of quantitative studies in the field and acquire a whole picture on whether the integration of technology into learning and teaching helps students perform better, compared with traditional teaching and learning methods. While governments and other stakeholders have been making efforts and investing money into the integration of technology in education, they need to know whether the students' performance and education efficacy are worth the effort and the investment. Numbers can talk. By using the talking numbers of quantitative studies, meta-analyses achieve that mission. They are exactly what meta-analyses can do.

The statement of Bangert-Drowns (1986, p. 398) is quoted here as a postlude to the chapter:

> Meta-analysis is not a fad. It is rooted in the fundamental values of the scientific enterprise: replicability, quantification, causal and correlational analysis.

Valuable information is needlessly scattered in individual studies. The ability of social scientists to deliver generalizable answers to basic questions of policy is too serious a concern to allow us to treat research integration lightly. The potential benefits of meta-analysis method seem enormous.

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10.5

EVALUATION OF THE DESIGN AND DEVELOPMENT OF IT TOOLS IN EDUCATION

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Evaluation of the Design and Development of IT Tools in Education

Information technology (IT) tools in education have primarily been intended to serve two distinct goals, first expanding access to educational opportunities for learners who would not otherwise have them, and second, improving the quality and effectiveness of teaching and learning for all. The *Digital Planet 2006* report from the World Information Technology and Services Alliance (http://www.witsa.org/) states as follows:

> Indeed, despite the expected peaks and valleys, countries around the globe are finding ICT the indispensable technology for increasing productivity, raising the standard of living, *delivering greater educational opportunities*, improving healthcare and human services and eliminating barriers to greater participation in world markets. [italics added by author]

Unfortunately, the evidence that IT tools are "delivering greater educational opportunities" around the globe extends primarily to the meaning of "greater" as "extended" or "more widespread." Obviously, "greater" can also mean "better" or "more effective," but the evidence for the impact of IT tools in attaining this second goal is sorely lacking. The bottom line is that the vast bulk of the research and evaluation studies conducted to date indicate that IT tools can be used successfully to extend educational opportunities to otherwise disenfranchised learners, but the dream of enhancing the quality or effectiveness for all with these same IT tools remains illusive. One plausible reason for the lack of impact with respect to enhancing the quality of instruction and improving learning outcomes is that there has not been a sufficient investment in sound evaluation strategies when IT tools are being developed in educational

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contexts. The purpose of this chapter is to describe the state of the art of evaluation strategies for IT tools in education, with a special focus on mixed methods used in service of the design and development of educational software.

Background

Some experts describe the history of IT as extending as far back to 3000 BC with the development of the first alphabet systems and evolving through the millennia to today's so-called Knowledge Society of the twenty-first century (Jonscher, 2000; Sörlin and Vessuri, 2007). But for purposes of this chapter, the design and development of IT tools in education (or educational software) is limited to the past 50 years, beginning with the earliest experiments in using mainframe computers to implement programmed instruction focused on mathematics and other subjects (Bitzer et al., 1961; Bushnell, 1962; Dick, 1965; Suppes, 1964).

Over these past five decades, many types of IT tools in education, especially educational software, have been designed and developed using instructional systems design approaches (Dick et al., 2004). Many, perhaps more, types of educational software have been developed using strategies other than formal instructional systems design such as software engineering (Sommerville, 2007), rapid prototyping (Connell and Shafer, 1989), or more recently, educational design research (van den Akker et al., 2006).

Regardless of what design and development process is utilized, it is useful to divide the evaluation strategies applied within these approaches as either formative (conducted to improve educational software as it is developed) or summative (conducted to demonstrate the effectiveness or worth of educational software after it is developed) (Scriven, 1967). Reeves and Hedberg (2003) describe six types of evaluation strategies that should be applied within the process of educational software development (review, needs assessment, formative evaluation, effectiveness evaluation, impact evaluation, and maintenance evaluation), but for the purposes of this chapter, the formative and summative distinction is most relevant and sufficient.

Formative Evaluation

Ideally, formative evaluation should drive the entire process of developing IT tools in education. Budget constraints or time limits may mean that some other evaluation activities are abbreviated or even eliminated, but formative evaluation should not be overlooked because it often yields the greatest payoff of evaluation activity (Reeves and Hedberg, 2003). The overall purpose of formative evaluation is to provide information to guide decisions about creating, debugging, and enhancing educational software at various stages of its design and development (Maslowski and Visscher, 1999). Some of the primary activities carried out during formative evaluation include expert review, user observations, and usability testing (Flagg, 1990; Rubin, 1994; Squires and McDougall, 1994; Shneiderman and Plaisant, 2004).

Although a flash of creative insight may sometimes be sufficient to enhance IT tools during their design and development, more often specific information yielded by formative evaluation activities is required to guide educational software improvement decisions. This kind of practical information can be collected in many different ways from a variety of different people, ranging from subject matter experts to learners who are representative of the target audience for the IT tools. Unfortunately, there is often resistance to rigorous formative evaluation among both designers and those who fund the design and development of educational software. This may partially derive from an unfortunate tendency within the larger software industry to develop new programs without substantial formative testing, then investing heavily in packaging and marketing the programs, and eventually using the feedback from the early adopters of the software to fix or improve the program before another version is released. The ethics of these "beta product" practices in the commercial software industry can be debated, but it seems unjust to risk exposing learners to educational software that has not been subjected to rigorous formative evaluation to maximize its efficacy before widespread dissemination.

This type of formative evaluation is especially successful when a full range of stakeholders are involved in the process. It would seem obvious that representatives of the teachers who will be expected to eventually implement the software in their classrooms should be engaged in the evaluative process, but it is surprising how often educational software has been developed without their input (Cuban, 1986; Perkins et al., 1997). Cox (1989) highlighted the importance of evaluating software in real schools with actual teachers:

> Many inexperienced software developers and users have based their evaluation criteria on superficial functional qualities, such as reliability, attractiveness of screen presentation, user-friendliness and program structure. But well organized school trials can provide important indicators about relevance to the curriculum, teacher strategies, pupil responses, and classroom organization. (p. 40)

In addition to teachers, the development team for educational software should include curriculum developers, subject matter experts, educational researchers, and software developers. Ideally, there would also be dedicated evaluators, both internal and external, although this is relatively rare outside of large-scale national projects (Collis and Moonen, 1988).

If dedicated evaluators are not available, educational software development team members should avail themselves of available evaluation instruments and guidelines. For example, Squires and Preece (1999) provided a set of "learning with software" heuristics for evaluating educational software that go beyond the types of weak checklists of surface features often found in such instruments. In a similar vein, Reeves (1994) described 14 pedagogical dimensions of educational software, each based on some aspect of learning theory or learning concept, which can be used as criteria for evaluating different forms of computer-based education.

The good news is that investments in formative evaluation usually result in an overall reduction in development and implementation costs over the lifespan of IT tools in education (Reeves and Hedberg, 2003), and hence resistance to formative evaluation should decline as formative procedures become more routine. Even within the larger software industry, there is an increased emphasis on usability testing and other formative practices (Bias and Mayhew, 2005; Nielsen, 2000), and hopefully this trend will extend into the world of educational software development to a desirable degree.

Summative Evaluation

Throughout the last five decades, the most common approach to summative evaluation of the effectiveness of IT tools in education has been to compare any instructional approach employing IT tools with the traditional classroom delivery approach (Clark, 2001). The dominance of comparative methods in evaluation is hardly surprising given that it appears to be basic human nature to compare anything new with what came before. In addition to appealing to common sense, the comparative method has long been the summative evaluation strategy most frequently recommended in the professional literature (Campbell, 1981). Indeed, experimental and quasi-experimental methods have long been heralded as the "gold standard" of evaluation methods. Suchman (1967) promoted experimental comparisons as a basis for evaluation, concluding that "the logic of this design is foolproof. Ideally, there is no element of fallibility. Whatever differences are observed between the experimental and control groups, once the above conditions are satisfied, must be attributed to the program being evaluated" (pp. 95–96).

Despite the advocacy by people such as Suchman (1967), Campbell (1981), and Slavin (2002), among others, there are significant weaknesses in the application of experimental comparisons to the evaluation of IT tools in education. Regrettably, these fundamental faults are frequently unacknowledged or ignored. First, as explained in more detail by Marshall and Cox (2008) and Liao and Hao (2008) in this Handbook, the strict control of treatment and control variables, as required by experimental methodologies, is impractical or unfeasible in most educational evaluation contexts. Second, decades of evaluation studies clearly indicate that there are substantive differences between the design of learning environments based upon IT tools and the actual implementation of those interactive learning environments. Obviously, experimental methods are limited to examining the differences between IT tools as implemented rather than as designed, but the actual implementation of educational software is often unexamined or poorly understood. Third, the tests used to measure educational outcomes in experimental studies are rarely investigated sufficiently, much less refined, with respect to their reliability and validity (see Marshall and Cox, 2008). In addition, these tests are often focused on results that are relatively easy to measure rather than on the higher-level outcomes that may actually be more important, but which are difficult to measure. Fourth, the experimental approach can only indicate which approach (IT tools vs. classroom instruction) was more effective, but cannot reveal the reasons for any differential findings. Fifth, although experimental evaluations may yield statistically significant differences, especially when large sample sizes are involved, the social or educational significance of these results is often quite weak.

Carey and Dick (1991) summed up the limited utility of experimental methods in evaluating instructional programs as follows:

> Such experimental studies are rarely employed in summative evaluation field trials for lengthy instruction because it is almost impossible to hold constant all factors in the design, much less those in the instruction. The list of study limitations often exceeds the list of study questions. (p. 300)

More recently, Chatterji (2004) argued that the emphasis on experimental methods in education, especially the kind of randomized controlled trials advocated by Slavin (2002), ignores "the critical realities about social, organizational, and policy environments in which educational programs and interventions reside" (p. 3). She advocated "decision-oriented" *evaluation research* over "conclusion-oriented" *academic research*, and recommended extended-term mixed-method designs as a viable alternative.

In light of the aforementioned weaknesses, it is surprising that many government agencies in the USA and other countries continue to recommend and in some cases even require that experimental methods be applied to the evaluation of any IT tools in education funded by those agencies. For example, on the website of the National Science Foundation (NSF) in the USA there is a page titled "How NSF thinks about evaluation" (http://www.ehr.nsf.gov/rec/programs/evaluation/nsfeval.asp), where it is stated that "Evaluation can be accomplished in various ways, and there is no single model, template, or algorithm that can be universally applied." However, later on the same page, under a section about the important criteria for evaluation, it is recommended that evaluations of NSF projects utilize "A strong evaluation design, with comparison groups and well-chosen samples, as relevant that clearly addresses the main questions and rules out threats to validity." My personal experiences as a proposal reviewer at NSF as well as anecdotal evidence by colleagues who review for other US federal agencies such as the US Department of Education and the National Institutes of Health indicate a strong bias in favor of experimental designs among both reviewers and agency personnel. Similar biases have been reported by colleagues from Australia, The Netherlands, South Africa, and elsewhere.

Contemporary Approaches to Evaluating IT Tools in Education

Fortunately, there are alternative evaluation approaches, especially mixed-method models that are gaining acceptance among designers, developers, and evaluators, and to a lesser degree among federal, state, and private funding agencies. In fact, the NSF website actually includes two *User-Friendly Handbooks* that describe how mixed methods can be employed in evaluations of projects that involve IT tools in education (Frechtling, 2002; Frechtling and Sharp, 1997). Advocates of "mixed-methods" evaluation approaches recognize that multiple perspectives are necessary to "triangulate" or "bracket" information and conclusions regarding complex phenomena such as the integration of IT tools in education. Greene and Caracelli (1997) describe two of the major advantages of mixed-method evaluation as the approach's capacity to:

– test the consistency of findings obtained through different instruments, a process known as "triangulation," and
– clarify the results obtained with one method with the use of another method, a process known as "complementarity."

In light of the complexity inherent in most educational contexts, evaluations of IT tools in education usually demand multiple or mixed methods (Mark and Shotland, 1987; Mertens, 2005). Mixed-method approaches allow evaluators to triangulate findings by using more than one method to collect data related to an evaluation question, the answer to which will inform an important design decision. Suppose a team of instructional designers is trying to decide whether the search functions within an educational website should only search across resources that have been prequalified as relevant, valid, and reliable sources, or allow open searching across the entire World Wide Web (WWW). One question the team might address to inform this decision could be, "What are teachers' attitudes toward the use of open searching on the Internet?" An e-mailed questionnaire designed to elicit teachers' views about Internet searching would be one way of collecting those data, but most people, including teachers, are turned off by questionnaires and wary of sharing information via e-mail. Thus, they may not provide sufficiently detailed information about their real opinions about this matter. Alternative strategies that could be used in tandem with each other include:

– conducting a series of focus groups with teachers, administrators, and parents about the pros and cons of open searching by students;
– analyzing the policies established by a representative sample of school districts concerning Internet access by students; and
– reviewing the professional research literature concerning recommendations for Internet search policies and procedures.

A Decision-Oriented Rationale for Evaluation

Since the onset of digital information technologies, IT tools in education have been the subject of much attention, ranging from under-qualified advocacy (Prensky, 2006) to research-based skepticism (Cuban, 2001). The complexities of designing, developing, and implementing educational software derive from competing theoretical foundations (such as behavioral vs. cognitive psychology), alternative pedagogical designs (such as instructivist vs. constructivist), an increasing array of technological delivery systems (such as DVD or Web 2.0), the challenges of introducing educational innovation in schools (Schlechty, 2005), and other factors. Meanwhile, the field of evaluation has evolved into a contentious one with many competing models and several conflicting paradigms (Stufflebeam and Shinkfield, 2007).

There are several plausible rationales for evaluation, including mandates from government funding agencies, but the strongest one is decision-oriented. Accordingly, the first step in planning an evaluation should be identifying the decisions that an evaluation should inform because decisions guided by sound evaluation are likely to be better than those based on habit, ignorance, intuition, prejudice, politics, or guesswork. Far too often designers of educational software make poor decisions about the design and implementation of IT tools in education because they lack the pertinent information that could have been provided by a better, more consistent investment in evaluation (Patton, 1997; Reeves and Hedberg, 2003).

There are many different types of decisions that must be made during the design and development of educational software. For example, some involve the content, e.g., where should the subject matter expertise required to develop relevant and accurate educational programs be attained and how can it be validated? Others involve the basis for sustainable funding; e.g., what kinds of pricing structures should be applied to educational software? Still others involve the provision of learning assessment within the software; e.g., should only the objectives aligned with basic skills be tested or should higher-order outcomes also be assessed?

Trying to anticipate the decisions that can be influenced by an evaluation of IT tools in education requires considerable effort and careful trust-building. Many stakeholders, especially those involved in funding or developing IT tools in education, do not wish to anticipate negative outcomes for their efforts, but these too must be considered. In most instances, evaluators would not be able to create an exhaustive list of all the decisions that must be made about educational software. Nevertheless, although there will always be unanticipated decisions, the effort to identify decisions up front is invaluable. Indeed, unless such decisions are identified in advance, any evaluation activities may be wasted.

After important decisions that must be made about educational software are determined, the evaluation questions that must be addressed to provide the information needed by the decision-makers can be clarified. The clearer and more detailed the evaluation questions are, the more likely that evaluators will be able to provide reliable and valid information to these decision-makers. One challenge in evaluation planning is limiting the questions to those that are the most relevant to the decisions that must be made without exceeding the time, money, and other resources allocated for evaluation. In many cases, there will be far more questions that could be asked in evaluating educational software than financial and temporal resources will allow, and therefore difficult choices must be made about which questions will actually be addressed. These choices should be made in collaboration with other stakeholders well in advance of any evaluation data collection activities. Evaluators must avoid the temptation to collect the data that is the easiest to obtain, e.g., learner evaluations of software, rather than collecting data that may be much more difficult to get, e.g., evidence of learning achievement, but which will ultimately prove much more useful.

The delineation of important decisions and unambiguous questions is essential before deciding upon the methods of evaluation. Unfortunately, too many evaluators and instructional designers start with the specification of methods. Their thinking may go something like this: "We have to do an evaluation. Let's begin by designing a survey." But survey methods are just one option for evaluation methods, and the first method to come to mind may not be the most appropriate option for answering the specific evaluation questions and ultimately informing the most critical decisions.

It may help to think of evaluation methods as building tools. Just as a carpenter would not select a carpentry tool (hammer, saw, or plane) before understanding the nature of the task that must be accomplished, evaluators should not choose evaluation methods until they understand as clearly as possible the questions that need to be answered in order to inform the decision-making process. There are numerous evaluation methods (e.g., usability testing) and even more specific data collection strategies (e.g., keystroke analysis) that can be used within any given evaluation of IT tools in education. Most carpentry jobs require multiple tools, and similarly, most evaluations require multiple methods.

The following key steps are required for the planning, implementation, and reporting of evaluations focused on IT tools in education:

– Identify the decisions that the evaluation should inform.
– Specify the questions that must be answered to provide the information needed to inform the identified decisions.
– Select reliable, valid, and feasible evaluation methods.
– Implement the evaluation methods in a rigorous and professional manner.
– Report the findings in an accurate and timely manner so that decisions can be informed as intended.

Primary Components of an Evaluation Plan

Planning an evaluation requires political savvy and astute negotiation skills. Evaluators often find themselves in the position of having to persuade their stakeholders of the value of anticipating difficult decisions and asking hard questions in an evaluation of educational software. Unwilling to confront the complexities involved in most evaluations, stakeholders in an educational software development project may demand direct and simple answers to complex questions. However, simple answers to complex questions are extremely rare, and “it depends” and other conditional statements are inherent in even the best evaluations.

A sound evaluation plan will expose as many of these conditionals as possible up front, but the difficult part is doing so without having the stakeholders decide to abandon evaluation altogether. Therefore, an evaluation plan should be presented in a straightforward, easy-to-understand manner. An evaluation plan should include the following sections:

– Introduction: The Introduction section introduces the major sections of the plan as well as the primary people involved in preparing the plan. It informs stakeholders about the type and amount of information upon which evaluation planning has been based, both in terms of human input and review of other materials.
– Background: The Background section of the plan describes the information needed to provide stakeholders with an understanding of the background of the educational software being evaluated. This section should provide enough information to convey the nature of whatever is being evaluated, but not so much detail as to overwhelm readers. The background should tell “the story” of the design and development project, and should include screen images from software to clarify its nature.
– Stakeholders: The Stakeholders section of the evaluation plan describes the primary and secondary audiences or consumers of the evaluation. Patton (1997)

recommends the use of the term "stakeholders" to designate evaluation audiences. Patton wrote, "…stakeholders typically have diverse and often competing interests" (p. 42). Competing interests in an evaluation should not be obscured, and therefore, information about an evaluation should be shared with as many stakeholders as is technically possible and politically feasible.

- Purposes: The Purposes section of the evaluation plan thoroughly describes the rationale and goals of the evaluation. Evaluation is inherently a political process, and thus all stakeholders should seek consensus about its purposes if it is to succeed. As noted earlier, there are two primary types of purposes, formative and summative. Many evaluations will have both formative and summative purposes.
- Decisions: The Decisions section of the evaluation plan is usually the most difficult part of a plan to prepare, but it must be included if the evaluation is to have a sufficient impact on decision-making.
- Questions: The Questions section of the evaluation plan should flow naturally from the Decisions section. For each decision that the evaluation should inform, there will be one or more questions that the evaluation must address. The answers to these questions provide the essential information the instructional designers and other decision-makers need to make their decisions in a timely manner.
- Methods: The Methods section of the evaluation plan spells out the overall evaluation design and data collection strategies. There are scores of designs and many more data collection strategies that can be used. Unfortunately, traditional evaluation textbooks do not provide sufficient practical guidance in the area of methodology because the examples they commonly include are based upon the assumption that one design will suffice (e.g., a quasi-experimental design). Most likely, a blend of several methods such as usability testing, expert review, and user surveys may be necessary to collect the information needed to answer the evaluation questions and ultimately inform the decision-making process.
- Sample: The Sample section of the evaluation plan specifies the people from whom data will be collected. These people are also called the evaluation participants. Except in rare situations, it is not possible to collect information from everyone in any given population of potential participants. Therefore some sort of sampling is required whereby a subset of the population is selected to represent the information that would be collected from everyone if that were feasible.
- Instrumentation: The Instrumentation section of the evaluation plan describes the measurement tools to be used. Copies of the instruments can be included in appendices for review by stakeholders. The descriptions in this section should provide enough information to permit readers to judge the various purposes and uses of instruments such as questionnaires, interview protocols, and observation recording tools.
- Limitations: The Limitations section of the plan describes any known limits on the implementation, analysis, interpretation, and application of the evaluation. Every evaluation has limitations, and there is often an arguable basis for alternative explanations of even the most robust findings. This section of your plan should also describe potential threats to the reliability and validity of the evaluation design and instrumentation.

– Logistics: The Logistics section of the plan describes who will be responsible for evaluation implementation, analysis, and reporting. It usually includes some sort of timeline that illustrates the logical dependencies among various evaluation activities. Evaluation data are often time-sensitive. Keeping track of when, where, and how various data need to be collected requires strong project management skills.
– Budget: The Budget section of the plan describes the finances for the evaluation. Evaluation is primarily a people-intensive process, and therefore, most of the money spent on evaluation will usually be for dedicated evaluation personnel or external consultant costs or both. Budgeting for evaluation is challenging because most people are reluctant to spend money for evaluation in the first place. When things get tight during a project, people often look at cutting the evaluation budget first. What should an evaluation cost? One rule of thumb is to budget 5–10% of an overall software development budget to evaluation.

Evaluation Reporting

Evaluations may be planned and implemented with great care and expertise, but unless they are reported in an accurate and timely manner, they will probably be fruitless. Evaluation results are just one source of influence competing for the attention of stakeholders, and not always the most compelling. Unfortunately, it is not obvious to everyone that evaluations are not ends in themselves, but a means to better decision-making. Unless decision-makers receive credible information provided by an evaluation at the times when critical decisions must be made, the evaluation might as well have never been done in the first place.

When presented with an evaluation report, most stakeholders want more than "just the facts." They expect clear explanations of how the data were collected and analyzed and how the interpretations and recommendations were derived from the results. Reporting an evaluation is as much about telling the "story" of the educational software design, development, and implementation project in a convincing manner as it is about rendering sophisticated tables, charts, and statistical analyses. People seldom remember figures and graphs, but they do recall stories. Moreover, they are much more likely to share stories, and thus, in turn, influence other stakeholders.

Although most evaluations are still reported as written documents, they are usually shared electronically as Adobe Portable Document Format (pdf) files or in other digital formats. Alternative reporting formats such as PowerPoint presentations, Web pages, and video can be utilized to present results in a compelling manner. Focus groups of stakeholders can be convened to share the evaluation results and obtain critical feedback.

The Future of Evaluation of IT Tools in Education

Most evaluations of IT tools in education have extremely limited exposure beyond the immediate context of the educational software development projects during which they are conducted. However, in the future, it seems reasonable and advantageous that evaluators and stakeholders should extend the reach of their evaluations, and in doing so, contribute to design principles that can advance the state of the art of IT tools in education. This can be accomplished through a process called design research (van den Akker et al., 2006). By focusing evaluations on the dual objectives of developing creative approaches to solving human teaching, learning, and performance problems while at the same time constructing a body of design principles that can guide future development efforts, the designers of educational software may eventually overcome the limitations that currently undermine their success in markedly enhancing the effectiveness of education.

To realize the benefits of a design research orientation in education software evaluation, evaluators should collaborate with designers and other stakeholders to develop a logic model of the education software within its eventual context of implementation (Chen and Rossi, 1983; Julian, 1997; Watson, 1987; Squires and Preece, 1999; van der Knaap, 2004). This logic model should clarify the structure of the software's design, its theoretical underpinnings, and how it will account for expected outcomes from both a practical and theoretical perspective. The model should describe all the critical subcomponents of the software and expected interactions among them. A typical model, as illustrated in Figure 1, may have different categories of subcomponents such as context, inputs, processes, and outcomes.

A design research orientation to evaluation may initially seem beyond the scope of work for instructional designers, project managers, evaluators, and other personnel engaged in the design, development, and implementation of IT tools in education.

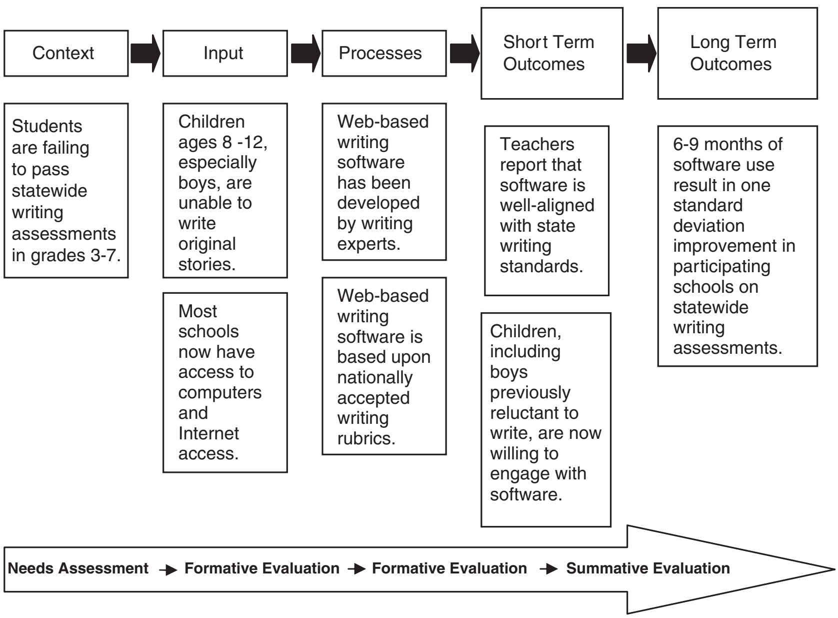

Fig. 1 Logic model for hypothetical educational software evaluation

But such an orientation will not only enhance the professional development of these personnel and the work that they are able to accomplish, but over time, will contribute to the design knowledge upon which future advances in IT tools in education will be based.

After all, designers and developers of IT tools in education are primarily involved in design work, and thus design knowledge is the primary type of knowledge that should inform their work. Design knowledge is not something that educational researchers derive from experiments for subsequent application by designers. It is contextual, social, and active (Perkins, 1986). As design professionals, the paramount goal of anyone involved in developing IT tools in education should be solving teaching, learning, and performance problems, and at the same time, deriving design principles that can inform future design, development, and implementation initiatives. Traditional educational researchers from fields such as instructional technology or educational psychology attempt to reveal esoteric theoretical knowledge that they think designers and other practitioners should apply, but this has not worked for more than 50 years, and it will not work in the future.

Other changes are afoot that will influence how evaluations of educational software will be conducted in the future. For example, according to Friedman (2005), outsourcing does not just refer to sending routine clerical tasks to any part of the world, but to the sharing of sophisticated and challenging knowledge work. In the still evolving global Knowledge Society, the needs assessment for a large-scale educational software project may be conducted in the USA, the content expertise may reside in Europe, the instructional design work may be done in India, and the production work may be accomplished in China, all for delivery to a client in the Middle East. Who takes responsibility for various evaluation activities in such a large-scale design and development project spanning many time zones and cultures remains unclear.

At the same time, distinctions among traditionally different market segments, e.g., K-12, Higher Education, and Corporate Training, are blurring. This trend is partially due to the development of learning objects that can be modified as needed for different purposes or audiences (Harman and Koohang, 2007). Standards for learning objects and other modular components of IT tools in education are being identified by a variety of international collaborators such as the Advanced Distributed Learning Initiative of the Department of Defense in the USA (http://www.adlnet.gov/) and the ARIADNE Foundation of the European Union (http://www.ariadne-eu.org/). These standards are supposed to provide better frameworks for developers, subject matter experts, project managers, instructional designers, and others to follow in developing interactive learning products that are reusable and interchangeable across a global scale and which are compatible with various forms of Course Management Systems, Learning Management Systems, and Learning Content Management Systems.

These initiatives hold great promise, but effectiveness data yielded by sound evaluation strategies seem to remain one of the weakest aspects of all the various standards schemes. Much work remains to be done in this area. One of the major challenges is obviously making evaluation (or design research) an essential component of any efforts to integrate learning objects and other instructional components into a learning environment. Parrish (2004) noted that "In the development phase, as well, formative evaluation of learning objects by experts can be made difficult if the reviewer cannot see the context of use" (p. 56). It will not be sufficient to assume that evaluation results from any one learning object or any particular arrangement of learning objects can be extrapolated to other times and contexts. Evaluation must be an ongoing process if we are not to mindlessly automate the design, development, and implementation of IT tools in education. To do anything less would mean that we will fail the dream of using IT tools to both extend and enhance learning around the world.

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10.6

METHODS FOR LARGE-SCALE INTERNATIONAL STUDIES ON ICT IN EDUCATION

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Introduction

International comparative assessment is a research method applied for describing and analysing educational processes and outcomes. It is used to "describe the status quo" in educational systems from an international comparative perspective. This type of assessment started in the 1960s and has been mainly focused on core subjects, such as mathematics, science and reading (literacy). Over time, assessments were also conducted that were in particular focusing on the use of ICT in education, the first one being the Computers in Education (CompEd) study conducted in the late 1980s and early 1990s under the auspices of the International Association for the Evaluation of Educational Achievement (IEA) (Pelgrum and Plomp, 1993).

Nowadays different types of international comparative assessments exist, such as the following:

- Projects by international organizations, e.g.: projects funded by the European Commission (Eurydice, 2004)
  - Exchange of experiences via the world summits on the Information Society by United Nations Educational Scientific and Cultural Organization (see www.unesco.org)
  - Secondary analyses of assessments conducted by the Organization for Economical Cooperation and Development (Organisation for Economic Cooperation and Development (OECD), 2006)
  - Worldbank (Hepp et al., 2004)
- Case studies of selected schools in a number of different countries (e.g., SITES module 2, a study looking at innovative pedagogical practices utilizing ICT; Kozma, 2003)

J. Voogt, G. Knezek (eds.) *International Handbook of Information Technology in Primary and Secondary Education, 1053–1066*.

– International assessments using national representative samples of schools, teachers, and/or students, and focusing on collecting and producing comparative indicators regarding educational processes and outcomes.

This chapter will in particular address the last category of large-scale international comparative assessments. In this chapter these projects are labelled as “assessments”, because of their primary function as explained in Figure 1. These assessments also exist on a regional basis (for instance, Bonnet (2004), projects of the Southern and Eastern Africa Consortium for Monitoring Educational Quality (see http://www.sacmeq.org/links.htm). This chapter will primarily focus on large-scale international assessments that are conducted on a worldwide scale by the IEA and the OECD. We will call these types of assessments Worldwide International Statistical Comparative Educational Assessments (WISCEAs) in order to distinguish them from qualitative assessments and from regional statistical comparative assessments.

In this chapter, the following questions will be addressed:

– Which WISCEAs addressed issues related to ICT?
– What were the major concepts and indicators that were addressed in these WISCEAs?
– How are WISCEAS designed?
– What potential outputs are provided by ICT-related WISCEAs?
– Which recommendations for ICT-related WISCEAs can be given?

These questions are covered in the following sections, starting with a short description of the history of WISCEAs in terms of purposes, methods, audiences, and organizations

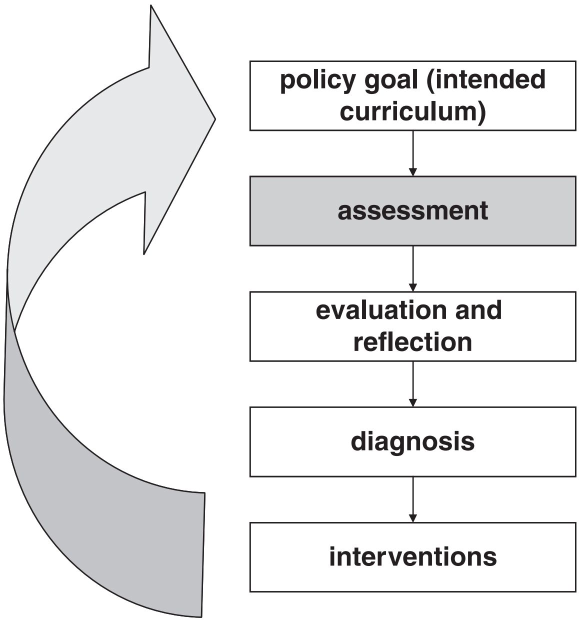


Fig. 1 Policy cycle showing several functions of WISCEAs

in particular with regard to ICT-related matters. This will be followed by zooming in on the research questions underlying WISCEAs, conceptual and design issues. Finally, potential outputs of ICT-related WISCEAs as well as recommendations for future ICT-related WISCEAs will be presented.

Historical Sketch of ICT-Related WISCEAs

Although scientific interest was the main purpose of the first WISCEAs initiated in the 1960s by the IEA, nowadays policy interests are the main driver for this type of assessment as is witnessed by the fact that the OECD has become a main player in this field by conducting the so-called Programme for International Student Assessment (PISA) (e.g., OECD, 2004). Although these organizations also run other types of comparative assessments (policy analyses, qualitative studies), they are most widely known for their "league tables" showing rank-ordered country scores on achievement tests. Since the first feasibility study of IEA on mathematics was conducted in the 1960s, more than 15 WISCEAs were reported by the IEA up until 2005. The OECD PISA assessment has been conducted and reported three times. Most WISCEAs were focused on basic school subjects such as mathematics, science and reading.

The IEA has a long tradition in conducting WISCEAs that are dedicated to ICT in education. The first one was the so-called Computer in Education (CompEd) study that was conducted in two phases between 1987 and 1992 (Pelgrum and Plomp, 1993; Pelgrum et al., 1993). The first phase targeted schools and teachers (users as well as non-users) at the primary and secondary level, while the second phase also included samples of students. The indicators collected in this study had high reliabilities (e.g., attitudes of school leaders and teachers, the extent to which computers were integrated in teaching and learning, self-rated competencies of teachers, ICT-competencies of students).

The second wave of ICT-WISCEAs consisted of the so-called Second Information Technology in Education Studies (SITES), which started with module 1 (SITES module 1) (1998–1999; see Pelgrum and Anderson, 1999, 2002). In SITES module 1 a large number of indicators were collected at school level in 26 education systems (in primary, lower secondary and upper secondary schools). Pelgrum and Anderson (2002) showed that many of the indicators from several concept domains (curriculum, infrastructure, staff development, management and organization and innovative practices) had high reliabilities within as well as across countries. This was followed by SITES module 2, qualitative case studies (174 in 28 countries) of ICT-supported pedagogical innovations (Kozma, 2003). SITES2006 was the most recent ICT-related WISCEA of IEA. In this assessment (which was focussed on national representative samples of lower secondary schools and mathematics and science teachers from 22 education systems) a large number of high-quality indicators were collected that relate to the concepts that are mentioned in Figure 3.

From CompEd to the three SITES studies a shift can be observed in interest among policymakers and researchers in the focus of ICT-related WISCEAs. The focus of interest has shifted from counting of computers and inventorying the use of computers and obstacles to use IT to how pedagogical practices are changing and adapted to the needs of education in a knowledge or information society ("twenty-first century"), and how IT is used in supporting these practices.

Recent WISCEAs that were focussed on core school subjects (Trends in International Mathematics and Science Study [TIMSS] 2003 and PISA 2003) also contained indicators of ICT availability and ICT use, but the ICT-related indicators in these assessments cover only a small number of aspects, compared to the ICT-dedicated WISCEAs of IEA in which typically hundreds of variables are measured.

Questions Underlying ICT-Related WISCEAs

WISCEAs may have several functions. Howie and Plomp (2005) distinguish the following functions: description (mirror), benchmarking, monitoring, enlightenment, understanding and cross-national research. Some of these functions (such as benchmarking, monitoring, understanding, cross-national research) can be explicitly addressed by the research design, while other functions are more or less collateral (mirror, enlightenment). In general, a basic purpose of WISCEAs is to contribute to educational improvement. With regard to ICT-related WISCEAs, major questions are as follows:

- Do students have sufficient opportunities to use ICT for learning purposes?
- Does the use of ICT for teaching and learning result in higher school effectiveness?
- Can the use of ICT contribute to diminishing inequities?

Target audiences of the WISCEAs are mainly macro-level actors: policymakers, inspectorate, researchers and special interest groups in educational practice. Although, in principle, the outcome from WISCEAs is also of interest to other actors (e.g., teachers and parents), the international reports of WISCEAs are not specifically targeting questions that are relevant for these groups (e.g., how well is my school performing?).

The design and methodology of WISCEAs are determined by policy and research questions that are posed at their start. In generic terms one may distinguish descriptive and analytical questions. Descriptive questions related to ICT are, e.g., "Is the access to ICT in schools measuring up with other countries?"; "To what extent (comparatively) are our teachers skilled for using ICT in teaching and learning?" Analytical questions are usually phrased in terms of potential causal factors, for instance, in generic terms: "To what extent does the use of ICT result in changes in the way that teaching and learning is taking place?"

Although assessment is the primary function of WISCEAs, several secondary functions can be distinguished, as is illustrated in Figure 1, which shows that policy issues and derived research questions constitute (ideally) the basis for designing an assessment. The results of the assessments are used for making inferences about strengths and weaknesses of the education systems of the participating countries (evaluation and reflection). Once weaknesses are spotted, analysis activities need to be undertaken in order to find the potential causes (diagnosis). This part of a study is guided by analytical research questions. The results of such analyses of the available data (in countries sometimes supplemented with additional data collection) may be used for undertaking interventions aimed at improvement of the education system.

Figure 1 illustrates that posing analytical questions a priori (that is, when designing a WISCEA) can be problematic when the descriptive results are not yet available. Therefore analytical questions in WISCEAS are often based on hypothetical outcomes inferred from reviews of research literature, or they are generated a posteriori and based on the observations resulting from the descriptions.

Policy and research questions form the start of any WISCEA. Examples of policy questions are as follows:

– What ICT equipment is needed in educational practice?
– Which competencies do teachers need in order to adequately integrate ICT in their lessons?

Examples of research questions are as follows:

– Which ICT infrastructure is available in schools and to what extent do educational practitioners perceive this as sufficient?
– What are the ICT-related competencies of teachers and in which areas do they need further training?

Concepts that are referred to in these questions (in the above-mentioned examples: infrastructure, teacher competencies) are organized in a conceptual framework which on an abstract level forms the link to indicators and constitute the basis for developing instruments.

In the next sections each of these aspects are discussed briefly.

Conceptual Frameworks

Conceptual frameworks mainly have a descriptive and structuring function: they more or less describe the "landscape" contours of the area that will be assessed and at the same time provide a structure for deriving relevant constructs. For instance, an important policy issue is equity of access to ICT (concept), which may be defined in terms of availability to students of ICT at home and school, their gender and the minority group to which they belong (constructs) for which indicators can be developed (such as responses to questions like "Do you have a computer at home which you can use for school work?"; "What is your gender?" or "In which country were you born?"). In the context of this type of study, an indicator is often called "variable" or "statistic".

An important distinction is between independent and dependent indicators, both of which can be used for descriptive purposes, whilst the independent variables play an important role in addressing the analyses questions shown in Figure 2.

The construction of a conceptual framework for a WISCEA is a complicated process that is usually not a linear one, but rather based on an initial proposal developed by an international coordinating centre which is further elaborated via intensive interaction with the representatives of participating countries who together take decisions about

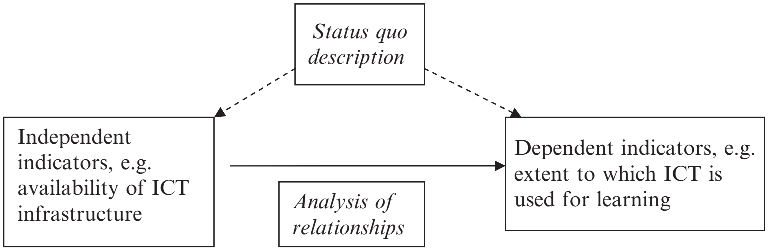


Fig. 2 Links between independent and dependent indicators

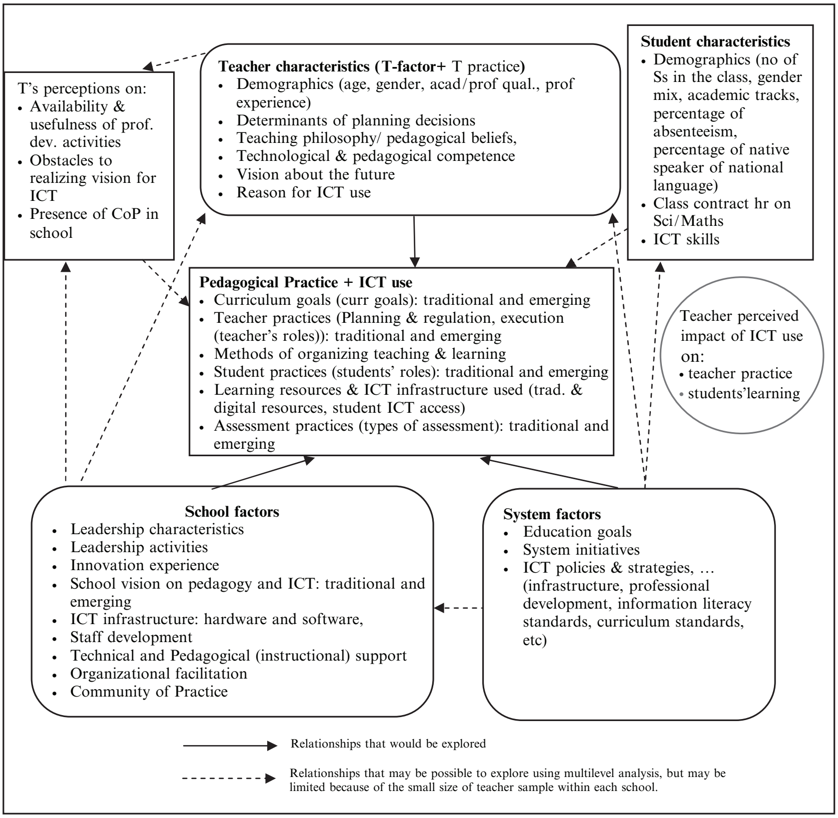
(political) relevance and feasibility. Quite often, when initial concepts are further operationalized, it appears that not always suitable and cost-effective indicators can be found for important concepts (e.g., lifelong learning skills of students). Hence, initial conceptual frameworks often need to be revised during the elaboration of a WISCEA design and after the pilot-testing of instruments in the participating countries. Furthermore, time and budget constraints prevent all the favourite issues of the participating countries from being addressed. This problem is often solved by allowing countries to add so-called national options to the international assessment measures.

An example of a conceptual framework of an ICT-related WISCEA is shown in Figure 3. This framework is taken from SITES2006, an assessment for which the data were collected in 2006 in 22 education systems. The starting point for this assessment was the policy issue of pedagogical innovation and the role ICT is playing in these innovations. This issue has grown from the more than 20 years of experience in a substantial number of countries regarding the introduction and use of ICT in education.

The SITES studies focussed on several concepts that, according to earlier research, influence the implementation of pedagogical innovations. These were operationalized in SITES2006 in terms of pedagogical paradigms. A contrasting pair was distinguished: traditional pedagogy (teacher-directed, whole-class teaching) and emerging pedagogical approaches (more responsibility and autonomy of students for their learning, working in small groups, lifelong learning skills). As illustrated in Figure 3, it was hypothesized that the extent to which these two approaches exist would be influenced by several (often interacting) "conditions" at the school and teacher level. ICT was conceived as one of the important conditions.

Design Issues

WISCEAs should be designed in such a way that high-quality data are collected that allow for generalizations to the defined national target populations and for comparisons between countries. The sections that follow discuss briefly several aspects that have to be taken into account when designing such studies. More in-depth descrip-



influenced by several (often interacting) 'conditions' at the school and teacher level.

ICT was conceived as one of the important conditions.
Legend. T=teacher, CoP – Community of practice

Fig. 3 SITES 2006 conceptual framework (after Law et al., 2008). *T* teacher, *CoP* community of practice

tions of design aspects of WISCEAs can be found in the technical reports from IEA and OECD (e.g., Martin et al., 2004; OECD, 2005). Information about technical standards for international comparative assessments as developed by the IEA can be found in Gregory and Martin (2001).

Instrument Development

To be able to make statements about the concepts (and related indicators) underlying the assessment, measures are needed that can be used for statistical generalizations.

Typically in WISCEAs, which are targeting students, the following types of instruments are distinguished:

– Context instruments: for collecting information about school external conditions (e.g., funding, regulations, curriculum). For instance, to what extent do curricula prescribe the use of ICT? Context data can be provided by the schools or by experts knowledgeable about the issues addressed.
– School instruments: containing questions about school characteristics (e.g., organization, infrastructure, school policies, e.g., on staff development). For instance, how many computers are available in schools or what is the vision in schools about pedagogical approaches?
– Teacher instruments: containing questions about instructional practices. For instance, to what extent do teachers use ICT for independent learning?
– Student instruments: tests for measuring achievement and student questionnaires about activities and background. For example, how often do you use in a typical school week a computer in learning mathematics?

The construction of international instruments is usually a very time-consuming activity in which many steps are taken in order to optimize the quality of the assessments. The steps include involvement of international and national experts, pilot testing, translation verification and lay out verification.

Populations and Samples

The purpose of WISCEAs is to provide good national estimates of the indicators that have been defined for students, schools and/or teachers. The challenge is to define populations in such a way that they are comparable across countries. This is a complex task that cannot always be solved to the complete satisfaction of all participants. The IEA and OECD use different approaches for defining populations. In IEA studies the definitions are age-grade-based, which means that within each education system a particular target grade is chosen that corresponds to an international population definition. Definitions that were used in SITES2006 (for what in most countries constitutes the lower secondary level) were, for example: "all schools where students are enrolled in the target grade, i.e., in the grade that represents eight years of schooling, counting from the first year of ISCED Level 1" (Law et al., 2008).

The main reason for choosing an age-grade-based definition is that in IEA assessments teachers and student data are linked and hence IEA is targeting for data collection in intact classes. It should be noted that linkage is also possible when targeting individual students, but it is more complicated because for most teachers the reference point for their instructional activities is an intact class.

The approach of OECD to defining student populations is different from IEA: it is age-based. In PISA-2003 the definition was "all students who are aged between 15 years 3 months and 16 years 2 months at the time of the assessment, regardless of the grade or type of institution in which they are enrolled and of whether they are in full-time or part-time education" (OECD, 2004). A practical problem in this approach is the collection of data from teachers of sampled students about their instructional practices because in a school the sampled students may belong to different classes with different teachers. To some extent this can be overcome by asking students to provide information about their teachers.

The student population definitions (defined either in terms of student's age or grade characteristics) have also implications for the definitions of teachers and school populations, in relation to which populations the results can be generalized.

Once the population definitions for each country are settled, samples can be drawn. These samples need to be of high quality in order to warrant good estimates for the whole population.

Data Collection and Quality Control

The collection of data is a very crucial phase in any WISCEA. The purpose is that a high percentage of the sampled respondents answer the questionnaires or tests or both as accurately and completely as possible. Any loss of data or inaccuracies (e.g., unreadable answers) will result in lower data quality and fewer possibilities for producing good estimates of population parameters.

Data collection is one of the biggest budget items for national teams, because it is time-consuming and requires quite high expenditures for materials (printing, mailing). Hence, one would expect that considerable budget reductions might be possible when the data are collected electronically, via online data collection (ODC). For a long time ODC was not feasible, because respondents (schools, teachers and/or students) did not have integral access to ICT, the Internet or were not competent enough to use these facilities. The IEA SITES2006 has been the first WISCEA that applied ODC on a large scale. From a feasibility test of ODC (conducted with two groups of respondents, randomly allocated to a paper version and an ODC version of the instruments), it was concluded that the results obtained from the two modes of data collection were comparable and reliable (Brečko and Carstens, 2006, p. 10). One of the most important issues is the level of dropout in Web-based questionnaires.

SITES2006 was a study that only used instruments at the school and teacher level. The sample sizes for these categories of respondents are usually relatively small in WISCEAs, and hence, the efficiency profit is much less than when ODC can also be used for students in those assessments that administer tests or questionnaires or both to students. The feasibility of using ODC for large-scale student assessments still needs to be explored.

Data Entry, File Building and Data Processing

During data entry the answers from respondents are entered in data files, as a first step towards creation of international data files. A series of checking and validation steps are needed to produce international data sets that are ready for further processing and analysis. This process roughly takes half a year.

The purpose of data processing is to produce statistics that were already envisaged when conceptualizing and designing the WISCEA. These statistics may be as follows:

- Univariates and based on one variable (e.g., the percentage of students having a computer at home) or they are composed out of a set of variables (e.g., mean number of possessions (out of a set of ten) in students' homes)
- Bivariates – for instance, breakdowns of test scores for boys and girls, or correlations between two scores, e.g., the math-achievement score and liking-of-math-scale
- Multivariate, e.g., structural models that are fitted on the data

Data Analysis

The purpose of data analysis is in general to find answers to the questions stated for the study. Several types of questions can be distinguished:

- "Why"-questions – e.g., "Why are the achievement scores in certain countries low?"; "Why are the scores on emerging-practice indicators in some countries much higher than in other countries?"
- Questions about hypothesized relationships – e.g., "Is the availability of ICT related to the extent that emerging pedagogical practices are applied in schools?"
- Exploratory questions – e.g., "Which school factors are associated with the occurrence of emerging pedagogical practices?"

International descriptive reports of WISCEAs usually contain statistics that are useful for descriptive purposes, benchmarking and monitoring. The variables in those reports are often starting points for further analysing the data, e.g., the breakdowns of achievement scores by different groups of students, such as those having computers at home, low medium and high social welfare index, etc. Recently, first reports on WISCEAs (in particular the PISA-2003 and SITES2006 reports) also contain results of more in-depth analyses, by means of regression analyses or modeling techniques. For a comprehensive analysis the "behaviour" of a large set of variables needs to be taken into account, which is often done by fitting models to the data.

Finding appropriate models that fit the data well is a time-consuming process, which often takes place after the first descriptive WISCEA reports have been published. Examples of statistical programmes for modeling data are LISREL and AMOS (part of the SPSS package). As the data often have a multi-level character (viz., school-, teacher-, and student levels can be distinguished), so-called hierarchical linear modeling programmes are also frequently used.

Reporting

As argued earlier in this chapter, an important step in any WISCEA is the valuation of the results. WISCEA reports offer a rich variety of statistics that can help the participants to judge the results for their country. In WISCEAs this usually is a relative judgment; that is, country statistics are valued on the basis of comparisons with other countries. A danger in interpreting the statistics, in combination with the use of league tables, may be that too much of an atomistic approach is used (focusing on one or a few subject areas) rather than trying to value an education system from a holistic perspective.

Potential Outputs of ICT-Related WISCEAs: The Example of SITES 2006

The results of SITES2006 (Law et al., 2008) show that many educational systems initiated in the past decade (policy) initiatives to encourage and implement pedagogical reforms that should lead to schools meeting the challenges of the information society.

Often these pedagogical reforms are labelled as aiming for lifelong learning goals, characterized by more autonomous and student-centred learning, incorporated in real-world settings, fostering students' ability to set their own learning goals, applying information-handling skills and to plan, monitor and evaluate their own progress, and fostering students' skills for working in teams. Connectedness is another aspect of the reforms, referring to the provision of opportunities for students to learn from experts and peers outside the school (even from other countries), and to foster students' communication skills in face-to-face or online situations, or both.

However, in a number of countries the effects of these reforms are becoming increasingly a major issue for public debate about the future of education and the direction of the reforms. For example, in the Netherlands initiatives were taken for a parliamentary inquiry about the detrimental effects of educational reforms and to investigate the complaints of students, parents, universities and employers about the diminishing knowledge and skills base of students who leave compulsory schooling.

Another example is Denmark, where for many years an increased use of ICT in education and training has been part of an education policy aimed at pedagogical reform. In 1998, the SITES module 1 study showed a comparatively high presence of teaching and learning activities in lower secondary school in Denmark that could be labelled as reform oriented (focussing on student-centred, active, and autonomous leaning). But preliminary analyses of data from SITES2006 indicated that Danish school principals have become less inclined to a reform-oriented pedagogical vision. However, in most other countries principals are not losing interest in such reforms.

It seems that we are currently experiencing in a number of countries a transition period between traditional and reform-oriented pedagogical orientations in education. Characteristic of such a transition period is that in some education systems signals can be observed indicating a desire to move back to the "good old days".

These examples illustrate the relevance of regularly monitoring the status of pedagogical practices and the use of IT in schools, including how stakeholders such as principals and teachers think about and apply educational reform, in order to be able to inform policymakers about the direction in which their and other educational systems are moving.

Recommendations for Future ICT-Related WISCEAs

Over the past 50 years the interest among educational stakeholders in large-scale international comparative assessments that are used for monitoring educational quality has constantly increased. Testing student achievement in traditional subject areas such as mathematics, science and reading has reached a high level of methodological sophistication. However, new challenges that involve the measurement of the impact of educational reforms that are associated with the introduction of ICT in societies and education need to be addressed.

The focus in SITES2006 was based on the assumption that education in the twenty-first century has to reflect the changes in the society and the demands these changes put on the citizens and therefore on schools and teachers (and students). As a consequence, ICT in education has been studied in SITES from the broad perspective of the possible contribution and support that ICT may have in education reflecting the needs and the characteristics of the twenty-first century.

This broad thinking about education and ICT (i.e., beyond just focusing on infrastructure and ICT courses) can be found in many countries that are trying to make education relevant for the children in the twenty-first century. Examples of policy initiatives can be found in the country reports included in Plomp et al. (2003b, 2008) on "Cross-national ICT policies and practices in education". Non-governmental initiatives also are reflecting this thinking – for example, the Partnership for 21st Century Skills, an organization in the USA, focused on infusing twenty-first century skills into education with members from the business community, education leaders and policymakers (see also Anderson, 2008). All these sources emphasize that education in the twenty-first century has to and will be different from education in the past and that ICT will allow for an important set of approaches and tools to realize this.

Taking these changes in education into account, the following domains seem relevant for an ICT-related WISCEA:

- Curriculum goals and content: Balance between new and "traditional" goals and objectives; learning goals and the use of ICT; information literacy competencies in the curriculum.
- IT-supported learning processes: Use of ICT for learning (e.g., bringing real-world problems to the classroom, simulations, inquiry-based learning, one-to-one tutoring); digital information handling (e.g., accessing information resources, reflecting on quality of information); ICT supporting communication.
- Infrastructure and learning materials: ICT infrastructure available for teaching and learning; digital learning materials (in relation to "traditional" ones); trends in ICT (e.g., laptops in schools, virtual learning environments).
- Teacher: Background (training) and competencies; perceptions and beliefs about education, and importance, use and effects of ICT.
- Learner: Attitude and motivation towards learning and the use of ICT; background, especially out-of-school access to and use of IT; learners' information literacy competencies.
- School management and (policy) environment: Policy and support; perceptions.

Although these domains do have overlaps, in combination they may provide a complete picture of education in the twenty-first century and the use of ICT.

Reflections

Although the most prominent function of WISCEAs (also the ones that are dedicated to ICT) is the assessment of the status of educational processes and outcomes in each of the participating education systems, these assessments have, as argued by several authors (Plomp et al., 2003a; Husén and Tuijnman, 1994; Postlethwaite, 1999; Kellaghan, 1996; Howie and Plomp, 2006), a number of additional functions, such as the following:

- Monitoring, by administering the assessments periodically in order to examine changes over time and analyse the covariates of such changes.
- Accountability, by investigating to what extent investments in education have paid off.
- Theory development, by exploring which factors are associated with the differences in outcomes between countries and between schools and students within countries, taking advantage of the notion of "the world as laboratory".
- Raising awareness of stakeholders about the functioning of the education system, by offering a mirror to portray their own education system.

One may hypothesize that WISCEAs (amongst others due to the huge media attention) have stimulated over the past decades the perceived need among policymakers for evidence-based policy-making. This is a development that Black (1995) characterized as a move from "rhetoric to facts".

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Section 11

INTERNATIONAL AND REGIONAL PROGRAMS AND POLICIES

11

INTERNATIONAL AND REGIONAL PROGRAMS AND POLICIES

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Section Editor

When studying the literature about how to improve education, in particular, through the use of information technology (IT), a common conclusion is that IT could, or maybe even should, transform education and not just be integrated into existing educational structures (Patrick, 2005). IT in education should do more than only be an addition to existing educational programs. A main question is if and in what way policies to stimulate the use of IT in education are able to reach that goal.

IT is described in the beginning of this handbook as the container name for all kinds of information and communication technologies that are commonly available in the educational sector at the time of publication of this handbook. However, many authors prefer to use the abbreviation ICT (information and communication technology), or other descriptions and abbreviations such as e-learning, online learning, virtual learning environments (VLEs), and so on. In the chapters of this section, both abbreviations, IT and ICT, will be used.

The idea of using IT as a lever for educational change is not new (Bork, 1984). This has been advocated since the early appearance of computer technologies (Braun, 1980). From the perspective of using IT to enrich existing educational structures, being integrated within existent educational curricula or/and as a lever for educational change, different aspects have to be taken into account. The first issue to deal with is of course the technical implementation and the necessary technical infrastructure (hardware, software, telecommunications facilities, housing facilities). The pedagogical implementation has to deal with issues at three levels: the organizational (macro) level of educational structures and institutions, the curriculum (meso) level, and the didactical and personal (instructor/student) (micro) level. Finally, issues about the quality of education, the impact on educational outcomes, and cost effectiveness are of critical importance. However, the realization of such prospects has often, if not almost always, remained far behind expectations (Cuban, 2001). Most of these issues are discussed in previous chapters. In this section, the main question is how policy deals with these

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issues. What is characteristic and common in policy documents about IT and education of international and national organizations? Are there indications that certain policy measures are more successful than that of others? What aspects can facilitate success? Is it possible to identify the contribution of particular policy decisions to improving and optimizing a positive impact of IT in education? These are the core questions to be dealt with in the different chapters of this section.

The section comprises the following chapters:

11.1 Evolution of IT and Related Educational Policies in International Organizations
11.2 Comparative Policies for ICT in Education
11.3 ICT and Educational Policy in the European Region
11.4 ICT and Educational Policy in the North American Region
11.5 IT and Educational Policy in the Pacific-Asian Region
11.6 ICT and Educational Policy in the Latin American and Caribbean Region
11.7 IT and Educational Policy in the Sub-Saharan African Region
11.8 IT and Educational Policy in North Africa and Middle East Region
11.9 Policy from a Global Perspective

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11.1

EVOLUTION OF IT AND RELATED EDUCATIONAL POLICIES IN INTERNATIONAL ORGANIZATIONS

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Evolution of IT and its Potential Impact on Educational Policy

In their book, *Does technology drive history?*, Smith and Marx (1994) explore the idea of technological determination, arguing that the evolution of technology has a major impact on society. There is no doubt that the evolution of technology, and in particular information technology, has a profound impact on education. For example Section 9 in this Handbook, about Emerging Technologies, gives many examples of how technologies can influence educational practice. However, Smith and Marx also indicate that this determination can be varied, according to circumstances and situations. If, indeed, the kind of impact of IT on education was undisputed it would be clear how to use an educational policy to optimize its impact. Reality, however, shows that issues are more complicated. Nuances have to be put in perspective.

The relation between technology and education has a long history. Since the invention of the radio, arguments have been raised that technology was profoundly going to change education (Saettler, 1990). However, surveys of the impact of technology on education almost constantly indicate significant changes in the technical infrastructure of schools, but at the same time stop short of implying major pedagogical changes in education as a result of the inclusion of technology (Doornekamp, 2002). Although the deeper causes of these results are complex, one line of argument can help explain this phenomenon. Collis and Moonen (2001) argue that technology in schools is being used in two different ways. The first one is its use as a "core" technology, meaning that major activities in the teaching–learning process are based on that technology. In most schools, the "core" technologies still in use are the blackboard

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and the textbook, with the teacher in charge of a face-to-face teaching–learning process. Gradually, however, the core technology in schools is being replaced, or at least augmented, by computer technology. This can happen in different formats. In many countries computer technology is used by teachers and pupils in computer classrooms or laboratories; or by a teacher as a presentation medium (computer + projector; now often replaced by a digital school board); or by teachers and pupils to access networks and in particular the Internet; or by instructors and students using virtual or virtual learning environments (VLE), learning management systems (LMS), or similar systems with different names. The main driving force for this change or augmentation of the core technology in schools is the general technology push in society. The main argument is "You cannot not do it", referring to the fact that everybody else is doing it. Although the "official" argument may be related to a pedagogical reasoning (such as preparing students for the knowledge society), marketing and public relations arguments often play an important role in the decision making. Governments and other political entities are following this societal movement and define and implement policies to respond to these trends. Starting as a bottom-up movement in individual schools, the use of IT become a typical top-down movement translated into policy. The impact of the policy is mainly related to curriculum, organizational, and infrastructural issues within the schools.

However, and besides the use of IT as a core technology, there is a second way of using technology in schools. This is, as Collis and Moonen (2001, 2005) describe, its use as a "complementary" technology. The uses of technology as "complementary" can be very diverse: for example, as a tool for a specific activity, such as communication, searching in databases, graphic applications, and supporting creation of music or drawings. This is the area where new developments in technology, such as those made available through personal digital assistants (PDAs) and Web 2.0 tools and processes, offer many kinds of features, from digital photography and video, webcams, GPS, podcasting, wikis, and blogs to mobile telephony. These features include specific applications of using the Internet, such as using Google Earth in geography lessons. Many more applications can be expected in the future. Many of the examples in Section 9 of this Handbook could be categorized as using technology as complementary to the existing core technology in schools. Typically such uses appear as innovative teachers make use of the potentials and affordances created by new technological developments. It occurs through a typical bottom-up approach via pioneer teachers or even pushed by students. Often the approach is a technological solution for a pedagogical problem that could not, or could hardly, be solved without the technological approach, or because the available technology suddenly creates new pedagogical approaches which were not possible before, for instance, using Google Earth, or searching and surfing a wide collection of digital resources. The impact of the use of these kinds of technologies is basically related to the pedagogical approach within a school (sector) and specific didactics within subject–matter areas. Given the long history of diverse opinions about learning theories and derived pedagogical approaches, it is very unlikely that a general policy for the use of "complementary" technology can be formulated and accepted. In addition and because of the very fast (and continuing) evolution of technology applicable as complementary technology in education, it is almost impossible for a government or other institutional bodies to develop and implement a policy for the use of complementary technologies.

This distinction between technology as core or complementary can help to better understand successes and challenges for an IT policy in education. From a logical point of view, the basic approach to implement a policy about IT and education should be to state as clearly as possible the objectives of the policy, and provide sufficient means and procedures for its realization, what Kozma (2008) calls strategic and operational policies. However, the rationality and arguments for such a policy will probably have to be limited to the application of "core" technology. As soon as a government tries to also provide policy suggestions about using technology at the "complementary" level, it will unavoidably come into conflict with the particular pedagogical and didactical approaches used by schools and individual teachers, with their broad diversity and differing motivations. Only when the use of technology moves from the complementary aspect to a more core aspect, can a general policy become successful.

The second part of this introductory chapter will deal with how international organizations are dealing with the issue of defining and stimulating policies for the introduction of IT in education. Such policies often assume a core technology role for IT, but in fact are applied to situations where IT is at best becoming a complementary technology.

An Overview of Policy Support by International Organizations

Many kinds of policies aimed to improve and optimize the impact of IT in K-12 education have been suggested at the national, regional, and international levels. At the international level, important international organizations have surveyed, developed, and stimulated the implementation of policies with respect to IT in education (UNESCO, 2005). For example, UNESCO has been organizing world congresses on IT and education (e.g., Paris in 1989 and Moscow in 1996) as anchor points for those involved with formulating policies of IT for education. UNESCO has also established in Moscow the "Institute for Information Technology in Education" (IITE, http://www.iite.ru/iite/about/mission). In addition, UNESCO regularly initiates projects to emphasize certain sectors or aspects of IT and education (e.g., the ICT in Education Policy project, stimulated by the UNESCO Bangkok office) and publishes series of reports (e.g., Anderson and Van Weert, 2002; Moore and Tait, 2002; and Resta, 2002, 2007), which should be seen as UNESCO's contribution to assist Member States in successfully integrating new technologies such as multimedia, e-learning, and distance education delivery in their educational systems. In these projects and reports, the terminology used for technology and its associated change aspects include open and distance learning, Internet and Web-based education, networked learning, informatics technology, information and communication technology (ICT), and e-learning. In addition, IT sometimes includes interactive radio, television, and hand-held electronic devices. This tendency to use terms relating to technology in an interchangeable way with terms relating to educational delivery and access, open and distance learning, as well as the substantial differences in the format of available technologies make the discussion about IT and policy difficult to synthesize.

On the other hand, models for implementation of IT in K-12 education often treat IT in a generic way. For example, in the publication by Anderson and Van Weert (2002, pp. 28–29) there is reference to a "matrix of indicators to determine a school's stage of progress in implementing ICT." The matrix mentions four stages of ICT development and eight characteristics of schools. The four stages are: emerging, applying, infusing, and transforming. The eight characteristics are: vision, learning and pedagogy, development plans and policies, facilities and resources, understanding of curriculum, professional development for school staff, community, and assessment. The UNESCO Bangkok office has published a series of "performance indicators" for IT in education, including indications of how to collect data in order to measure the performance indicators. One of the areas is "ICT-based policy and strategy." Some of these indicators are being used in the framework to be presented later in this chapter.

The World Bank is another international organization active in educational policy relating to IT in education and "works in partnerships with government and organizations worldwide to set up innovative programming and timely research relating to IT in education" through its World Bank Institute (http://www.worldbank.org/). The World Bank initiates projects, for instance the World Links for Development (Kozma, 2004), "to establish global, educational on-line communities for secondary school students and teachers around the world, in order to expand distance learning opportunities, enhance across nations, build broad support for economic and social development, and train teachers to integrate information technology into the classroom" (p. 362). The World Bank also publishes reports about "global trends and policies." A recent one gives an overview of trends in national e-strategies in 40 countries (World Bank, 2006). The World Bank, through its involvement in the Development Program (infoDev) (http://www.infodev.org/en/Topic.13.html), also supports research such as a detailed analysis of 17 ICT-for-development projects it had funded in the past several years to capture lessons about how, and why, such projects succeed or fail (Batchelor et al., 2003). The infoDev program has also published so-called Knowledge Maps about IT in education (http://www.infodev.org/en/Publication.8.html; http://www.infodev.org/en/Publication.156.html).

Complementary to reports on policies produced by international organizations, many reports have been produced by researchers, executing projects funded by local, national, or international organizations. As typical examples and only looking in the near past, there are reports on "Cross-national policies and practices on computers in education" by Plomp et al. (1996); "Cross-national information and communication technology practices and policies" by Plomp et al. (2003, 2008); "Users' views of new information technologies in education: studies from multiple nations" by Morales et al. (2001); and The u Teacher project, executed in the context of the e-learning initiative of the EU with reports about "European teachers toward the knowledge society" and "A common European framework for teachers' profile in ICT for education," both edited by Midoro et al. (2005).

Each of these organizations and reports contribute to and evaluate how policies about IT in education have evolved and had an impact in practice. Interesting, in this respect, is the approach worked out in the Knowledge Maps, published by the infoDev program. With respect to the policy issues, the following conclusions are mentioned in these knowledge maps. These conclusions refer, in the first place, to what are called less-developed countries (LDCs). However, they also reflect what is going on in other countries.

Some conclusions taken from the World Bank's Knowledge Maps include:

- While much of the rhetoric (and rationale) for using ICTs to benefit education has focused on ICTs' potential for bringing about changes in the teaching–learning paradigm, in practice, ICTs are most often used in education in LDCs to support existing teaching and learning practices with new (and, it should be noted, often quite expensive) tools.
- While impact on student achievement is still a matter of reasonable debate, a consensus seems to be that the introduction and use of ICTs in education can be useful to help promote and enable educational reform, and that ICTs are both important motivational tools for learning and can promote greater efficiencies in education systems and practices.
- Different parts of government are responsible for ICT in education policies in different countries**.** There does not appear to be a standard coordinating body responsible for the formulation of a country's ICTs in education policies. In some countries this is strictly the purview of the Ministry of Education (which may have a separate ICT in education policy, or fold ICT strategies into existing education policies), while in others it is handled by the Ministry of Science/Technology (if such an institution exists) as part of a larger technology or information policy, although in most cases there is no national policy at all.
- There is no database of existing policies. There is no standard repository for existing ICT in education-related national policies, although regionally the European Union has done a good job of collecting them for European countries' (see the Helios yearly report; http://www.education-observatories.net/helios), as has UNESCO-Bangkok and the Asian Development Bank in the Asia-Pacific region (see http://adb.org/Documents/Reports/ICT-Education-Training/ict-education-training.pdf).
- Successful policy requires consultation with a diverse group of stakeholders. It is believed that the formulation of successful policies related to ICTs in education must include not only the Ministry of Education, but also a variety of stakeholders from other government ministries, as appropriate (often this includes the Ministry of Finance, the PTT and ministries related to science/technology/IT, labor and rural development), communities and other civil society groups (including NGOs) and the private sector.

The main objective of this section of the Handbook is to identify policies that have been successful or have met serious challenges. International organizations have been investigating these issues and have come up with some conclusions. As an extra review of those conclusions and to find out if relevant differences occur between regions of the world, Chaps. 11.3–11.8 in this Handbook will investigate policies about IT in education for those different regions. In order to facilitate the comparison between the results in the regions, a joint structure and framework for the following chapters is presented in the third part of this introductory chapter.

A Framework to Categorize Educational Policies in Relation to the Introduction of IT

Besides policy suggestions formulated in internationally focused reports, almost every country in the world has, or will in the near future, establish a national policy on IT and education, explained in a "white paper" or described in a Ministry document, and often based upon preliminary research on already existing policies abroad. Given the participation of most countries in one or more of the many international or regional organizations, such as UNESCO, OECD, the European Union, or multinational organizations at the regional level, it is of no surprise that often policies chosen in individual countries have been discussed between politicians referring to policy suggestions made by organizations in which the individual countries share membership. As a consequence, policies in different countries often show some resemblance to each other, be it that the implementation of a policy, of course, depends on many kinds of internal conditions and circumstances.

When investigating national programs for the stimulation of IT in education, a typical shift can be found. In most cases, the first main policy interest is about aspects dealing with establishing the necessary technical infrastructure, often in combination with changing the curriculum to introduce aspects of "learning about IT," and often in combination with the setting up of training programs for in-service teachers to inform them about the technical aspects of IT. In most cases, depending upon circumstances and financial means, this phase works out quite well. In a second phase, the emphasis shifts to trying to integrate IT in the different subject areas, as a kind of augmentation to existing programs. The training of in-service teachers is focused upon developing new pedagogy and didactics to make good use of the potential of IT in the different subject areas. Many surveys about these issues indicate, regrettably, that this phase does not work out very well (Valcke et al., 2007). Earlier in this chapter, it was mentioned that the differences in use of technology as core or complementary play an important role in this respect. Integrating technology into the different subject areas implies that the pedagogical and didactical approaches of those subject areas have to be adjusted or even changed. Therefore a strong argument is often that the real potential of IT can only be realized when the educational system is transformed, creating the right affordances for IT to be exploited as it should. This could be accomplished in a third phase: transformation of the educational system. There are examples that have been tried in this direction. A typical example of this situation occurred recently in the Netherlands. In 1999, the Dutch Ministry of Education introduced the so-called "Studiehuis-approach" for the higher lever of secondary education (De Groot, 2004). The central idea was to make the organization of the school schedule and separations between subject areas much more flexible and at the same time provide infrastructural facilities in order to create circumstances for the optimal use of the facilities provided by the Internet. This could have been a good example of a "transformation" of the existing educational system. However, after 5 years the experiment had to be scaled down. The main reasons were the dissatisfaction of many parties (students, teachers, parents, universities) about the needed (extended) amount of time involvement in combination with the (disappointing) outcomes. This example illustrates (again) that educational change, or transformation, is a very complex process. The multitude of actors and factors playing a role in an educational system are very much connected to each other. They can be compared to the cogwheels of a watch: turning one wheel starts or follows the turn of many other connected wheels. Simply introducing IT in education to stimulate a transformation of the pedagogical/didactical approach of the system, disregarding the impact of such an intervention on many other aspects, is almost a guarantee for failure. This problem is the main challenge of a transformational policy with respect to IT and education.

Given the potential multitude of national policies, Chaps. 11.3–11.8 in this Handbook can only refer to "typical" policies in the different parts of the world. It is obvious that it is not advisable to try to describe the policies of every nation. Not only because there are often reports available that cover most of the countries of a region (many of these are referenced in the following chapters of this section), but also mainly because it is the intention of this section to arrive, within a limited amount of pages, to a global and comprehensive overview of existing policies. In the previous part of this chapter, reference to the influence of international organizations on the policy of member states has already be mentioned as an explanation for the existence of comparable policies. From that perspective, the chapters of this section have been chosen to describe issues and trends in the IT-related educational policies in the major continents and regions of the world. This choice was made as it can be assumed that, beside comparable aspects of a policy, specific economic and cultural influences can have a dominant impact on how policies in education are being formulated and put into a global timeframe. In that respect the following regions were chosen: Europe, Asia-Pacific, North America, South America and the Caribbean, Sub-Saharan Africa, and the Middle East and North Africa.

The organization of the regional-analysis chapters (Chaps. 11.3–11.8) is based upon the following global structure:

1. *Socioeconomic, educational, and cultural context*

In the introduction of the chapter the socioeconomic system and the educational system of the region and their interaction will be, in a global way, described. The main idea of this first part of the chapter is to get a good background picture of that region. The diversity of the technological, pedagogical, and cultural situations in a region has, most probably, a profound impact on what kinds of policy can be possible.

2. *Rationales and influencing factors for a policy about introducing IT in education*

Assuming that in each region there will be more similarities than dissimilarities, a kind of common set of objectives for IT as part of educational policy will be identified. The basic reasoning is to find out, if possible, if lessons learned in practice outside of a local setting have any influence on formulating a policy or on decision makers in the local setting.

3. Specific policies about the introduction of IT in education

Using a common two-dimensional framework, a global and comprehensive overview of specific policies in a region can be indicated. Table 1 shows the common framework with a sample of countries positioned within it. Rows and column categories are a combination of indicators used in documents published by UNESCO (1989, 1996). The column categories are based, with some addition and specification, on the stages mentioned by Anderson and Van Weert (2002). They globally coincide with categories identified by UNESCO and based upon a situational analysis of IT integration into the educational system: (a) countries with no specific IT in education policy or plan, (b) countries that are either in the stage of developing their policies but are not implementing them yet, (c) countries that have been applying policies for 3 years or more, and (d) countries which are already integrating IT into education in an advanced way. The row categories were also identified in another UNESCO document about performance indicators for IT for education (http://www.unescobkk.org/index.php?id = 1092).

The information in this table is only an example of how the table could be used (not based upon facts). In the following chapters the cells will not be filled by individual countries but by categories of countries reflecting a similar policy.

4. Reflections and future steps to improve the introduction of IT in education

Based upon the reflection in the previous part of the chapter, challenges/problems and success factors of IT policy in education can be mentioned reflecting on the fit between the intentions of policy and the realities of implementation.

Thus in Chapter 11.3–11.8 of this section, the authors will describe how in their respective regions, governments have dealt with the creation of policies to introduce IT in their schools. Some authors will argue very strongly that "transformation" of the educational system is necessary in order to create a real chance for IT to have an impact. On the other hand, the surveys in the chapters will indicate that such transformation is, at this moment, hardly happening.

First, however, a chapter about comparative policies for IT in education will highlight, in more detail, issues of importance in this area. And in Chapter 11.9 of the Handbook conclusions about challenges, opportunities, and success factors will be presented and discussed.

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Table 1 Abbreviations of countries: NL (Netherlands), BU (Bulgaria), IT (Italy), SL (Slovenia), SW (Slowakia)

	No policy yet	Emerging policy	Applying policy	Infusing policy	Transforming education by policy	Definition
National/subnational policy document for IT in education		BU	SL	NL		A policy document which provides for the mandate, goals, objectives, strategies and activities, organizational structure by the government (Ministry of Education) regarding IT use in education
Master plan with a time frame			SL	NL		A blueprint which transforms the policy into action as scheduled including who, what, where, when, how to achieve objectives
Budget plan and appropriations				NL		Budget allocations as included in the national and subnational or local budgets. It also looks into other sources of funds apart from government funding
Organizational structure responsible for implementing the master plan				NL		Refers to organizational structure with item positions, job descriptions, and salary scale either as a department, unit, or sector in the ministry with the primary function of implementing policy of IT for education based upon master plan. This structure could either be permanent, subcontracted agency, or a committee

(continued)

Table 1 (continued)

	No policy yet	Emerging policy	Applying policy	Infusing policy	Transforming education by policy	Definition
Monitoring and evaluation scheme or mechanism				NL		Detailed plan to monitor and evaluate progress of implementation of activities based on master plan as evidenced by monitoring and evaluation schedules, instruments, plan of data gathering and analysis of monitoring and evaluation data and presence of reports
Statement of inclusion of women, minorities, and those with special needs in IT policy			IT			A special statement in the IT policy on education for inclusion of these special groups
Manner by which the country and schools implement IT for education if no IT policy exists		SW				Often, countries are implementing IT activities or projects and using ITs in schools even if there is no national IT educational policy
Definition	No policy	Governments are thinking about it or planning it	Small scale (more or less ad hoc or on a small project basis) implementation	Large scale (in a planned systematic way) implementation	Implementation is transforming fundamental structure of education	

Country data are fictive, for illustration purposes only. See Ch. 11.3–11.9 for actual data.

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11.2

COMPARATIVE ANALYSIS OF POLICIES FOR ICT IN EDUCATION

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International Significance of ICT Policy

As we enter the twenty-first century, there has been considerable international attention given to the role that ICT can play in economic, social, and educational change. This role has been most pronounced in the world's developed countries, where technology has permeated businesses, schools, and homes, and changed the way people work, learn, and play. The impact that ICT has had to date in the developed world, and the potential yet for further dramatic changes, is reflected in a range of multinational policy documents. For example, the leaders of the world's eight major industrialized democracies (G8 Heads of State, 2000) have noted that ICT has become an engine of growth for the global economy and has the potential to contribute significantly to sustainable economic development, to enhance public welfare, to strengthen democracy, to increase transparency in governance, to nourish cultural diversity, and to foster international peace and stability. At the same time, the group emphasizes the need to develop human resources capable of responding to the demands of the information age and to nurture ICT literacy and skills through education, training, and lifelong learning. The Organization for Economic Cooperation and Development (2001, 2006) also emphasizes the economic importance and impact of ICT in developed countries and points out the need for these countries to develop a workforce with the skills to use ICT to increase productivity, as well as the need for young people to develop ICT skills in preparation for adult life.

But it is not only the leaders of developed nations who stress the importance of ICT. The United Nations and the World Bank both advocate the use of ICT to support the development of the world's poorest countries. A World Bank (2003) report cites the potential that ICT has to improve efficient delivery of resources to the poor, to bring markets within reach of rural communities, to improve government services,

J. Voogt, G. Knezek (eds.) *International Handbook of Information Technology in Primary and Secondary Education, 1083–1096*.

and to transfer knowledge needed to meet the Millennium Development Goals. The African Heads of State (African Union, 2004) concur citing the potential for ICT to promote trade, improve health care, enhance good governance, and make education more available. In this regard, the World Bank report notes that ICT can increase access to education through distance learning, enable a knowledge network for students, train teachers, and broaden the availability of quality education materials. At the World Summit on the Information Society, the United Nations (2005) notes the potential of ICT to expand access to quality education, to boost literacy, and to provide universal primary education in developing countries.

Much has been promised by multinational organizations for ICT to address the world's economic and social needs, especially in the area of education. But it is left to individual nations to deliver on these promises. National policies and programs can be an important tool for the realization of ICT's promise in education, and they are the focus of this chapter. The chapter presents a framework of alternative rationales and program components that can be used by researchers and policymakers to analyze, formulate, revise, and compare national ICT efforts. The framework consists of four alternative policy rationales – or "strategic" policy positions – and five components of ICT programs, or "operational" policies. Strategic and operational policies of various countries are used to illustrate these rationales and components. The chapter concludes with recommendations that countries can use when formulating or updating their educational ICT plans.

The Rationale for Strategic Policy for Educational ICT

National ICT policies can serve several important functions (Jones, 2003; Kozma, 2003a). Strategic policies can provide a rationale, a set of goals, and a vision for how education systems might be with the introduction of ICT, and how students, teachers, parents, and the general population might benefit from its use in schools. These strategic policies can motivate, change, and coordinate disparate efforts, so as to advance a nation's overall educational goals. Companion operational policies can set up programs and provide resources that enable these changes.

This is not to say that important things cannot happen without national policy. ICT-based innovation can and does occur in classrooms and schools without there being a close linkage to national policy (Jones, 2003; Kozma, 2003a). Also, there are often many ICT programs and projects sponsored by NGOs and corporations, apart from national policies and programs. But without the guidance of national policies and the resources of corollary programs, it is less likely that individual school and classroom innovations will be sustained. Nor is it likely that individual effects will accrue across a country to have an overall impact on its educational system. Similarly, without the shared vision of a national policy, the efforts of NGOs and corporations may very well go in divergent directions or work at cross-purposes, and their contributions to a nation's education effort are more likely to be marginalized or even neutralized. In brief, without a strategic rationale to guide the national use of technology in education, ICT policy is only operational. Policy becomes techno-centric, promoting the purchase of equipment or the training of teachers without providing a strong educational purpose or goal for the use of technology.

Strategic Educational ICT Policy Rationales

An analysis of national ICT policy statements identifies four alternative, somewhat-related rationales that are used to justify the investment of funds on educational ICT. These high-level statements can be thought of as “strategic policies.” Some strategic policies promote the use of educational ICT to support economic growth or promote social development. Some policies focus more specifically on the impact of ICT on the education system, either to advance education reform or to support education management.

Support Economic Growth

A particularly common rationale for investment in educational ICT is the role it can play in preparing a future workforce and supporting economic development. The key to this policy approach is an articulation of specific ways that the educational deployment of ICT can support these broad economic goals, lest the connections between the two be hollow platitudes. For example, a major economic goal for most countries is sustainable economic growth. Economists attribute such growth to increases in productivity, which can include the absorption of more-productive equipment, more skilled and productive workforce, and the creation of new knowledge (Stiglitz and Walsh, 2002). Corresponding education policies can connect the use of ICT to the development of students’ ICT skills, which can be applied in the workforce, to develop their capacity to use technology to solve complex real-world problems that can contribute to productivity, and to their development of new kinds of “twenty-first century” and lifelong-learning skills, which support knowledge creation, innovation, and entrepreneurialism in a “knowledge economy” (Kozma, 2005; Anderson, 2008).

Singapore exemplifies the use of this approach, where education policy has always been strongly linked to the development of human capital (Ashton et al., 2002; Lee et al., 2008). The most recent economic development plan in Singapore challenges businesses and workers to move beyond productivity gains resulting from the pervasive use of technology to the development of a knowledge economy, which relies on the development of new businesses based on research, innovation, and knowledge creation (Economic Review Committee, Singapore, 2003). In coordination with this economic plan, the Education Ministry instituted a number of reforms under the title “Learning to Think, Thinking to Learn: Towards Thinking Schools, Learning Nation” (Ministry of Education, Singapore, 2000). The country’s second ICT Master Plan, launched in 2002 (Mui et al., 2004) and updated in 2006 (Ministry of Education, Singapore, 2006), integrates ICT with changes in curriculum, assessment, instruction, professional development, and school culture to prepare them to participate in the country’s knowledge economy.

Jordan is another example of using an economic-based education ICT policy. Faced with persistently high unemployment and poverty, the government of Jordan created a program of economic and social transformation in 2001 to develop high value-added sectors and to establish a knowledge economy (Ministry of Planning and International Cooperation, Jordan, 2004). The top priority in this program has been the development of the nation's human resource. The Educational Reform for the Knowledge Economy was a program launched in 2003 in support of these human development priorities. In this regard, the Ministry of Education, Jordan, states the following:

> The ability of the educational system to develop and nurture creativity and innovation among learners [is] a cornerstone of an educational system that contributes to the development of a knowledge economy in Jordan. To do this, the educational system must itself be capable of nurturing an environment that encourages individuals to think in creative ways, innovate to solve problems, and capture what is learned and apply this within the wider system. (2005, p. 18)

To accomplish this, Jordanian education policy commits the ministry to reform curriculum so as to balance traditional subject matter with learning-process outcomes that make effective use of ICT and that engender knowledge creation and management.

Promote Social Development

Other countries have focused more on the potential social impact of ICT and governments have justified ICT investments with policies that promote their use to share knowledge, foster cultural creativity, increase democratic participation, make government services more widely available, and enhance social cohesion and the integration of different cultural groups and individuals with different abilities. Within education, socially oriented policies offer the prospect of connections between classrooms across cultures, increased parental participation, student access to specialized educational services, and the delivery of educational services to remote populations. As with the economic rationale, the key is to articulate specific ways that educational ICT can support these broad social goals.

The education policy of the European Commission is of this sort. The Commission's policy of "information society for all" (European Commission, 2000, 2004) emphasizes the need to bring every business, school, home, and citizen into the digital age. One goal of the policy is to promote digital literacy that would provide students with new skills and knowledge that they will need for personal and professional development and for active participation in an information-driven society. The policy also addresses ICT's contribution to learning, especially for those who, because of their geographical location, socioeconomic situation, or special needs, do not have easy access to traditional education and training. Through networking among schools, the policy promotes collaborative projects between countries and cultures that can contribute to improving intercultural dialogue, mutual understanding, and social integration across the Union.

Within the European Union, Finland illustrates a national policy that focuses on the social impact of ICT. In its economic, social, and educational policies, the government of Finland places a very high importance on collaboration and knowledge sharing. The Finnish Information Society Program envisions a society "in which knowledge and expertise form part of the culture and also the key factor in production" (Information Science Advisory Board, Finland, 2000, p. 5). The country's education policy is coordinated with this vision. As part of the Information Society Program, the Ministry of Education in Finland (1995, 1999, 2004; Kankaanranta and Linnakyla, 2004) developed the Information Strategy for Research and Education. The goals of this policy emphasize the need to develop information society skills among all students, the building of open education and research networks, and the development of educational information products and services.

The social impact of ICT is also, perhaps especially, a concern among less-developed countries. Chile, for example, has used its educational ICT policy to address the social inequities in the country. Beginning in the early 1990s, education policy in Chile began to address inequities caused by years of neglect and privatization under military rule (Cox, 2006; Cox and Lemaitre, 1999). These policies focused initially on educational improvements and ultimately on reform that extended the school day and the required period of matriculation, improved teacher quality, and provided better resources, particularly for the poorest-performing schools. A central part of this policy was the widespread introduction of ICT, the training of teachers in their use, and the development of an educational portal on the Web (Hepp 2004; Hinostroza et al., 2003; Laval and Hinostroza, 2002). Particular attention was given to ICT access for rural schools, most of which are attended by the nation's significant indigenous population, who have been traditionally underserved by the education system. Rural schools account for a third of Chile's schools, yet they are attended by only 10% of the country's students, often in one-room school houses, many without telephone access and some without electricity. As of 2004, 80% of the nation's schools had been equipped with digital resources and 55% had Internet access, as a result of the policy (Hepp, 2004). More specifically, nearly 2,000 (or more than 60%) of the rural schools have broadband Internet access; more than 90% of rural communities have Internet access through community information centers.

Advance Education Reform

Any major change in an education system can be, and often is, called *reform*. But here the term is used to refer to major curriculum revisions, shifts in pedagogy, or assessment changes. ICT can play a particularly important role in supporting education reform and transformation (Means and Olson, 1995; Means et al., 2004).

The kinds of education reforms that have been associated with the introduction of ICT include curriculum reforms that emphasize high levels of understanding of key concepts within subject areas and the ability to apply these concepts to solve complex, real-world problems (Bransford et al., 2000). Other curriculum reforms emphasize what are sometimes called "twenty-first century skills," qualities that prepare students for the knowledge economy, such as creativity, information management, communication, collaboration, and the ability to direct one's own work and learning (International Society for Technology in Education [ISTE], 2000; National Center on Education and the Economy, 2006; Partnership for the 21st Century, 2003, 2005; Resnick and Wirt, 1996).

ICT-related pedagogical changes treat the students as active agents who are engaged in collaborative projects that solve complex, real-world-like problems or in sustained investigations and interactions that generate new ideas by building on and extending the ideas of others (Scardamalia and Bereiter, 2006). The pedagogical role of teachers is to structure and support these practices by providing resources and explicitly modeling cognitive and social processes and prompting students to take up these practices (Blumenfeld et al., 2006; Bransford et al., 2000; Krajcik and Blumenfeld, 2006). Assessment reform emphasizes the need for continuous assessment that is integrated into regular, ongoing instructional activity and involves new assessment methods that include performance tasks and portfolio assessments (Mislevy et al., 2003; Pellegrino et al., 2001).

International studies have reported the use of these technology-based reforms in schools and classrooms in many countries (Kozma, 2003b; Pelgrum and Anderson, 1999). These ICT-based curricular and pedagogical approaches are beginning to appear in national educational settings around the world. For example, Australian schools and teachers are integrating ICT to support experiential, constructivist learning in schools and across learning sites; engage students in personalized, collaborative, connected, and interactive learning; and broaden and use new pedagogies and assessment approaches (Ministerial Council on Education, Employment, Training and Youth Affairs, Australia, 2006). Similarly, the South African education ICT policy document (Department of Education, South Africa, 2003, p. 13) states the following:

> Learning through the use of ICTs is arguably one of the most powerful means of supporting learners to achieve the nationally stated curriculum goals. In particular, the use of ICTs for learning encourages:
> learner-centered learning;
> active, exploratory, inquiry-based learning;
> collaborative work among learners and teachers; and
> creativity, analytical skills, critical thinking and informed decision-making.

Support Education Management

Some countries advocate the use of ICT to improve the management efficiencies or accountability of schools or the education system more generally. Consequently, these policies emphasize computer-based testing and the use of digital data and management systems. For example, the current educational ICT policy of the United States emphasizes the use of technology to efficiently deliver online content and assessments and to provide principals, teachers, and parents with student performance and attendance data that can be used to personalize instruction, support decision-making and the allocation of resources, and promote accountability (Department of Education, United States, 2004). Similarly, the educational ICT policy of Malaysia stresses the use of ICT to increase the productivity, efficiency, and effectiveness of education management through office automation and data analysis (Ministry of Education, Malaysia, 2003).

Multiple Rationales

These four policy rationales are not mutually exclusive. Indeed, a number of countries have used two or more of these rationales together in mutually reinforcing ways. For example, Singapore combines an economic rationale with an education reform one, arguing that by reforming the curriculum to provide students with learning skills, creative thinking skills, and communication skills, it will prepare a workforce of excellence for the future. Similarly, Finland has combined the social and economic rationales by claiming that the collaboration and knowledge sharing of the information society are key factors that support a highly productive economy.

Operational Components of ICT Policies

Although strategic policies provide a vision of a future enriched by ICT and justification for the often significant expenditures required to employ ICT, it is the operational policies that offer the hope that these visions can be realized. Operational policies – typically framed as action plans, programs, or projects – often consist of one or more of the following five components and these components can be used to analyze, compare, and formulate national policies.

Infrastructure Development

Operational policies often include a provision and budget allocation for technical resources that are needed to accomplish the nation's strategic goals. This is typically a policy emphasis in the early stages of a country's use of ICT in education. Such plans often include the amounts and type of computer and multimedia hardware that will be purchased, but they may also refer to resources related to television and radio, especially in developing countries. Increasingly, the Internet and local networking resources are also included, along with a budget for educational software (Quale, 2003). One example of an infrastructure development policy is that of Malaysia which has set the goal of supplying computers to schools at the ratio of one to every ten students by 2005 and one to every five students by 2010. At the same time, the government plans on supplying teachers with one computer for every five teachers by 2005 and one computer for every teacher by 2010. Infrastructure policies and programs may also address inequities in the current distribution of these resources. For example, Chile began distributing computers with its *Enlaces* educational ICT effort by first addressing the inequities that existed in the urban centers and then those that existed in remote rural areas.

Teacher Training

Teacher training is a key element to education reform, particularly training that focuses on classroom practices and engages teachers in a community of professional practice and development (Bransford et al., 2005; Fishman and Davis, 2006; McLaughlin and Talbert, 2001). Consequently, teacher professional development is an essential component of ICT operational policy, particularly those policies that connect with education reform. ICT teacher-training policies frequently spell out a specific set of skills that teachers are to acquire, as well as specify the duration of training. These skills are often operational ones. Especially in the early phases of ICT introduction, teachers need training in the operation of hardware, software, and, to some extent, networking. For example, the Enlaces program in Chile provided basic training to two thirds of the country's teachers by 2002 that consisted of e-mail, Internet, productivity software, and administrative uses. However, as the use of ICT progresses, teachers need more advanced skills in how to integrate ICT into the curriculum and into everyday classroom practice (UNESCO, 2008). For example, the purpose of the in-service training program in Finland is to provide teachers with the knowledge and skills needed to reform the pedagogical practices in their schools, especially with regard to collaborative teaching and learning, networking, and team work. Singapore starts by providing teachers with 24 hours of workshops on basic ICT skills, such as text applications, spreadsheets, and interactive digital resources, but then offers advanced training and resources for teachers in the areas of media and digital-resource development, technology planning and evaluation, action learning and research, and specialized ICT applications in humanities, mathematics, science, and languages.

Technical Support

Another important operational component is ongoing technical assistance, which teachers need not only in early phases of ICT use but also as hardware and networking technologies become more sophisticated and educational applications become more complex. Along with teacher training, assistance is needed to support teachers' operation and connection of hardware and software, as well as to integrate the use of ICT across the full range of curricular subjects. For example, Chile developed a collaboration between the Ministry of Education and institutions of higher education to provide both training and ongoing technical support to schools all across the country, including those in rural areas.

Pedagogical and Curricular Change

An especially important component of operational policies, particularly for strategic policies that promote education reform, is the articulation of ICT-related changes in curriculum, pedagogical practices, and assessment. For example, an important component of Singapore's reform was to create a better balance in the curriculum between the acquisition of factual knowledge and the mastery and applications of concepts, and the development of individual curiosity, creativity, and enterprise. Thus the curriculum was broadened beyond a set of core skills and values to include information skills, thinking skills and creativity, communication skills, knowledge-application skills, self-management skills, and character development. To develop these skills and attitudes, cross-discipline project work was introduced into the classrooms. Assessment was revised to measure students' skills in analyzing and applying information, thinking, and communicating. The plan also strengthened the connections between the school, the home, and the community, as part of a larger social-development plan that encouraged a more-active participation of citizens in community life.

Content Development

Some countries, because of the uniqueness of their curricula or special considerations of culture and language, find a need to emphasize the development of digital content as part of their operational policy. For example, the ICT program in Chile supported the development of *La Plaza*, a socially oriented educational portal organized as a community square that includes a post office (e-mail), information kiosk (digital content), and a cultural center (virtual collaborative workplace). The ICT program in Finland encourages the production of Finnish-language instructional materials on the Web, and this is now one of the business sectors that the government is nurturing as part of its economic-development program.

Policy Recommendations

The strategic and operational policy elements provided earlier can serve as a framework for the analysis and comparison of national policies. But there are particular substantive recommendations that can help policymakers use this framework to craft particularly effective educational ICT policies.

Policy Alignment

National ICT policies will have the greatest impact if they are aligned with other strategic and operational policies. This alignment is of three sorts: strategic-operational alignment, horizontal alignment, and vertical alignment. Alignment between strategic and operational policies assures that ICT programs and projects are directly tied to the nation's goals and rationale. For example, strategic policies that emphasize economic development should be matched by operational programs that use ICT to develop new workforce skills, not just purchase new equipment, and strategic policies that emphasize pedagogical reform should be aligned with ICT training that provides teachers with new pedagogical skills, not just new technology skills.

Horizontal alignment assures that ICT policies are consistent with other policies within the education system. For example, changes in ICT policies can both contribute to and benefit from corresponding changes in curriculum, pedagogy, assessment, and teacher training, and it behoves ICT policymakers within the ministry of education to coordinate their policymaking efforts with those in other departments. More generally, policymaking efforts in the education ministry can benefit from coordination with those in the ministries of economic planning, telecommunications, labor, and rural development. Often policy coordination of this sort requires the guidance of the highest-level policymaker, the minister of education in the first instance and the prime minister in the latter. Some countries constitute cross-ministry councils to guide and coordinate related policies with shared goals.

Vertical alignment refers to the coordination of policies up and down structural layers. That is, national policies should guide and be coordinated with those at the state, provincial, or local level. This will assure that resources allocated at the national level are appropriately applied at the state and local levels to have the maximum impact on schools and classrooms.

Distributed Policies

In some countries, educational policies may be the sole prerogative of the central government. In these countries, ICT policy may be formulated as a discrete policy statement within the Ministry (Department) of Education, such as that in Singapore. In other countries, it may be integrated into the overall national education policy, such as that in Malaysia and Chile, or it may even be embedded in the national telecommunications policy, such as in Egypt, where the Ministry of Communications and Information Technology leads the nation's ICT-based Egypt Education Initiative, in collaboration with the Ministries of Education and Higher Education (Ministry of Communications and Information Technology, Egypt, 2006). This sort of policy integration has the advantage of bringing more political weight and resources to bear on the effort. But to have maximum impact within the education system, the strategic and operational ICT policies need to be articulated in explicitly educational terms within the Education Ministry.

On the other hand, many countries have a federal political structure or a decentralized education system, where educational decision-making is vested in the states, provinces, or local districts or villages. In these situations, much of the above-mentioned discussion applies to policymaking at the local levels. But the national ministry or department can still play an important role. One possibility in these cases is for national ICT policy to be strictly operational, providing resources that support the general use of ICT, but make them available for use by local agencies according to their own strategic policies. Alternatively, national strategic policy can be formulated as a vision that guides local efforts, or it can be articulated in general terms to advance important countrywide economic and social goals, while leaving the local agencies to craft operational policies that accomplish these goals.

Policy Implementation

There are often huge gaps between policies and the changes in classroom practice that they are intended to affect (Cohen and Hill, 2001). Policies are articulated, but teachers are often not aware of the specifics of these policies or their goals. In turn, policies are implemented as programs, but often these programs are not effective in achieving change at the classroom level. A study by Cohen and Hill (2001) found that policies were most effectively implemented in classrooms where teachers had extended opportunities to learn policy-related materials. Rather than general reviews of policy statements or discussions of their implications, the most effective teacher-development experiences were concrete, content-specific, and instructionally useable practices directly connected to policy. Consequently, ICT policy implementation can best be assured when teacher professional development includes specific skills and tasks that incorporate ICT into their everyday classroom practices and explicitly connects these practices to ICT and broader education policies.

Private–Public Partnerships

The introduction and widespread use of ICT is an expensive proposition for any country. An important resource in this effort can be private–public partnerships. These partnerships can involve the ministry of education, along with universities, private NGOs, or private corporations. For example, the Ministry of Education in South Korea entered into an agreement with Intel to train a majority of the country's 400,000 teachers, principals, and professors in coordination with its ICT master plan (Intel, 2005). The World Economic Forum and its sponsors support ICT-based education reform in Jordan, Egypt, India, and Palestine (http://www.weforum.org/en/initiatives/gei/index.htm). Related to this effort, both Intel and World Links Arab Region (an NGO) are training teachers in Jordan, as part of that country's master plan. These partnerships can be particularly important in developing countries, where the demands for resources are significant and the available funds scarce. For example, the *Telefonica OCT Chile* supported the *Enlaces* program by donating telephone lines and unlimited Internet connections to schools, along with free e-mail accounts for teachers and students (Hinostroza et al., 2003).

Outcome-Oriented Policies, Programs, and Evaluations

The use of ICT in education constitutes a significant investment, and this requires a significant return in terms of learners served and the number of learners that become productive workers and citizens. Strategic policies should not only offer sweeping visions, but specific goals for how technology can advance economic, social, and educational development. Operational policies should not only provide programs and resources, but also describe how these visions and resources will impact the educational system with measurable outcomes. Policies and programs should call for indicators, monitoring, and evaluation plans by which these outcomes can be tracked (Wagner et al., 2005). Both process and outcome measures should be used to monitor the progress of policies and programs, and provide information to policymakers that can be used to revise and refine policies and programs. The implementation of monitoring and evaluation components will increase the likelihood that national ICT education policies and programs will indeed be implemented and benefit students, teachers, schools, the economy, and society, in general.

Resources

Policymakers can benefit not only from these recommendations but from a large collection of resources that can aid them in policy formulation and implementation. Among these are works that list the current ICT policies of other countries, such as *Cross-National Information and Communication Technology Policies and Practices in Education* (Plomp et al., 2003, 2008) and the *Meta-Survey on the Use of Technologies in Education in Asia and the Pacific* (UNESCO, 2003). UNESCO also has a policymaker's toolkit for ICT in education (http://www.infodev.org/en/Project.11.html) and a set of ICT standards for teachers(http://portal.unesco.org/ci/en/ev.php-URL_ID=25731&URL_DO=DO_TOPIC & URL_SECTION=201.html). And the infoDev program at the World Bank has a variety of knowledge maps, guides, and handbooks (http://www.infodev.org/en/Topic.4d.html) that can be most helpful. With these resources, policymakers can begin to craft and refine policies that can help ICT deliver on its promises.

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11.3

ICT AND EDUCATIONAL POLICY IN THE EUROPEAN REGION

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Socioeconomic, Educational and Cultural Context

Europe, as every other region of the world, is affecting – and it is affected by – worldwide social, political and economic trends such as globalisation (or the end of nation-states), the rise of the knowledge economy and society, the diversification of life and learning trajectories, changing skills and competences at work (Institute for Prospective Technological Studies [IPTS], 2005) and the ICT revolution (Leonie Consortium, 2005). However, there are some specific "European" trends that affect most of the continent. One could argue, despite national differences, that Europe is an "aging continent". This also implies potential shortfalls in the size and capacity of the workforce. Changes in the age structure of the population will affect every category of public spending to some degree. Three areas of public spending are particularly sensitive to demographic shifts: income security, health care and education. Therefore, pressure for reform on current education and training institutions as well as on the current European welfare systems is definitely a hot topic in the agenda of all European policymakers. Moreover, one could argue that some of the worldwide trends mentioned earlier have a European connotation. For instance, the globalisation or internationalisation process in Europe cannot be separated by the process of European integration.

The European Union (EU) is redefining how Europe is viewed by others and how Europe views itself. Economies are becoming tied together through the creation of a "common market" with the same rules and regulations. Having said that, there is no doubt about the fact that Europe is featured by very significant diversities. Europe is home to unity and dissent, prosperity and poverty, harsh climates and idyllic resorts. Despite the unifying effects of the EU, some areas of Europe continue to become more splintered because of people's war over lands and ideas. Yugoslavia has already split into five separate countries and tensions continue in Serbia-Montenegro. Tensions remain high in the Basque region straddling the Spain–France border. Northern

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Ireland has been a hotbed of dissent and violence. Flemish and Walloon peoples in Belgium continue to have tense relationships. Wales and Scotland continue the debate of the value of sovereignty apart from England.

It has been suggested that Europe is divided into four major regions based on environmental, cultural and economic similarities (United Nations Statistic Division, 2006). Eastern Europe consists of Belarus, Czech Republic, Estonia, Latvia, Lithuania, Moldova, Poland, Russian Federation, Slovak Republic and Ukraine. Eastern Europe also contains Balkan Europe, which includes the countries of Albania, Bosnia-Herzegovina, Bulgaria, Croatia, Hungary, Romania, Slovenia and Serbia-Montenegro. Western Europe, the industrial heartland of Europe, consists of Belgium, France, Germany, Luxembourg, the Netherlands, the Republic of Ireland and the United Kingdom. Also included in Western Europe is Alpine Europe: Austria and Switzerland. Northern Europe includes Denmark, Finland, Greenland, Iceland, Norway and Sweden. Southern Europe, sometimes called Mediterranean Europe, consists of Cyprus, Greece, Italy, Malta, Portugal and Spain.

However, there are several other cleavages that do not mirror this rough differentiation. One could mention, for instance, the differentiation between countries belonging or not to the Euro-zone (comprising at the moment 12 member states of the EU), or the subscribers of the Schengen treaty (Wikipedia, n.d.) of free movement of people (comprising some members of the EU and some non-members such as Norway) or could refer to different welfare systems, varying educational systems and so on. "Variable geometry" is often associated with the discourse about Europe.

This is also reflected in the field of e-learning policies, and before this, ICT-in-education policies. (It should be noted that in Europe the terms e-learning, eLearning and e-Learning are used interchangeably.) The chapter focuses mainly on the ICT-in-education policy of countries within the EU and the ICT-in-education policy of the EU itself. It is difficult to formulate remarks that apply to the whole of Europe, as first of all, there are definitely different starting points in Europe, with several European countries having national policies about ICT in education in the early 1980s. Focusing on the current situation, there are still considerable differences in the overall "e-readiness" of countries. Table 1 provides an overview of the prevalence of ICT across Europe. It demonstrates that different baseline levels of ICT infrastructure are still significant.

Different levels of ICT infrastructure and use are confirmed also by other research. According to the L-Change yearly report (L-Change Consortium, 2003), there are significant disparities in Europe with regard to the enabling contextual factors. Not only the baseline levels of ICT infrastructure are diverging, but also the arrival points, e.g., the implementation results of e-learning policies in Europe, are varying. It is difficult to identify mechanistic patterns. One may argue that a higher level of e-readiness might multiply the impact of e-learning policies, but on the other hand it might also lower the level of attention and the related resources of these policies in the agenda. The lack of new targeted ICT programmes in Denmark can be an example of this argument.

Moreover, positive contextual factors might be influencing policies and also the other way round. Another level of complexity is related to the actors involved in these policies. "In some countries, such as the United Kingdom and France, the state has

Table 1 E-readiness ranking, selected European countries (The Economist Intelligence Unit, 2006)

2006 Rank in region	2005 Rank in region	Country	Overall ranking (of 68)	E-readiness score (out of 10)
1	1	Denmark	1	9.00
2	3	Switzerland	3	8.81
3	2	Sweden	4	8.74
4	4	UK	5	8.64
5	6	Netherlands	6	8.60
6	5	Finland	7	8.55
7	7	Norway	11	8.35
8	8	Germany	12	8.34
9	9	Austria	14 (tie)	8.19
10	10	Ireland	16	8.09
11	11	Belgium	17	7.99
12	12	France	19	7.86
13	13	Spain	24	7.34
14	14	Italy	25	7.14
15	15	Portugal	26	7.07
16	16	Greece	29	6.42

a key role in setting standards and attainment targets shall be lifted through the use of ICT. Other countries (the Netherlands and Nordic countries) follow the approach of setting the overall goals and targets, but leaving more freedom and autonomy for schools" (Blamire and Balanskat, 2002).

The aim of the following sections in this chapter is therefore to provide an overview of ICT-related educational policies in Europe, taking into account this complexity. First of all, it presents an aggregate picture at European level, illustrating a shift in focus in the main objectives of these policies, from the initial techno-enthusiasm to the better awareness of the social, organizational and pedagogic implications in the implementation of e-learning-related policies. Main common trends, as well as some specific trends taking place in certain countries (or, as it is going to be argued, in certain clusters of countries), will be underlined. A particular emphasis will indeed be placed on the different baseline levels of readiness of different European countries and regions. This will be the main argument of the paragraph dedicated to the implementation matrix in the section Specific Policies About ICT and Education in the EU of this chapter. A critical analysis will conclude the chapter, pinpointing the main challenges and obstacles of ICT and education policy in Europe.

Rationales and Influencing Factors for a Policy About ICT in Education

Before providing an overview of ICT educational policies in Europe, there is a need to clarify what is meant by ICT educational policy. According to the definition provided by Kozma, ICT educational policy is "a rationale, a set of goals, and a vision for how education systems might be with the introduction of ICT and how students, teachers, parents, and the general population might benefit from its use in schools" (Kozma, 2008).

The rationale of ICT educational policies in Europe is definitely related to the transition towards the knowledge society (Anderson, 2008). As pinpointed by many observers, knowledge is the main vector of evolution of western societies and this has profound implications for ICT educational policies. The key role of education in the knowledge society has led to the sector enjoying the lively interest of policymakers in Europe and elsewhere.

At a conference of the European Council (of government leaders and leaders of state) in March 2000 in Lisbon the participants established the following strategic objective for the EU for the immediate future: "*to become the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion*" (p. 2 Presidency Conclusions – Lisbon European Council, 2000). Strategic objectives for education were subsequently proposed by the European education ministers and adopted by the European Council. Among these objectives, further specified in Barcelona in 2002, the importance of integrating ICT in modern education and training systems was emphasized in view of enhancing the quality, access and openness of European education and training systems.

In relation to the Lisbon strategic objectives, the European Commission has formulated the eLearning Initiative (European Commission, 2000), followed by the eLearning Action Plan (2001–2004) (European Commission, 2001), which sets out the need for new approaches to education and training and continued development of quality multimedia contents and service. At that time, many European countries had started to develop an e-learning strategy or already had an established strategy for ICT in education (eWatch Consortium, 2002), also in the framework of e-Europe (European Commission, 2002).

For instance in Germany, in 2000, the Federal Ministry for Education and Research (Bundesministerium für Bildung und Forschung launched the initiative "New Media in Education", targeting schools, universities and vocational training (Federal Ministry for Education and Research in Germany, 2000) with the objectives to develop infrastructure, content and competences. The Italian Action Plan for the Information Technology Society (2001–2003) had similar objectives, including an emphasis on renewing school organisation and management and fostering pedagogical innovation (Ministry for Technological Innovation, 2001). The Finnish strategy "Education, Training and Research in the Information Society, the National Strategy for 2000–2004" (European Schoolnet, 2004) also shared these goals but also included a reference to virtual schools and virtual universities. In the UK, the Department for Education and Employment launched three major programmes aimed at further exploiting ICT in education, as part of the overall strategy for Lifelong Learning and developing the UK into a Learning Society. These were the National Grid for Learning, the University for Industry and the UK e-University.

In several countries dedicated departments within the Ministry of Education or dedicated governmental agencies, such as the National Centre for Technology in

Education in Ireland, were established (http://www.ncte.ie/), in many cases building upon earlier agencies or centres for ICT in education.

Despite different formulations and some national specificities, a pattern can be identified in these policy statements. A key word in the "first-generation" policy statements was certainly "integration", especially in terms of growing convergence among European countries in view of the Lisbon process, based on the "open method of coordination". However, despite these attempts of integration, the focus of the "early days" strategies, including those of several European countries in the 1980s, was to a great extent on infrastructure development. For instance the L-change research on indicators of e-learning development (L-Change Consortium, 2003) demonstrates that the attention of policymakers and e-learning stakeholders has been very much on ICT penetration and infrastructure at the beginning of policy development within many of the nations in the region. The "pupils per computer" rate was typically the main success indicator of early ICT-in-education or e-learning policies. There were claims to tackle other complementary measures such as e-skills of learners and learning facilitators or content development. However, "in many other EU countries they were either disproportionally smaller in terms of investment, or not synchronised (usually late, but sometimes early) in relation to the availability of technology in schools." (eWatch Consortium, 2002). Moreover, users' needs and concerns were generally not systematically identified, analysed and addressed in these strategies. The failure of the UK e-University (Wikipedia (n.d.) was a paradigmatic example of the lack of a real consideration of users in the mainly top-down policy strategies.

Specific Policies About ICT and Education in the European Union

With specific regard to EU policies, the e-learning initiative has been followed by the eLearning Programme (European Parliament and Council, 2003) for 2004–2006, which is, according to the European Commission, a further step towards realising the vision of technology serving lifelong learning. It focuses on a set of actions in high priority areas, chosen for their strategic relevance to the modernisation of Europe's education and training systems. The four action lines of the eLearning programme are as follows:

- Promoting digital literacy
- European virtual campuses
- e-Twinning of schools in Europe and promotion of teacher training (http://www.etwinning.net/ww/en/pub/etwinning/index2006.htm)
- Transversal actions for the promotion of e-learning in Europe (European Parliament and Council, 2003).

Other EU-funded programmes have financed initiatives aimed at promoting ICT for learning.

The Socrates programme has a specific line, Minerva, (European Commission, 2004a) specifically dedicated to open and distance learning (ODL), and the educational use of ICT. The vocational training programme Leonardo da Vinci

(European Commission, 2004b) supports many projects that make extensive use of ICT for training purposes. The EU's VI Framework Programme for Research and Technological Development is also supporting research on the contribution of information society technologies to innovation in education and training through its Technology Enhanced Learning Strategic Objective (European Commission, 2005).

Many European countries have also a fully deployed policy and a set of initiatives dealing with ICT educational polices (Euser Consortium, 2004; Gerhard and Balanskat, 2006). A shift in focus can be observed in these "second-generation" policies. Although "*It cannot be said that the technology infrastructure and access problem is now solved in Europe*" (eWatch consortium, 2002, p. 75), especially in the new member states, the focus nowadays is not any more on infrastructure but on the necessary complementary measures such as teacher training, competence building, content development and other measures that can ensure real qualitative development. Along these lines, the Finnish Ministry of Education has launched in 2002 a national program called OPE.FI (http://www.ope.fi) in order to improve the ICT skills of the in-service teachers and teaching personnel. The German initiative Bildungswege in der Informationsgesellschaft (http://www.big-internet.de/) aims to improve the capacity of judgement, to increase sensibilities with respect to value judgments in the use of new media, to develop new forms of teaching and to help increase the quality of studying and lecturing.

Moreover, policies are evolving to an approach in which "ICT per se is losing emphasis in favour of the benefits that ICT can offer to the pressing needs of society and economy. Innovation, competitiveness and inclusion become thus main foci of ICT for learning in general" (IPTS, 2005, p. 22). e-Learning is usually addressed – directly or indirectly – within broader policies and initiatives concerning the following: information society development, e-skills, lifelong learning and continuous training, digital literacy, innovation for growth and competitiveness, and employment strategies. This means also that there might be some developments enabled by ICT that are not any more classified as "ICT-related". For instance, in Sweden "only just over a third of teachers participate in developments described as related to ICT but over 80%, much more than in any other country, participate in other forms" (OECD, 2004, p. 30).

The early-days claims of integration have been refocused in many senses and at different levels, e.g.:

- Integration of ICT into learning systems and learning practices
- Integration of ICT educational policies with other policies (R and D, social inclusion, employment)
- Integration among sectors of learning systems/disciplines enhanced by ICT
- Integration of groups at risk of social exclusion in the Knowledge society
- Integration of the eLearning discourse into the lifelong learning agenda (Helios Consortium, 2006)

Another significant development of ICT-related policies for education concerns the increased availability and dissemination of practices, which actually poses a problem of mainstreaming innovation.

However, the widening of the perspective of ICT educational policies has not corresponded to a higher place on the agenda for these policies. Evidence for reinforcing this argument is the lack of explicit reference to e-learning in several EU-level and national educational policies (ODL Liaison Committee, 2004). For instance, in the proposal for the new integrated European programme for lifelong learning after 2007, the disappearance of a specific action dedicated to e-learning in favour of a generic reference to learning innovation within a transversal action is emblematic.

In fact Key Transversal Activity 3 of the above-mentioned programme, crossing the sectoral lines of the Comenius, Erasmus, Leonardo da Vinci and Grundtvig programmes, focuses on "*experimentation with the generalisation of innovative approaches to teaching and learning (e-Learning) with respect to new pedagogy, services, technology and content*" (European Parliament and Council, 2006, p. 7).

This is not only a terminological problem, but also a substantial one. A EUN thematic dossier states as follows:

> The curve of political priority for the integration of ICT in education, whether it was considered a banner issue or not, has passed its peak and is on the decline in a considerable number of European countries. In Denmark for example, despite having been an outstanding early-starter in the integration of ICT in schools and being renowned for its work in training teachers in ICT integration in classroom practice, no specific new, targeted ICT programmes are planned. (McCluskey, 2006, p. 1)

However, as mentioned earlier, despite the "early days" ambitions of integration, the picture is still rather fragmented because of different starting points and varying degrees of implementation.

In this rather-fragmented picture, is it possible to draw some generalizations with specific regard to e-learning policies in the European region? Most of the efforts to compare e-learning policies in Europe attempt to compare European countries by clustering them into "groups of alikes". For instance, the above-mentioned L-Change report defines a cluster of high-performing countries (including Denmark and UK as two examples); another as intermediate (including Germany, Spain, France and Italy); and a cluster of low-performing or "delayed" countries, also with regard to e-learning policies (including, for instance, Greece and some new member states, such as Romania) (L-Change Consortium, 2003).

Along similar lines, the study "The use of ICT for learning and teaching in initial vocational education and training, November 2005" (Ramboll Management, 2005) has categorised the EU member states into three categories (front-runners, the middle group and beginners), also in terms of e-learning policies implementation (but not focusing exclusively on that). The front-runner countries are typically characterised by a high degree of e-readiness, specific strategies concerning the use of e-learning, and many institutions that are co-operating with private partners or other institutions. The frontrunner category includes Austria, Finland, Sweden, Denmark and the UK. The middle group consists of Germany, Ireland, France, Netherlands, Belgium and Luxembourg. This study also affirmed that new member states are confronted with challenges similar to those facing the old member states belonging to the middle and beginner groups.

Also the Helios Consortium's yearly report "Evolving e-learning" (Helios Consortium, 2006) carried out a comparative analysis of European countries' e-learning policies and practices and explored the possibility of clustering European countries into "high-performing", "average-performing" and "delayed" countries. However, it does not formulate judgements on the classification of each state to a cluster or another. This seems to be a promising approach when it comes to comparing the degree of implementation of different European countries in relation to the UNESCO matrix of performance indicators to be applied to ICT educational policies used in the regional chapters of this section of the handbook (Khvilon and Patru, 2004; Moonen, 2008).

In our view, it is indeed possible to describe the degree of evolution of e-learning policies in Europe. However, the reliability of the exercise can be improved if it refers simply to clusters of countries and not necessarily to specific countries, as it is not easy to provide a grounded judgement on the classification of each country to a certain cluster for each of the dimensions proposed in the matrix. Therefore, the matrix shown in Table 2 proposes the relative positioning of high-performing countries, average-performing countries and low-performing countries in Europe with regard to the analytic dimensions proposed.

Reflections and Future Steps to Improve a Policy About ICT in Education in Europe

With regard to the achievements so far of European e-learning policies, one could mention the following:

– A strong mobilisation effect of national authorities, higher education, industry and several other stakeholders, which was mainly achieved at the beginning of the period considered here, i.e., from the late 1990s to 2004–2005, when the rhetoric of ICT in education and later, e-learning, was still strong.
– Massive networking activity at the European level, thanks to the fact that projects containing e-learning elements were actually supported, not only, of course, within the eLearning Action Plan and the neighbouring MINERVA Action of the SOCRATES Programme, but also in other EU-wide programmes such as Leonardo da Vinci, Grundtvig, LINGUA, Erasmus and IST. Even in European initiatives such as EQUAL and in the Cooperation Programmes of the EU with other parts of the world e-learning has gained some room as a result of the early years' mobilisation. More information about these EU programmes can be found at http://ec.europa.eu/education/programmes/socrates/socrates_en.html
– A substantial contribution to the evolution of the rhetoric of e-learning away from just computers, connectivity, competitiveness and cost-effectiveness, and towards content, context, collaboration and learning communities, thus facilitating the integration of e-learning and ICT in the processes of endogenous innovation of education and training systems.

Table 2 Comparisons of categories of European countries on policy dimensions for ICT in education

	No policy yet	Emerging policy	Applying policy	Infusing policy	Transforming education by policy
National/sub-national policy document for IT in education			LP	HP, AP	
Master plan with a time frame			LP	HP, AP	
Budget plan and appropriations			LP, AP	HP	
Organizational structure responsible for implementing the master plan		LP	AP	HP	
Monitoring an evaluation scheme or mechanism		LP	AP	HP	
Statement of inclusion of women, minorities and those with special needs in IT policy			LP	AP, HP	
Manner by which the country and schools implement IT for education if no IT policy exists			LP	AP, HP	

HP high performing, *AP* Average performing, *LP*, Low performing

– As a result of EU and national initiatives, a wealth of new R and D results and developments have become available, not necessarily in the way politicians were looking forward to, but they led to the formation of an increasingly professionalized community, a factor undervalued by some political comments (ODL Liaison Committee, 2004).

However, there are still several interrelated challenges for ICT-related educational policies in Europe. Despite the abundant references of lifelong learning in the policy discourse, the following might indeed be true:

– E-learning has not reached the majority of learning facilitators. If, on the one hand, the "innovation champions" within private and public organisations are now much more aware of e-learning potential "at certain conditions", on the other hand, those who were resisting e-learning from inside the education and training systems have had the time to build their case against it (ODL Liaison Committee, 2004). Moreover, how many non-conventional pedagogic paradigms, for instance, have been able to dialogue with and enter strategically into e-learning? Ultimately, along the lines of Patrick (2008) in this section, on North America, to what extent has education been transformed because of ICT? These questions have not been tackled enough by ICT educational policies so far.
– E-learning has not convinced the majority of learning investors, as those who were betting too much on e-learning growth have learnt that its uptake is more complex than expected.
– E-learning has not reached the majority of "learning divided", i.e., the digital divides, those people who do not have access to ICT-based learning provision since they do not have access to ICT (Cullen, 2005).
– E-learning has not reached the "learning resistant", i.e., those people who are not motivated to use ICT. In particular, it has been underlined that e-learning has been so far more suitable for self-disciplined, mature, independent, experienced learners who are also willing to ask for help (which requires self-awareness) (Aceto et al., 2004).

These challenges can be related to the difficulties of current European e-learning policies. Despite significant national specificities, common patterns of difficulties can be identified. First of all, as mentioned earlier, EU-level policies but also national policies in member states have reduced the amount of resources attributed to e-learning. Probably most decision-makers involved in these bodies, understandably, have very little personal experience of e-learning or the use of ICT in learning and fail to appreciate the full potential of ICT, or do not clearly perceive the benefits of it. If we go beyond a superficial criticism of this lack of understanding, we will probably find visions of the world (Boltanski and Thévenot, 1991) and rooted values that made, and still make, a large number of educational policymakers, managers and teachers resistant to the initial rhetoric of e-learning, because this rhetoric was expressed by simplified visions and over-optimistic statements on the virtues of ICT in learning. In our view this "visions and values" tension has had the practical result of the interruption of a dialogue that, a few years ago, was starting.

Moreover, in many cases there is a lack of systematic consultation by decision-makers at different levels in the policy-making process of the professional environment of open and distance learning, and eLearning. In several European countries many actors at different levels (regional, local, national, public, private, partnerships) are entitled to promote e-learning policies. Therefore, despite the claims of integration, it is not rare to experience duplications of initiatives and fragmentation of resources. Additionally, the unbalanced emphasis, especially in the first period of policy, on European competitiveness rather than equity and inclusiveness should be mentioned. This has been corrected in the more recent phase, at least in the declaratory policy statements, but produced reluctance in the educational community to join the promotional messages on eLearning (Aceto et al., 2004).

Finally, there has so far been too much focus on formal education as opposed to post-initial, non-formal and informal learning, wherein the use of ICT may be integrated without facing a strong institutional resistance or at least inertia. There is a need, in Europe as elsewhere, for "*more political attention on these emerging bottom-up phenomena in the use of technology – often leading to informal and non formal learning experiences often as valuable as formal ones in terms of skills development and knowledge building and sharing*" (Helios Consortium, 2006, p. 101).

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11.4

ICT IN EDUCATIONAL POLICY IN THE NORTH AMERICAN REGION

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Educational and Cultural Context

In a globally competitive world, many countries are centering their education improvement strategies around e-learning. In North America, over the past 10 years, the United States has connected virtually every school building in K-12 education to the Internet (US Department of Education, 2005). Virtual schools in the United States have tremendous annual growth rates for enrollments (from 50,000 in 2000 to more than 500,000 in 2005) (North American Council for Online Learning [NACOL], 2007; North Central Regional Education Laboratory [NCREL], 2005; Roblyer, 2008). Mexico has digitized its entire K-12 educational content and curriculum. Mexico's initiative to provide every teacher with a laptop computer and training on digital content is changing the way teachers are trained in colleges and universities (Secretaría de Educácion Pública [SEP], 2004). Canada is developing digital curriculum and instructional models to spearhead online learning programs across vast rural areas and increase access to quality education for all students (Council of Ministers of Education, Canada, 2003).

Throughout the North American region, new, twenty-first-century models of education marked by personalized and individualized instruction, using formative assessment, providing feedback to instructors and students in real-time, connecting information from schools into the homes, and supplying fresh, accurate data for decision-making in the classroom and board room are made possible by online learning, providing a torrent of information in a digital environment. The focus for information and communication technology (ICT) in schools is shifting from devices to processes. Infrastructures with ubiquitous computing, wireless, high-speed networks and digital platforms, or learning management systems, support increased mobility and flexibility and are necessary drivers of a new delivery system of education powered by online learning. Important areas of investment are digital curriculum

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and instruction as new teaching models are emerging in a networked, collaborative, communicative world. The online environment will help transform schools, restructure outdated processes, and help realize the promise of technology in education.

Despite similarities in this context, it is important to note the education policy paradigms that dominate each country in North America. The United States constitution does not provide authority for a federal education system. Instead, schools are managed locally by school boards in 15,000 school districts under guidance of policies set at the state level. The United States established a federal Department of Education in 1980 to provide more funding equity to poorer schools with the goals of providing better access to excellent educational opportunities. With a budget of $61 billion in fiscal year 2005–2006, the federal government's contribution to elementary and secondary education is only 7–8% of total spending (US Department of Education, 2007). It is important to note that the US federal government provides a larger proportion of technology funding for schools, providing as much as 50% of the ICT spending in education in districts across the nation, indicating how important the national role is in providing ICT in schools.

In contrast, Mexico has a federal system of education that is centrally controlled and managed by the Ministry of Education. The Ministry of Education in Mexico sets all educational policies from academic standards, ICT programs, and teacher training, and provides funding for schools. This has enabled Mexico in the last several years to digitize their entire K-12 educational content and curriculum and make it available to all schools, community technology centers, and libraries (SEP, 2004).

Canada also has no constitutional authority for educational power at the national level. In addition, there is no federal agency equivalent to the USA's Department of Education. The absence of a national educational department in Canada means that national ICT efforts are coordinated through provincial governments. Larger implementations are coordinated around connectivity initiatives and rely on provincial governments to provide leadership in each region (Council of Ministers of Education, Canada, 2003).

Specific Policies About ICT in Education

The powers in charge of educational policy vary across North America and change comes slowly depending on how strong a locus of control is in a particular country. The locus of control for teaching, content standards, and governance varies markedly in each of the North American countries. The specific policies and their implementation reflect this across the North American region.

United States of America

The United States Congress created a federal Office of Educational Technology (OET) in 1996, within the Department of Education to maximize effective use of ICT in schools. Since then, the federal government has taken a central role in funding, coordinating, and researching the effective use of ICTs in education (OET, n.d.). While there are 50 individual states and more than 15,000 school districts setting independent policies, the federal government's efforts to provide a national vision, backed by funding and policy guidance, have led the way in enhancing educational opportunities through technology.

The federal government has provided and updated the National Education Technology Plan every 4 years since 1996. In 1996, the United States created four ICT goals for education, known as the Technology Literacy Challenge:

– All teachers in the nation will have the training and support they need to help students learn using computers and the information superhighway.
– All teachers and students will have modern multimedia computers in their classrooms.
– Every classroom will be connected to the information superhighway.
– Effective software and online learning resources will be an integral part of every school's curriculum (OET, 1996).

In support, the Department of Education released the nation's first national educational technology plan in June of 1996, *Getting America's Students Ready for the 21st Century: Meeting the Technology Literacy Challenge*. Since that time, tremendous progress has occurred toward achieving those goals. The National Center for Education Statistics (NCES) reports, for example, that in 1994, only 35% of public elementary and secondary schools, and 3% of all instructional rooms, had access to the Internet. Today, nearly 100% of public schools and 93% of instructional rooms have access to the Internet (NCES, 2006).

Concurrently in 1996, the USA launched a major national ICT program, E-Rate, within the Federal Communications Commission's Universal Service Program. E-Rate funds schools and libraries across America for Internet connectivity and telecommunications at $2.25 billion annually (US Department of Education, n.d.-a). This is the largest federal program designed to provide connectivity and ICT to schools. The USA has other federal programs aimed at funding connectivity, including Rural Telecommunications Grants through the US Department of Agriculture and within Housing and Urban Development. As an overarching national ICT policy goal, the President of the United States announced a goal to make broadband Internet access available to every home in America by 2007.

The early focus on infrastructure and developing technology skills set a strong direction. Subsequent plans expand on those same themes by adding focus on providing digital content and instruction, and by expanding options for students any time, any place with e-learning. The second US National Education Technology Plan in 2000, *e-Learning: Putting a World-Class Education at the Fingertips of All Children*, set five national goals:

– All students and teachers will have access to information technology in their classrooms, schools, communities and homes.
– All teachers will use technology effectively to help students achieve high academic standards.
– All students will have technology and information literacy skills.

– Research and evaluation will improve the next generation of technology applications for teaching and learning.
– Digital content and networked applications will transform teaching and learning (OET, 2000).

The second plan begins a shift from integration ICT into old models of teaching to transformation of teaching and learning, and importantly provides added resources for research and evaluation of ICTs in education.

As one of the numerous provisions in the comprehensive education reform law, the 2001 *No Child Left Behind Act* (NCLB)(US Department of Education, n.d.-b), the United States formalized a technology literacy requirement for all students in the eighth grade. Federal law requires that access is open to all students regardless of gender, special needs, background, or income level – and there are regulations known as "Section 508" in the *Americans with Disabilities Act* that mandate that all students have accommodations or access to use online resources. Each of the 50 states needs its state technology plan to be approved by the federal government in order to receive *NCLB Enhancing Education Through Technology* funding and must include how it will meet requirements.

The National Education Technology Plan 2004 was titled *Toward a New Golden Age in American Education: How Today's Students, the Internet and the Law Are Revolutionizing Expectations* (OET, 2005). The latest version of the plan shifted from setting goals to providing a vision of systemic approaches to transforming education using ICTs. The plan notes that transformation, not integration of ICT into old instructional models, is needed to realize the productivity benefits for supporting broader educational reform goals. The plan concludes, "Some of the most promising new educational approaches are being developed outside the traditional educational system, through e-learning and virtual schools. Reforms within the system will require strong leadership and a willingness to restructure the learning environment in fundamental ways."

Tremendous progress toward transformation is underway and driven by planning, policies, and local implementation fermenting major changes in how we teach, learn, and manage public education using ICTs. This is an exciting era in education in the USA.

Mexico

By most standards, Mexico's connectivity to the Internet in schools is low, especially in rural areas. In recent years, Mexico's Ministry of Education proactively realized that more must be done to include ICTs in education and launched significant initiatives to improve. In 2004, Mexico's Ministry of Education launched a $1 billion, nationwide effort known as Enciclomedia to digitize all educational content related to the national academic standards (SEP, 2004). By 2005, Enciclomedia had digitized the entire K-12 curriculum and made available the digital content on the Internet, on compact discs, and at regional centers. In addition, Mexico's ICT in education goals included installing at least one computer in every classroom preloaded with digital content and educational software into as many as 100,000 primary school classrooms. Teacher education programs at universities were instructed to teach pre-service teachers how to use the Enciclomedia software and digital content. Mexico is also piloting an effort to provide every teacher with a laptop computer (SEP, 2004).

Coordination of ICT programs in education with community technology centers in rural regions provides limited access to the quality digital content on local networks, and other programming is available through digital satellite. The Telesecundaria program allows students in the most isolated regions to access broadcasts on satellite television (SEP, 2000).

Mexico's ability to scale national digital resources and training is a real benefit – its governance structure allows a centralized approach for ICT implementation at every level of education. Although there is a long road ahead, at the current pace, Mexico may begin setting examples for how to approach ICT use in education through systemic transformation using access, software, and proper training. Mexico, taking a systemic approach, is undergoing a renaissance and expansion of ICT use in schools.

Canada

Canada relies on provincial governments to set educational policies, in the absence of a federal agency. Owing to the vast geographic challenges across Canada, the provinces have initiated several large-scale efforts to connect schools across the large distances, including the Connecting Canada initiative (Council of Ministers of Education, Canada, 2003). Begun in 1998, the Connecting Canadians program facilitated access to the Internet and building infrastructure for governmental, economic development and educational goals, including Canada's SchoolNet and Smart Communities (Government of Canada, n.d.). SchoolNet goals include providing connectivity, access, and teacher training for computers. In most provinces, the focus is as much on digital content and instruction as it is on infrastructure. Alberta, Ontario, British Columbia, and Quebec all offer online courses. Training teachers and developing high-quality digital content is another important aspect, and provinces are working together toward the creation of a learning-object repository to store digital content more effectively in a centralized manner. Many provinces have developed quality criteria for online learning. Although Canada has no federal education department, these programs broadly support ICT use in education across all provinces (Council of Ministers of Education, Canada, 2003). Canadian provinces are managing rapidly growing online programs, with more than 25,000 enrollments in online courses in Alberta alone.

Regional Summary

In North America, enrolment in virtual schools has exploded: student enrollments in online courses has grown from 50,000 in 2000 to more than 500,000 in 2005, at an estimated growth rate of 30% annually (NACOL, 2007; NCREL, 2005; Roblyer,

Table 1 Comparison of countries in the North American region

	No policy yet	Emerging policy	Applying policy	Infusing policy	Transforming education by policy
National/subnational policy document for IT in education					USA, Canada, Mexico
Master plan with a time frame			USA	Canada	Mexico
Budget plan and appropriations				USA, Mexico, Canada	
Monitoring an evaluation scheme or mechanism				USA, Mexico	
Statement of inclusion of women, minorities, and those with special needs in IT policy					USA
Manner by which the country and schools implement IT for education if no IT policy exists					

2008). Canada is realizing similar growth rates in each province. Mexico has digitized its entire K-12 educational content and curriculum. Mexico's initiative to provide every teacher with a laptop computer and training on digital content is changing the way teachers are trained in colleges and universities. Canada is developing digital curriculum and instructional models to spearhead online learning programs across vast rural areas and increase access to quality education for all students.

The actions described in this section are summarized in Table 1.

Reflections and Future Steps to Improve a Policy About ICT in Education

Old benchmarks to evaluate ICT progress in education were designed so that it would be easy for administrators to measure. Counting Internet access points and the number of computers is relatively easy compared to a systemic evaluation of the extent to which the technologies support access to the end user – how students are improving their learning: any time or any pace with accelerated learning, improved download capabilities and access speeds, facilitation of competency-based learning environments, and increased engagement for students. Too many computers have been integrated blindly into old instructional models in an existing classroom. Today, while investments are sizeable, the implementation of old models is difficult to justify and results are lacking for how the old models improve student achievement. New models of virtual schools and online learning show great promise and increase access to the best educational opportunities and quality teachers.

In today's schools, we must make the best educational opportunities available to all students, regardless of their neighborhood, geography, or income level. All students should have access to the best educational opportunities available and be academically prepared with a full complement of twenty-first-century learning skills (see also Anderson, 2008), rigorous coursework, and high expectations for the future.

For this, what we need is not the integration of computers into the old models; instead we need transformation. Education policy must shift from incremental strategic planning to systemic redesign using information technology as a base for the new design. When the system is redesigned to meet the needs of students, of the globally competitive workforce, and for the needs of society for lifelong learning, a new system will emerge that must use technology as a new delivery system to allow any time, any place, any path learning. A new delivery system must take advantages of the flexibility technology allows and improve education to become as mobile and flexible as today's networked and distributed society, particularly in North America.

This does not mean we would not need physical schools. They will need to be flexible and retrofitted for a modern world of learning. For example, the Massachusetts Institute of Technology in the USA recently completed an assessment of their academic building space. The total amount of space in academic buildings for traditional classroom lectures is only 3%. The vast majority of space is wireless, enables mobile computing, is flexible, allows students to form working groups and interact more easily, and enables faculty to interact with students in small groups inside conference rooms, and students and faculty access the vast databases across the world – they are driving learning into the networked, collaborative, worldwide scientific research community online in a quest for better analysis, experimentation, understanding, and growth of new ideas – whether face-to-face or virtual.

E-learning and online learning are asking education leaders to rethink, redesign, and transform education policy at every level when considering the new delivery system.

Education leaders must rethink the following:

- Policy – Legislation must enable every student to access online courses; laws must enable the creation of virtual schools and online programs to be managed; curriculum regulations must be revised to consider digital content.
- Funding – Funding models at each level of government must follow the student and enable students to enroll in online courses taught by the best teachers outside of the walls of their school building, be competency-based, without seat-time requirements.
- Management – Governance policies and management models for virtual schools need to be flexible to enable innovation, growth, and responsiveness to customer needs.
- Teaching – New teaching models are emerging that require new methodologies and strategies using the Internet.

– Training – Administrator and teacher-preparation programs need to include understanding models of virtual schools, teaching online, and internships online, as well as training in-service.
– Access – All students need access to modern learning environments; virtual schools are one-to-one models of computing with all teaching and learning over the Internet.
– Quality – New quality measures are needed for all courses (traditional and online). Online courses can measure competency, and seat time becomes a relic of an industrial model measuring time, not learning.

In the last decade much progress has been made on goals for connectivity and Internet access, but a bigger picture is taking shape. Important areas of investment are digital curriculum and instruction as new teaching models are emerging in a networked, collaborative, communicative world. The online environment will help transform schools, restructure outdated processes, and help realize the promise of technology in education. Online learning in the next 10 years will revolutionize schooling as we know it. In a globally competitive world, businesses and countries alike are centering their education and training strategies around e-learning.

In response to this, education policy must shift from incremental strategic planning to systemic redesign using ICT as a base for the new design. This does not mean that we will not need physical schools. They will need to be flexible and retrofitted for a modern world of learning.

What is needed is a systemic approach to transforming education and system redesign powered by ICT. Today's students are using technology inside and, to a significantly greater degree, outside of schools. Are our schools ready for today's students?

Reforms and change require leadership to support new models of teaching and learning focused on twenty-first-century skills. We are awakening to an opportunity to transform every area of the system through redesign of policies, management, and funding models required when implementing large-scale online learning programs across political boundaries. We are all nations on the move toward next-generation education models. These new models use ICTs to enable collaborative, communicative, connected networks across distances – bridging the best-trained instructors into the most remote buildings to teach more challenging, rigorous content to all students with high expectations for all. A new revolution powered by online learning will bring justice.

We have a tremendous chasm to cross in education reform, and this is our opportunity to power next generation education through online learning and rely on ICTs as our host for the revolution.

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11.5

IT AND EDUCATIONAL POLICY IN THE ASIA-PACIFIC REGION

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Socioeconomic, Educational, and Cultural Context

When reviewing the educational policies involving IT within the Asia-Pacific region, it is simultaneously an easy and a hard task. On the one hand, the availability of well-formed or comprehensive policies tends to mirror the general levels of human and economic development. Knowing the latter thus provides one with a reliable yardstick of the capacity levels and experience in promoting IT among respective national systems. On the other hand, the huge diversity of educational systems, colonial histories, languages, cultural practices, governance, and physical infrastructures within even a single country precludes making generalizations without numerous caveats (Adams, 2002; Maclean, 2002). How could it be otherwise for the region stretches from the Indian subcontinent northwards to the Central Asian Republics, eastwards to encompass Northeast Asia and extending over the Pacific island states while its southern borders terminate at the Antipodes? It becomes understandable that save for geographical proximity, some nations could well be from another continent. Such are their many differences between them.

Large population numbers (as well as one of the world's lowest national population densities in Mongolia [1.5 persons km^{-2}]), uneven enrollments in primary education, and poor quality instruction exacerbate the challenges of education here where 75% of the world's illiterates call their home. In fact, the most glaring intraregional digital divides in the world are to be located in this region. While it is an empirical matter whether prosperous states here espouse teaching models or educational systems

J. Voogt, G. Knezek (eds.) *International Handbook of Information Technology in Primary and Secondary Education, 1119–1132*.

characteristic of liberal Western democracies, the introduction of IT in education has definitely problematized established cultural models of good teaching (Richards, 2004). A listing of the problems in IT policy implementation will thus reveal a patchwork of micro- and macroissues that governments have to juggle with other development priorities (Asian Development Bank [ADB], 2004). These difficulties in providing a unifying picture can be observed when the Digital Access Index – a rough approximation of IT penetration – is compared with other country-specific statistics among selected states in the region (see Table 1).

Rationales and Influencing Factors for Policy About IT in Education

At the risk of oversimplification, there are a few interrelated justifications that have captured the imagination of advocates of IT in education: the socioeconomic, educational reform or management, and human-development rationales (see also Kozma, 2008). Having achieved the provision of basic educational needs, more-prosperous states have desired to leverage on all that IT promises to improve learning and training for life in the information society. By means of "easy-to-understand lessons," IT would inculcate new literacies and a "zest for living" for schoolchildren under the *Education Reform Plan for the 21st Century*, which had aimed to make Japan the most advanced IT nation in the world by 2005 (Ministry of Education, Culture, Sports, Science and Technology, n.d.). Similarly, rallying under the banner of ubiquitous learning as early as 1995, the Republic of Korea had laid out detailed procedures to incorporate IT across the lifespan and beyond the school to workplaces and homes. By so doing, it was hoped that the boundaries between the physical and the virtual would be porous enough to allow information and objects to be freely shared anywhere and anytime (Ministry of Education and Human Resource Development, 2005). These ambitious goals to plug into the knowledge-based economy appear to be an extremely widespread policy vision (see Selwyn and Brown, 2007), although the vocational, pedagogical, and societal drivers for IT use have not been fully understood just as it has led to a certain homogenization of rhetoric among politicians and aid agencies (Sein and Harindranath, 2004).

From an educational-change perspective, many of the regional IT polices can be said to adopt either traditional (i.e., learning IT skills such as productivity tools, using the Internet, programming, networking, information systems, which are taught separately) or emerging modes (IT closely integrated with classroom teaching). Most states seem to belong to the former category while a minority (again those with better access to resources) characterizes the latter. According to Moore (2005), more states should really emphasize the "I" in IT as part of information-literacy mastery instead of narrowly focusing on the development of skills in the use of IT. Of course, no classification can tell the full story; curriculum development agencies in Malaysia, which originally started off with mastering traditional IT literacy, are now quickly adopting integrative models of IT; yet both pedagogies thrive alongside each other (Chan, 2004). Like the *Smart School* concept in Malaysia, some urban and private schools in Thailand and the Philippines can count themselves to be among the forefront in

Table 1 Some key human development indicators among selected nations from the Asia-Pacific region

Country	Human development index value	Total population (in millions)	Urban population (% of total)	GDP per capita (PPP US$)	Combined gross enrolment ratio for primary, secondary, and tertiary (%)	Gender-related development index	Gini Index	Digital access index (DAI)*
Japan	0.943	127.7	65.6	27,967	84	0.937	24.9	0.75
Hong Kong (SAR), China	0.916	6.9	100	27,179	74	0.912	43.4	0.79
Singapore	0.907	4.2	100	24,481	87	?	42.5	0.75
Republic of Korea	0.901	47.5	80.3	17,971	93	0.896	31.6	0.82
Brunei Darussalam	0.866	0.4	76.1	19,210	74	?	?	0.55
Malaysia	0.792	24.4	63.8	9,512	71	0.791	49.2	0.57
Thailand	0.778	63.1	32.0	7,595	73	0.774	43.2	0.48
Samoa (Western)	0.776	0.2	22.3	5,854	71	?	?	0.37
Kazakhstan	0.761	14.9	55.9	6,671	85	0.759	32.3	0.41
Philippines	0.758	80.2	61.0	4,321	82	0.755	46.1	0.43
People's Republic of China	0.755	1,300.0	38.6	5,003	69	0.754	44.7	0.43
Fiji	0.752	0.8	51.7	5,880	73	0.742	?	0.43
Sri Lanka	0.751	20.4	21.1	3,778	69	0.747	33.2	0.38
India	0.602	1,070.8	28.3	2,892	60	0.586	32.5	0.32
Cambodia	0.571	13.5	18.6	2,078	59	0.567	40.4	0.17
Nepal	0.526	26.1	15.0	1,420	61	0.511	36.7	0.19
Developing countries: East Asia and Pacific	0.768	1,928.1	41.0	5,100	69	?	?	?
South Asia	0.628	1,503.4	29.8	2,897	56	?	?	?

All statistics obtained from United Nations Human Development Report (2005) except for DAI (International Telecommunication Union, 2005)
*DAI is a composite index comprising four categories of infrastructure – affordability, knowledge, quality, and actual usage of IT
(?) indicates missing or unknown values

e-learning, whereas the vast majority of public schools seem to be comfortable with traditional learning paradigms and tools (Pagram and Pagram, 2006; Rodrigo, 2005). It is slowly being recognized that gaining the support of parents and the wider community to accept IT usage in class as normative will require major sociotechnical changes. That said, emerging pedagogies using IT are one of the foremost nationally desired outcomes expressed by Australia, Hong Kong, Japan, Singapore, Thailand, and Chinese Taipei (Plomp et al., 2003). There is also much activity in distance-education initiatives to boost both overall instructional quality and higher education sectors (e.g., the University of South Pacific) that are sustainable, affordable, and sensitive to local norms (Reddi and Mishra, 2005). Because of the impending explosion in tertiary enrolments in Asia, especially in the People's Republic of China and South Asia (e.g., the National Open School in India, Distance Education Partnership Program in Sri Lanka), these forms of e-learning will probably require innovative public–private partnerships for successful delivery (ADB, 1997).

Another feature of IT-in-education policies here is the wide mix of top-down (centralized) and bottom-up (decentralized) approaches that most often involve a national or IT master plan coexisting with more-localized planning documents such as provincial or school-level initiatives. Most national master plans paint broad visions to achieve and usually specify ways to increase IT infrastructure and build knowledge capital. However, there were anomalies as when Singaporean schools experienced tight bureaucratic control in the past and yet were actively encouraged to innovate for IT. Each state within Australia likewise enjoys the freedom to determine how best to achieve national and state goals while adhering to a common standard on assessing student IT achievements and outcomes (Fluck, 2003; United Nations Educational, Scientific and Cultural Organization [UNESCO], 2003). With four types of school management schemes in India, IT policies exist at national, state, and district levels; each of which may embrace different objectives in conjunction with private-sector tie-ups. Experience does nonetheless show that top-down IT initiatives tend to be more prevalent and necessary at the early stages of policy implementation to ensure uniformity and buy-in by stakeholders (UNESCO, 2004a). Provided there is consistency, both levels serve different albeit complementary functions (Jones, 2003).

Above all, IT is seen by many as an important part of the solution to alleviate the chronic problems of development and poverty in the region (ADB/Organisation for Economic Development and Cooperation, 2002). If investments in educational IT behave in a fashion similar to that of science and technology education with regard to enhancing economic expansion, IT can help large sectors of society leapfrog into the information age, though by itself it seems a necessary but not sufficient condition (Asia-Pacific Economic Cooperation [APEC], 2005). It is unlikely in the near future that the poorest countries will realize even a fraction of what the developed world presently enjoys, for the key enabler for successful IT-enabled projects in developing nations is adequate infrastructure – perhaps *the* greatest impediment given its high capital costs. This directly impacts the price of access; the rates for leased lines in Viet Nam and some Pacific Islands, for instance, are among the highest in the world. The next biggest obstacle is perhaps the lack of appropriate instructional content in vernacular languages – myriad in this region – that severely negates investments in IT hardware and software. Other policy concerns are the inequalities existing among the richer nations such as Australia (rural–urban divide) and Japan (generational divide) not to mention the gross inequalities of access experienced by women, aboriginals, the disabled, and minority groups in many other countries. An underappreciated area is the work of large multinational firms (e.g., Coca Cola, Agilent Technologies) and especially NGOs in poverty alleviation in the area of nonformal, basic literacy, especially through IT applications such as skills delivery. These kinds of grassroots initiatives have the potential for real change that is community-based, retain low-cost, and combines local needs with local solutions. Here we see the necessity of nimble flexibility and openness in implementing local IT policies, which can, for example, permit the hosting of telecenters on school premises operating after hours with some income generation.

Regional groupings (e.g., *e-APEC*, *e-ASEAN*) and international aid agencies (e.g., ADB, International Development Research Centre, The World Bank, UNESCO) play critical roles in influencing IT policy and resource sharing across the region. The ADB, for example, has recently completed its first loan that was solely devoted to integrating IT in basic education in Uzbekistan (ADB, 2006), and the genesis of the successful Malaysian Smart Schools project can be traced back to 1997 with a $40 million bank loan. The Bangkok office of UNESCO hosts a major portal for matters related to IT policies in the Asia-Pacific and has recently helped assemble a toolkit to assist planners in all aspects of policy-making (UNESCO, 2006). Under the *e-Pacifika* project, sponsored by the United Nations Development Program (UNDP), UNESCO, and the British Broadcasting Corporation World Service Trust, high-level politicians in the 14 Pacific Island states were sensitized to the benefits of regional and national IT strategies, including those for the education sector, which many states previously did not possess or deem important (Chin, 2005). Because of their nonpartisan and apolitical mandate, these aid agencies are well positioned to coordinate and pool resources (and policies) among member governments. APEC education ministers have likewise been alerted to the value of regional collaboration in research and development for new IT teaching strategies as well as establishing communities of practice among participating states (APEC, 2004). These initiatives are subsumed under *e-APEC Strategy2* launched in 2001, which is a long-term action-oriented plan to strengthen human capacity building and promote entrepreneurship as one of three broad goals. What is now recognized is that sustainability issues in IT policy or projects must enjoy local ownership (UNESCO, 2004a). Thus, in the popular SchoolNet project, ASEAN (Association of Southeast Asian Nations) nations are managing on their own (with public–private partnerships) but with an eye towards a regional network under UNESCO auspices (UNESCO, 2004b). This project is part of a high-level *e-ASEAN* plan to enable comprehensive use of IT in government, business, and society that first saw light in the Hanoi Declaration of 1998 to develop IT infrastructure and promote science and technology.

Specific Policies About the Introduction of IT in Education

Although it is obvious that many countries in the Asian-Pacific region did not begin on the same starting line, most would agree that they can be grouped into three broad categories without passing any judgment whatsoever other than their relative state of IT-in-education policy development (see Loxley, 2004).

- Advanced: e.g., Australia, Chinese Taipei, Hong Kong (China), Japan, New Zealand, Republic of Korea, Singapore. Mature IT policies with capacity for expansion; generally experiencing few or temporary bottlenecks in terms of implementation and/or bandwidth and affordability; existing national master plans and many lower-level (e.g., district, provincial, school) plans with adequate funding; experience with IT integration in school curricula by IT-trained teachers; innovative, trend-setting, and capable of course correction during implementation; evaluation frameworks articulated and clear.
- Evolving: e.g., India, People's Republic of China, Malaysia, Philippines, Sri Lanka, Thailand. Fairly comprehensive formulations at the national level with various support plans; results from IT pilot projects feed into new learnings for the system; policies usually enjoy strong political backing, though sometimes constrained by fiscal or manpower factors; connectivity and access growing slowly; teachers usually trained only in basic computer literacy and software applications if at all; sporadic IT integration in teaching; lack of suitable content in local languages.
- Less developed: (characterizing the majority of states in the region) Possibly with national-level policies but lacking resources (e.g., hardware, software, human capital) for proper implementation; IT policies usually not a current development or political priority; generally reliant on donors and aid agencies for drafting policy frameworks; small pockets of IT innovations funded by external agencies; very poor IT access and connectivity generally; rudimentary teacher training in IT.

An argument can be made that countries falling under each of the three groupings would share certain areas of opportunities as well as needs and problems. This translates into something useful for Asian policymakers who had expressed that learning from the experiences of countries with similar situations as their own was highly desirable (UNESCO, 2004d). Table 2 fleshes out in greater detail how these three categories of states align themselves against certain key indicators regarding IT in education policies in the Asia-Pacific.

Policy Documents, Time Frames, and Budgets

Having a national or subnational IT policy seems important on two counts: they function as supporting or enabling factors for sustainability and transferability of classroom IT innovations as well as increasing the likelihood of transforming how students learn in the classroom (Jones, 2003). According to a global survey conducted by Adamali et al. (2006), the use of IT in education is a focus area in 88% of all national IT strategies. Over half of these policies mentioned teacher training, connectivity issues, and distance learning, and more than 30% discussed curriculum development and quality assurance.

Countries in the Asia-Pacific exhibit the typical pattern in that the few advanced nations have various enabling policies, IT champions, and physical infrastructure in place. The Republic of Korea has exceeded many of these prerequisites admirably in

Table 2 Three categories of states in the Asia-Pacific grouped according to key IT-in-education policy features and indicators

	No policy yet	Emerging policy	Applying policy	Infusing policy	Transforming education by policy
National/subnational policy document for IT in education		LD	LD, E	E, A	A
Master plan with a time frame		LD	LD, E	E, A	
Budget plan and appropriations		LD, E	E	A	
Organizational structure responsible for implementing the master plan		LD, E	E	A	
Monitoring an evaluation scheme or mechanism		LD, E	E, A	A	
Statement of inclusion of women, minorities, and those with special needs in IT policy		LD	E, A		
Manner by which the country and schools implement IT for education if no IT policy exists		LD	LD		

LD less developed, *E* evolving, *A* advanced
Data obtained from Loxley (2004), Moore (2005), Plomp et al. (2003), and UNESCO (n.d.-a)

that every school now has its own LAN and Internet connectivity. Each classroom has PCs and multimedia equipment, and all teachers have been issued with computers. If anything can be summarized from these efforts, it is that success in promoting IT in education seems to depend on large-scale government-led efforts over a long period of time. With so many thresholds to overcome, less wealthy states, which form the bulk of countries in the region, are understandably cautious and less capable of promoting the use of IT in education. Mongolia (under the *National Vision for ICT development of Mongolia up to 2010*) and Bhutan are exceptional in having rather comprehensive and forward-looking IT in education policies (Moore, 2005).

Organizational Structures

The Australian *Learning for the Knowledge Society* areas of policy concern typify most advanced nations: human development; infrastructure; online content, applications, and services; policy and organizational framework; and regulatory framework (Kearns and Grant, 2002; UNESCO, 2004c). Using different words, others have expressed similar concerns about the necessary links between hardware, software, and training; between IT and curriculum development; and between technological and cultural change. Few would quibble with these domains, but what is underexplored is how these all can be fitted together in a holistic and integrated framework (e.g., policy conflicts in the People's Republic of China, Myanmar, Philippines, and even between the federal and state governments in Australia; see Farrell and Wachholz, 2003). It is difficult to coordinate different ministries, private industries, and NGOs to work in tandem towards a common objective, which small states such as Singapore can perhaps experience more readily. While the Japanese experience in promoting IT use in education has been exemplary, the local environment has not been able to support all its downstream implementation. These so-called IT roadblocks have involved the (a) lack of technical and institutional support for IT use, (b) institutional barriers of IT use, especially the Internet, and (c) a misguided focus on technology over pedagogy (Bachnik, 2003). With its large landmass, uneven development between her provinces, and conflicts between old and existing systems, the Peoples' Republic of China faces many obstacles in its push towards the information society (Chin, 2005). This plea for organizational coherency seems to be a nonissue for some countries such as Thailand, which had overlapping IT policies and master plans that were drafted by different government ministries since 1995 with the launching of its own SchoolNet project.

Monitoring and Evaluation Schemes or Mechanisms

Because implementing IT polices are always contingent and highly contextualized affairs depending upon people, policies, and place across different levels, it is unfortunate that monitoring and evaluation are *the* aspects that are most lacking. Out of a possible score of three for the monitoring and evaluation aspects of national e-strategies, the East Asia and the Pacific region as a whole measured 0.88 whereas South Asia a mere 0.17 against the global average of 0.61 (Adamali et al., 2006). It has been further claimed that of those few nations across the globe that have articulated some kind of evaluation of educational IT policy, even fewer provided budgetary details for its implementation. The Republic of Korea and Australia apparently are the only ones in the region that have a sound set of performance indicators to measure the impact of national IT programs and initiatives (UNESCO, n.d.-b). Even Singapore has failed in this area (contra UNESCO, 2004c), for there was said to be "little or no real indication of substantive issues relating to how exactly IT is integrated in the Singapore curriculum as a whole, and how it transforms subject-specific practice in particular" (Towndrow, 2005, p. 509). These blind spots in policy were reportedly traceable to the weakness of her IT master plans to spell out exactly how the revamped IT-infused teaching would look like or what teachers needed to know or believe.

Statement of Inclusion of Women, Minorities, and Those with Special Needs in IT Policy

In the rush to embrace IT in education, the inclusion of the needs of marginalized and disabled peoples have sometimes been added as an afterthought, if at all. It is thus felt that much more needs to be improved in this area, though we recognize the provisioning constraints that many states face and that these divides actually reflect deeper preexisting social inequalities. The Republic of Korea has been exemplary in that it developed a *Comprehensive Plan for Resolving the Digital Divide* in 2001, which saw widespread IT education training, free Internet access points, and proposed connectivity to distant farming and fishing villages. Likewise, Maori and Aboriginal communities have benefited from polices that have brought IT into local classrooms in New Zealand and Australia respectively. Nepal and Sri Lanka among others have tried to concretely erase some of these barriers by funding scholarships for poor but capable students to pursue higher studies in IT as well as for technicians in the public and private sectors.

Manner by Which the Country and Schools Implement IT for Education If No IT Policy Exists

The type of projects that fall under this category are numerous but they seem to characterize the situation in the less-developed states who rely heavily on financial and technical know-how offered by foreign donors and aid agencies. It is uncertain to what extent is the degree of coordination among the latter when planning for projects in member countries, although there was an infrastructural-building emphasis in the past. These projects are generally ad hoc in nature or on an experimental scale that can be scaled up once proven viable, which to date has been infrequent. In our experience, the diffusion model of IT training (e.g., trainers teaching other colleagues) is in principle an excellent means of resource sharing and learning from peers but often these schemes suffer from dilution effects.

In what follows, these above-mentioned IT policy issues will be illustrated with two brief country studies from Sri Lanka (evolving IT level) and Singapore (advanced IT level).

Sri Lanka

Sri Lanka presents an interesting paradox in that while her general literacy and human development indices are high for a South Asian nation, IT literacy is only possessed by about 5% of the population. Continuing on educational reforms (e.g., the *General Education Project* funded by the World Bank) begun in 1998, Sri Lanka has sought hard to equip her population to be ready for life in the twenty-first century. One such government initiative has been the *National Policy on IT Education* in 2001, which aimed to strengthen human and physical infrastructure across the island. Overlapping with the e-Sri-Lanka IT roadmap, the Ministry of Education was entrusted with infusing IT in education, improving the quality of learning more meaningfully through modern teaching methods and assessment, and increasing opportunities for the poor and those living in the conflict zones. The Ministry was itself reorganized in view of these major reforms that were taking place. With additional funding from the ADB, Nordic Development Fund, and School Development Societies for the *Secondary Education Modernization Project* from 2001–2006, the independently assessed results for Sri Lanka have been nothing short of spectacular.

Starting from scratch (only 15–20 schools in urban areas had any IT facilities), there are now about 1,200 schools with 20 computers, printers, and other equipment in each air-conditioned computer-learning center (CLC). When one considers that nearly 700 of these schools had no electricity initially and that now they are Internet ready and that 1,400 principals and 24,000 teachers have received basic computer-related skills, one has to applaud the solid gains that have been made. Students who have been interviewed reported that lessons are now more enjoyable, which has been reflected in increased attendance and punctuality rates for teachers as well. Special attention was paid to recruiting and training Tamil-speaking teachers, given that schools in poor and conflict-affected areas are mainly located in the North of the country. There was additional help obtained from Microsoft and Intel for software training and facilities management – a model of public–private partnerships. Because the tight accountability frameworks demanded by donor agencies have demonstrated very positive gains in educational quality and efficiency, the latter have extended their projects till the end of the decade in close partnership with the Ministry of Education. Problems remain of course, of which one was the lack of trained instructors in the past and appropriate software and educational tools. Others include political instability, regulatory uncertainties, policy gaps, coordination issues, and the lack of foresight at macro and strategic levels. Unless a more forward and high-level vision for IT is enforced, it is feared that many of the existing and future benefits of IT will be eroded in the e-Sri-Lanka plan (from websites of ADB [http://www.adb.org/Documents/Periodicals/ADB_Review/2006/vol38-3/switched-on.asp], Digital Review of Asia-Pacific 2005/2006 [http://www.digital-review.org/05_SriLanka.htm], Sri Lanka Ministry of Education [http://www.moe.gov.lk/], The World Bank [http://www.worldbank.lk/WBSITE/EXTERNAL/COUNTRIES/SOUTHASIAEXT/SRILANKAEXTN/0,menuPK:232812~pagePK:141159~piPK:141110~theSitePK:233047,00.html]).

Singapore

Singapore's efforts in implementing educational IT policies can be viewed from two perspectives: policies that build infrastructure and those that develop human capital, especially in K-12 settings. Since the formal introduction of the IT Master Plan 1 (1997–2002), efforts began to move towards an IT-rich environment both in schools and society at large (i.e., an "intelligent" nation by 2000). In her desire to also attract high-end industries, Singapore is now developing interactive and digital media whereby technology workers find their counterparts in the media industry such as in computer-animated movies. This aligns well with the expressed need to equip her citizens with literacies for interpreting, constructing, and deconstructing multimodal forms of meanings and meaning-making. The second IT Master Plan (2003–2006) built on the first master plan and saw an emphasis on making IT systematically and holistically integrated into school curricula. This ran parallel to the *Thinking Schools, Learning Nation* policy vision that linked personal and national development together. What is in the cards under the new *ICT for Education* project (2006–2008) are fourfold: (a) establish minimum IT standards for schools, (b) support schools that wish to develop their local IT policies, (c) encourage local ownership by schools, and

(d) strengthen integrated IT pedagogies. The crucial question is whether educational IT policies actually worked, on the ground, in Singapore. Being a developmental state, Singapore adopted a centralized approach where education was but one aspect of the larger national information infrastructure (Castells, 1996). And because of her size, political situation, and other issues, these policies in IT were able to achieve success in terms of infrastructure provision and budget. Whether a comparable level has been achieved in the equally valuable "soft" areas (e.g., quality learning by students) remains to be documented however and therefore this is one area where more research is needed. If anything, the *Teach Less, Learn More* vision in 2005 was an admission that much more needed to be done and that IT was not a panacea for building human capacity and innovation in schools. A new funding program to encourage schools to be creative and think outside the box with regard to IT has just been launched by the education ministry (data from various Singapore government websites, e.g., http://www.moe.gov.sg/edumall/mp2/mp2.htm and http://www.moe.gov.sg/).

Reflections and Future Steps to Improve a Policy About IT in Education

The region certainly presents many rich case studies, although the lack of systematic monitoring and evaluation programs mitigates the lessons that can be learnt from policy implementation. In general, it is felt that policies that concentrate on infrastructural issues are more easily fulfilled and visibly accountable whereas those advocating excellence in classroom IT practices remain constantly challenged. What needs to be remembered is that the quantity of IT usage is no guarantee of student achievement; sound pedagogy is always paramount, not technology such as what is properly driving educational IT policies within the central Asian republics (Farrell and Wachholz, 2003). Also, investments in hardware should be staggered in view of its steep depreciation; policies that invest heavily in infrastructure need to be cognizant of the tension between costs and demand-usage. The most sensible approach is perhaps to fund projects that enable tangible usage and life-style changes. When end-users realize how they can benefit from increased productivity and learning, resistance to educational IT fades. The fine tightrope that governments walk between advocating IT as a technological fix to social, economic, and educational problems and wanting to preserve the present social order further exemplifies the many tensions in IT policies. At another level, not many less-developed states in this region have achieved very clear transparency, accountability, and consultative processes with regard to policy-making. Neither have the poor regulatory structures, piecemeal efforts, lack of supportive leadership, conflicts between policymakers and IT experts, and weak monitoring frameworks helped the situation.

It is possible to make some educated guesses about future trends here. We foresee the rise of national SchoolNets and vernacular educational media, especially those catering to the two most populous nations of India and China. Chinese Taipei has already been trying to position herself as the center for e-learning software and hardware for the global Chinese community since 2002 under her well-funded *e-Taiwan* program. This would be reflective of a larger trend whereby the English language cedes part of its global cultural dominance to other indigenous languages. The burgeoning middle-classes and urbanization of the Asian countryside will also influence governments to address the educational needs of the most accessible and educable, which IT will surely feature in no small measure. The Asia-Pacific has one advantage over other regions in that its relative youthfulness of its population here make these sectors more receptive to harnessing newer (and cheaper) forms of educational IT. Given this, the pace of change here will be more rapid compared to other regions. Teacher quality will therefore have to keep pace; knowledge building rather than transmission-oriented pedagogies will have to be part of teachers' repertoires as we are recently observing in the Teacher Network Communities and Knowledge Society Network in East Asia (Laferrière et al., 2006).

We expect the present situation whereby some advanced nations are helping and collaborating with less-developed states in IT-related fields to accelerate. This assistance normally takes the form of donated hardware, training programs, and scholarships that require small initial outlays but with large future spill-over effects and goodwill generation. Rather than the West playing this dominant role in capacity building and erasing the numerous divides, the new government/agency-to-government players will originate from the Asia-Pacific. At no time, however, would this mitigate the role of local policy-making for strong nationalistic identities and cross-national differences will persist (Selwyn and Brown, 2007). With better technical and vocational education using IT and sector-specific improvements in educational quality, some emerging nations would probably enjoy new-found growth in niche areas such as what recently happened with tertiary education in South Asia. These pockets of excellence, as far as we understand, depend as much on chance as on coordinated, forward-looking planning.

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11.6

ICT AND EDUCATIONAL POLICY FOR THE LATIN AMERICAN AND CARIBBEAN REGIONS

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Socioeconomic, Educational, and Cultural Context

Under the label Latin American and Caribbean countries, and according to a classification made by the United Nations Educational, Scientific, and Cultural Organization (UNESCO), this region includes 18 nations – Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, and Venezuela – and 15 countries occupying islands in the Caribbean region (note that Mexico is also sometimes classified as being in North America and thus is also discussed in the North American chapter in this section). In all these countries economic, political, social, and cultural conditions give to the region a wide diversity whose main traits are educational shortages, resource unavailability, diverse and dispersed populations, low levels of equity access and quality for basic services, and disconnections between education, employment, and quality of life. All of these difficulties ideally should be resolved in order to guarantee to these populations the benefits of justice and equity in the twenty-first century.

For over a decade, Latin American and the Caribbean countries have been enhancing their attempts to overcome ancestral social insufficiencies that affect their inhabitants and hinder development. Unfortunately, notwithstanding governmental concern, the shortcomings have increased, broadening the social gap as well as unemployment, fostering a considerable migration of their populations to national economic centers abroad in search of opportunities for survival(Ávila Muñoz, 2001–2002). Social inequality is a perennial problem. These inequalities are rooted in demographic, economic, and cultural issues. Therefore, it is necessary that these countries promote equitable educational opportunities. Traditional pedagogy is inadequate and cannot respond to the needs arising from the different learning groups. This situation can

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probably be solved through the planned use of educational technology resources (UNESCO, 2005).

Despite the fact that, according to data from international organizations, the Latin American and Caribbean countries' basic education (primary and secondary levels) coverage serves about 90% of their needs, quality and coverage of basic education call for permanent attention. To move into higher educational levels the less-favored population must complete a junior high school education. Nevertheless, junior high school coverage is still markedly insufficient and shows high drop-out levels. In addition, illiteracy among adults has not been completely eliminated (Urquiola and Calderón, 2005). According to data from UNESCO, the literacy rate in the more-developed countries of the region is at 98.7% while in the less-developed nations of the region it is at only 70.4%, the latter being compounded by women's marginal conditions (UNESCO, 2001b).

Although one can take for granted that the shortcomings of traditional teaching are less conspicuous at the beginning levels of the educational system, where students need to acquire, with their teachers' help, the habits, skills, and competencies oriented toward independent learning and research, the status quo's negative effect can also be seen in middle and higher educational levels. Beyond the beginning levels these effects are no longer due to teachers' performance, but to that of the students. Among the different causes are the operating conditions of the institution and the socioeconomic and political situation of the region.

Quality and coverage of basic education are just some of the many problems the region experiences. It is necessary to also pay attention to the middle and higher educational levels, including all their different options, in order to be prepared for a global market economy. The focus should be on ensuring a quality education for the population, granting (or extending) complete basic education for workers in the labor force, as well as a certification of competencies for the workforce. For middle and higher educational levels, distance education represents a valuable (while not yet completely explored) alternative (Brunner, 1999; Piñón, n.d.).

In recent years there has been a growing interest in learning about and taking advantage of the information and pedagogical potential of information and communications technology (ICT). ICT is considered important for overcoming shortages in the prevailing pedagogical methodology of the majority of schools in the Region. Particularly the poor learning levels across educational structures are an important reason for students' school dropout (Ávila Muñoz, 2001–2002).

Rationales and Influencing Factors for a Policy About ICT in Education

Rationale and Policy Development

The application of ICT in education could have important national and international effects in the context of alternatives to overcome current inequalities. To introduce these technological advances to traditional educational systems in less-developed nations implies solving two major challenges (Comisión Económica para América Latina y el Caribe [CEPAL], 2003):

– To promote in the countries an intense process of change based on the participation of the entire society, and particularly that of teachers, in order to advance from the general knowledge of ICT management and its educational possibilities up to the point whereby ICT incorporation into the classroom is made possible.
– To secure financial support for required resources. Besides interest and participation, additional financing efforts are required. These efforts will only be solved through the interaction of all economic sectors, given the economic depression in which most countries of the region are immersed.

At the same time it is necessary that technology infusion is placed within identified educational program with goals and objectives clearly defined (Hinostroza, 2004). Attention must be given to population sectors with particular characteristics by gender, age, special conditions, race, languages, and demands. By providing differentiated educational options and complementary educational programs that counterbalance inequalities and provide attention to specific needs, this situation may be resolved. Appropriate applications of technological resources can help transform society.

In developing countries, one of the most common deficiencies is found in adult education and labor training. Deficiencies exist in coverage, quality of education, and diversification of learning opportunities. There are also insufficient resources to attend the increasing number of adults demanding education (CEPAL, 2003).

The issue of equality may be solved once a policy of infusion of new technologies has been determined, if attention is given to avoid inequalities stemming from selective and limited access to digital-era technology. Great opportunities are apparent, as well as major and inherent risks that need to be accurately defined and avoided.

Access to technology is mediated by socioeconomic characteristics of the environment. Usually, technology incorporation becomes more feasible in urban areas than in poor rural ones, and within urban middle class sectors rather than in urban poor sectors. Those differences exist not only with regard to the incorporation of technological resources, but in all innovative educational models. Paradoxically, the marginal areas are the ones requiring better conditions to overcome the delays imprinted by social marginality.

In Latin American and Caribbean countries, the formalization of the *governing documents* for educational policy represents a sign of change in regional public administration. Educational administrators tend to link interventions to strategic programs with goals and objectives clearly set, and in doing so redirect efforts and resources – although resources are still insufficient in most cases. On the basis of information obtained from different mechanisms, each country has identified its educational system's needs, strengths, and weaknesses. Through this means countries can attend to international politics regarding the knowledge and information society, taking into account issues such as lifelong education, or at least that all people have basic education as a minimal benefit.

With regard to access to technology, the people from the central and southern regions of the Latin American and Caribbean are faced with deep inequality, compared to that of the countries in the north, a fact that reflects itself in differential access to information distributed through the Internet. According to published sources, information available in the Internet doubles every 4 years (Amin et al., 2001; Comisión Interamericana de Telecomunicaciones, 2002). Although selected groups in all countries enjoy wide access to education and technology, unfortunately, there is a contrasting reality of millions of children and teenagers excluded from social and technological development.

To diminish social-polarization effects, governments have addressed the issue of technology in education from different perspectives, ranging from short-run "pilot" project operations to isolated experiences with limited coverage and massive projects with no proved scope or results. There are some cases where private-sector initiatives with limited coverage have been presented, as well as participation in projects of international institutions and organizations engaged in developing technology in education. One example is the Computers for Communities Initiative created in Canada for Latin America and Caribbean Countries, where computers were reconditioned as tools for digital literacy, social inclusion, and job creation in poor communities. In 2005 pilot projects were reported in El Salvador, Guatemala, Guyana, Jamaica, and Venezuela (Organización de los Estados Americanos, 2006).

Other Barriers to ICT in Learning

What is becoming evident is that the region's nations are exploring an alternative solution in technology-based education, targeting excluded populations in need of literacy, better health practices, citizenship, education in values, and work training.

Countries in the region are also advancing in another essential aspect closely linked to quality of education. They develop national systems of educational assessment that will monitor research and development in order to learn about the effects, achievements, and limitations of different scenarios for educational ICT use. This may lead to proposals for projects based on appropriate ICT use for each scenario. But this will not be possible if teachers are not trained in using ICT as a tool to promote learning. The perspective of incorporating ICT use in schools is not one-sided. Besides its role in school administration, in most countries ICT is considered a pedagogical aid, a tool to widen access to culture, as an information source to introduce its use within society, and to form professional skills for the workforce (UNESCO, 2005).

Change within educational systems is not easy. New scenarios demand pedagogical models to stop the school-work axis from being teacher-centered, without nullifying the teacher's importance in leading a process that implies "teaching to learn", and applying learning strategies that recognize students' personal differences and open development opportunities to every subject's potential. Collaboration in studying and learning as a permanent process implies a new pedagogical approach around computers and a rational use of the potential of the Internet. The teacher must know it is possible to form learning communities based on participation, dialogue, reflection, and analysis to address the construction of knowledge and, simultaneously, to share self-advancements among equals. School work must surpass the classroom limits and reach for the promotion of the environment as a shared responsibility. An ecological view over natural resources, the social well-being, the civic culture, the family and the wide concept of community (local, national, and regional) may acquire new values and presences within the classroom (CEPAL, 2003).

There are initiatives in several countries in the region offering education beyond the classroom. These initiatives build on the growing integration of distance-education programs, the creation of projects giving access to communication and information technology through community plazas (sometimes called community centers for learning), the production of educational shows for educational television, and the creation of expert networks in education, health, and culture. All these initiatives serve people in several educational and social levels focused in the necessities of each sector.

There are still problems to overcome. It is difficult to sufficiently equip classrooms and community settings with the necessary tools and resources. A viable path seems to exist in establishing solid commitments with private sectors within the national economy that could support the acquisition of equipment, technical assistance, modernization, and maintenance. Another path is to link national projects to organizations or groups, such as financing sources to equip and simultaneously to train those who represent the main end-users: officials and administrators, teachers, promoters, and designers, among the main actors involved (Muñoz Rojas and Mominó, 2005).

Specific Policies About ICT in Education

During the last years of the twentieth century, Latin American and Caribbean governments made several attempts to incorporate technology as a social development tool within their countries. Each government promotes a number of actions according to the characteristics of its scenario, ranging from issuing state policies, considering the initiatives of international organizations, or from alliances with private-sector groups interested in developing educational technology.

At the *Seventh Meeting of Education Ministers for Latin America and the Caribbean*, carried out in Cochabamba, Bolivia, in 2001, recommendations were issued in order to find solutions for the social and educational problems affecting the region. Special attention was paid to those problems connected to creating equal learning conditions for all, offering a flexible and diversified educational supply that was attractive to the most-vulnerable population sectors. These recommendations focused on enhancing quality for both formal and nonformal education models (UNESCO, 2001a).

In the World Bank's annual report (Banco Mundial, 2002) the need for regional governments to adopt urgent measures to overcome the skills and technology-development deficits was pointed out. The report stated that in the year 2002, the number of poor people in the region went "up to nearly 169 million." The report's main tenet was that investment in skills and technology plays a central role in steadily increasing productivity and income for a long period of time because they are complementary and it is more productive to make interventions in a synchronized way. The report recommended that countries "build their skills and technology levels from bottom to top, in a sequential and coordinated manner." For most Latin American and Caribbean countries that means an investment increase in basic education and in teacher training, along with a greater emphasis on instruction quality within schools. In the same report (Banco Mundial, 2002) three progressive stages were identified for the technological evolution of a country – adoption, adaptation, and creation – and the authors formulated the reach of policies that must be designed to address the specific challenges at each stage.

- Where lower technology adoption levels are present, a greater attention to basic education level is recommended. Countries within this level are Haiti, Guyana, Paraguay, Bolivia, Guatemala, Honduras, Ecuador, and Nicaragua.
- For those going through the adaptation stage (Brazil, Colombia, Costa Rica, Peru, El Salvador, Panama, and Venezuela), the policy would be to maintain investment in basic education, to promote developing more specialized skills, research, technology development, and promoting links among enterprises and universities and higher-education institutions, among other measures.
- Among those countries with a more-advanced adaptation phase oriented toward the creation of products and processes applying technology (Chile, Mexico and, to a certain level, Uruguay and Argentina), there is a need to increase higher education access, to create links between universities and companies, and to stimulate research and technological developments.

Another example of an international organization providing input to regional decisions about ICT in education is UNESCO. UNESCO issued a *Manual for Teachers* where a model was presented differentiating four progressive stages for technology incorporation into education: emerging, applying, infusing, and transforming. (Anderson and Van Weert, 2002). The process starts with providing a computerized infrastructure in school and by providing teacher training. Later on, in what is identified as intermediate stages, an interest in planning, leadership, and the organization of technological tools in a school network emerges. In the next stage the network has already earned a place in some school activities and the need for teacher training on ICT use has become evident. As the process moves forward, the vision focuses on other possible uses of technological tools.

These two examples are structured upon core components of the process of technology implementation: infrastructure, planning, and the organization of teacher training, within a systematic connection indispensable for accomplishing the integration of technology into educational communities.

Jara Arancibia (2004) notes that countries within the region, such as Mexico, Argentina, Honduras, El Salvador, and Nicaragua, are making progress in educational reform. She identifies the following three stages:

- Decentralization of public educational systems
- Development of a system to monitor the quality of the education system

– A focus on school effectiveness pertaining to the incorporation of ICT and realizing network connectivity

The Appropriate Introduction of ICT in Schools

According to the signing members of the *Seventh Latin America and Caribbean Meeting of Education Ministers* (2001), society is now keen on the development of projects associated with the use of ICT. In these projects, the issue of equipment and supplementary service-acquisition costs must not be the only issues addressed. These projects should also focus on teacher training, setting up of Internet sites, and the operation of school networks. Also relevant is the recommendation to include other tools such as TV and interactive radio networks as means of enhancing training programs designed for teachers.

ICT provides the possibility of reaching major audiences and groups with special needs with a consistent quality. In countries of the Latin American and Caribbean region they could help to consolidate educational systems in general, to spread knowledge, and to reduce the educational delays affecting the adult population. In addition, using ICT can contribute to the formation of a technological culture within society, based on the multiplicity of applications in various fields of the economy and goods and services production.

Although technology may help to increase the supply and coverage of educational services through supporting more-varied and flexible programs in response to increased and diversified demand, it may also cause conflict for teachers during the adaptation period and lead to a possible rupture in the cognitive relationship with the class, when students surpass the teacher in resource handling or when students lack access to ICT and teachers expect students to have it. Thus prior to the process of implementation, the incorporation of technology demands educational research to provide support to technical and pedagogical training projects and programs designed for school faculty. Capitalization of experiences reached by higher-education institutions, domestic and international, as well as counseling and support from international organizations, will contribute to reduce the gap between the developed and the underdeveloped in all the countries in the region. This will facilitate integrated *content-process* proposals involving technology resources and new methods for teaching and learning appropriate to satisfy syllabus needs within formal and nonformal education, in extramural education, for society, for training and updating, and for parents, teachers, and other stakeholder groups.

Expert assistance must be present at all times, all the way from the stage of design, up until the start of the proposed pilot application. Such proposals should always be subjected to evaluation prior to their being massively generalized, and once their relevance has been attested and their viability defined.

Incorporation of new technologies should take place within a comprehensive planning process, with clear objectives and well-defined strategies, and include procedures and assessment criteria that allow knowing, assessing, and determining the advantages and disadvantages of the proposal in order to decide on its feasibility and to make the necessary adjustments before starting to upscale the process. This does not imply that planning must be rigid and inflexible. On the contrary, it needs to allow for the necessary adjustments to take place during the operation phase while keeping the objectives that gave rise to the original plan (Brunner, 1999).

Although projects showing the efforts made in the use of technology in education have been carried out in Latin America and the Caribbean, there is still a lot to be done concerning educational scenarios related to ICT. Projects with this intention will have to consider, among other things, the recommendations made by international organizations and develop mechanisms for interchanging projects among countries (UNESCO, 2001a).

It is especially important that the region learns to select the best experiences from both the industrialized countries, as well as those stemming from the region itself, and that it develops the capacity to tailor these experiences to the needs and characteristics of different educational scenarios. To develop sustainable educational projects it is necessary to identify alternative sources of sponsoring, communicate innovative proposals, build educational networks, and bring into public attention (and thus preserve) the region's heritage, culture, and idiosyncrasy. To accomplish this, the training of technical and professional experts, people capable of reconciling the varying interests of the community, will have to be properly rethought.

Based on the tenet that no country can forfeit the use of technological progress in education, it is important to develop those strategies that allow focus not only on overcoming educational deficiencies, but also on strategies that can ensure high quality of the contents being offered through these technologies, and guarantee their proper use on the side of those individuals who are being granted access to them, which is why such strategies must be adequately supported through local, regional, and national policies.

It is important to bear in mind that some of these attempts have occurred in response to the inertia of international policies and the demands of market globalization. When economic policy overshadows educational policy, one is at risk of losing one's perspective about the true educational needs that ought to be catered for.

Reflections and Further Steps Toward Improving ICT Policies

Sadly enough, countries have not been able to systematize the educational experiences in the Latin American region into the form of a matrix as is done in the other chapters in this section of the Handbook, as the information at hand was not adequate. On one hand, it is necessary to enhance research about ICT in education in the Latin American and Caribbean region so as to be able to learn about what is being done, how it is being done, and what results are being achieved. Then, based on experience, one must stop and reflect upon the poor as well as the acceptable practices to eventually correct strategies, provide feedback, and redirect the research already done. Thus each new project can be enhanced, opening a window of opportunity for the replicating of such research.

ICT is available and it plays an important role within our cultural and, to a certain degree, within the educational scenarios of the region. Yet, the path to implement ICT is not necessarily preset, which is why research and systematization efforts need to be addressed so as to enhance the bases through which an adequate orientation is to be achieved. In this regard, the following are potential actions to take into consideration:

- With the help of ICT a regional catalog of tested educational programs could be created, containing relevant information on methodological criteria, operation context, achievement, and insufficiencies.
- Conducting comparative studies and evaluation studies on the use and application of technology and media within specific learning environments (face to face or distance learning) involving different technological and communicational approaches.
- Creating a database of best educational practices by thematic content, level of education, and educational area, with an assessment of the results rendered, in order to be replicated or reformulated through the use of technology.
- Collecting educational experiences where other media (TV, radio, press, low-cost media) were used. Owing to its coverage, TV continues to be a powerful resource: its messages reach wide and diverse audiences regardless of the quality and cultural level of the productions. Nowadays, the convergence of media is a reality.
- Designing educational services for different groups, with specific topics based on the pertinent use of technology within participant models. After evaluation, such topics could be logged and later distributed among the academic community of the region.
- Avoiding the use of new technologies in education, when guided only by a false modernization scheme. The aim would be to reach a decision based on potential advantages and usability, as against other media, perhaps more beneficial and adequate to the context where they are to be used.

Technology is an important component of today's society, but it is by no means the magic answer to educational problems. Not every technological application renders similar results when used in different scenarios. Success depends upon both a prudent selection of technological resources as well as the models and methodology through which they are employed in reforming education.

It is of paramount importance that school institutions promote the incorporation of ICT through projects that cater to the schools' educational goals. It will turn ICT into true instruments for learning betterment, serving teachers and students, pedagogical advisers, educational authorities, and parents, who might be in search of opportunities for training and knowledge acquisition.

Thus, it is necessary to bear in mind the infrastructure conditions required for all Latin American and Caribbean inhabitants in order to be able to have access to and take advantage of the options offered by educational technology involving ICT. In this regard, it is important to observe each country's current connectivity condition, so that governments could trigger the necessary mechanisms for a reduction of the digital divide. This will undoubtedly be very beneficial in structuring any possible educational scenario with technology projects.

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11.7

IT AND EDUCATIONAL POLICY IN THE SUB-SAHARAN AFRICAN REGION

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Socioeconomic, Educational, and Cultural Context

Through the lens of critical analysis, this chapter presents an overview of information technology (IT) and education policies in sub-Saharan Africa (the African countries south of the Sahara desert). The focus is on sub-Saharan Africa, not Africa in total, as Northern Africa is similar in many ways to the Middle East. IT-in-education policies in Northern Africa and the Middle East are discussed in the next chapter of this section (Ibrahim, 2008).

The sub-Saharan region is a big one with diverse ethnic groups and different socioeconomic and education systems. There are 42 countries located on the sub-Saharan African mainland and 6 island nations. Before the 1960s, most of sub-Saharan Africa was under European colonization. In the nearly four decades after attaining political independence from the major European colonial powers, education has been seen as playing a central role in promoting the social and economic development of the region. As the political transformation of sub-Saharan Africa took place, leaders of newly independent governments viewed colonial educational policies of the past as biased against economic development, especially given the relatively low levels of educational enrolments in most sub-Saharan countries at the time, and the relatively small numbers of secondary- and higher-education graduates that were being produced.

Given sub-Saharan Africa's historical legacy, most of the region's educational systems have been modeled largely on their European counterparts. Although sub-Saharan educational institutions have been modified partially to respond to local conditions, by and large, formal educational programs reflect the basic primary-, secondary-, and higher-education structures and standards found in

J. Voogt, G. Knezek (eds.) *International Handbook of Information Technology in Primary and Secondary Education, 1145–1159*.

European countries. For most sub-Saharan countries, this meant that educational policy and the allocation of resources to education have taken place essentially through the public sector rather than through the private sector, at the national level rather than at the local level, and frequently through the coordination of educational policy targets with national development planning of one form or another (LeBel, 2000).

According to LeBel (2000), a common assumption in many sub-Saharan countries has been that the setting of national educational policy reflects popular demand in which decisions are based on popularity and not entirely on proper educational needs assessment. As elsewhere, in sub-Saharan Africa, education contributes to economic growth. Yet as sub-Saharan countries confront recent low rates of economic growth, and as the social demand for education increases, the educational sector is in a bit of crisis (LeBel, 2000). The protracted and deep-rooted economic crisis that has affected nearly every country in sub-Saharan Africa has adversely impacted on the well-being of the majority of the people (Mayor and Binde, 2001; Sarr, 2000; Teunissen and Akkerman, 2005). As a consequence, many sub-Saharans have experienced a decline in their welfare owing to a fall in real incomes and declining social sector expenditure per head (Basu and Stewart, 1993).

In addition to that, many of the current education systems in the region are unable to cater for all their learners (at both the formal and nonformal levels). The education systems are often stretched with less-than-necessary financial resources, reduced number of teachers (many of whom are either under- or unqualified), and insufficient and poor-quality learning resources (Naidoo, 2003).

At the same time, the world has entered the knowledge and information society, driven by information and intellectual products as raw materials (see also Anderson, 2008). In this context, the ability to transmit data over an information and communication infrastructure is a crucial resource for any nation to participate effectively in the global information society and to address development challenges. This poses an additional challenge to sub-Saharan countries as education may demand more IT infrastructural resources. However, the successful deployment of ITs can contribute to the development of knowledge societies in the sub-Saharan countries and contribute to bridging the digital divide.

Despite the daunting challenges facing basic education in sub-Saharan Africa, the region is finding its own way in education. And even though resources are limited, there is no shortage of innovation, optimism, and courage. There is reform in the education sector to improve the availability, quality, and equity of basic education in the region (Nwaobi, 2007; LeBel, 2000). The social and economic progress of the sub-Saharan people, durable peace, and sustained development in sub-Saharan Africa depend on the success of the education systems. Nowhere in the world has sustained development been attained without a well-functioning system of education, without universal and sound primary education, an effective higher education and research sector, and equality of educational opportunity.

Rationales and Influencing Factors for a Policy About IT in Education

The reforms in sub-Saharan education systems are geared towards achieving United Nations millennium development goals (http://www.un.org/millenniumgoals/). Recently, the continent's education ministers adopted a 10-year plan in which science and technology teaching must undergo reform at all levels of sub-Saharan educational systems (African Union, 2006). The plan pronounces teaching methods that should highlight links between science and technology on one hand, and the learner's culture and environment on the other. The plan aims at improving learning outcomes, promoting the use of indigenous knowledge, and encouraging more girls to pursue scientific careers.

Science and technology education is seen as the most important tool in existence for addressing challenges to development and poverty eradication, and for participating in the global economy (Okrah, 2004). Technologies such as IT are perceived and therefore employed to bring the plan to success. IT is seen to provide a window of opportunity for educational institutions and other organizations to harness and use technology to complement and support the teaching and learning process. Furthermore, IT appears to have the potential to transform the nature of education: where and how learning takes place and the roles of students and teachers in the learning process. Naidoo (2003) pointed out three key points, or benefits, of IT that the region can enjoy: IT can result in improved learning; It offers the greatest support to learners from disadvantaged backgrounds; and it impacts the society in which the learners reside.

The task for the education sector is to identify ways of creating necessary conditions within the education system to maximize the benefits of IT, and thus support development. Proper acquisition of skills for productively transforming knowledge and information into innovative products and services will define successful knowledge economies and societies. Because knowledge and information have become the most important currency for productivity, competitiveness, and increased wealth and prosperity, nations of the region have placed greater priority on developing their human capital. The sub-Saharan governments at different levels are thus focusing on strategies to increase access to and improve the quality of education through IT (United Nations Economic Commission for Africa [UNECA], 2003).

Mansel and Wehn (1998) noted that knowledge and human capital are essential to all aspects of development. They further observed that key to this form of development is to ensure that all people in a country have the ability to acquire and generate knowledge. This is where IT becomes vital. They are the primary tools to enable the acquisition, generation, access, and use of knowledge that forms the bedrock of effective development. IT needs to be enhanced by an IT policy that ensures people are capable of using it to source and assimilate information and transform it into useful knowledge. IT policy often defines broad strategies and approaches to issues; sometimes polices establish more-specific actions. The rapid integration of IT into learning environments raises many issues that demand the development of effective IT policy. IT policy issues are particularly diverse and challenging, in part because the rapid rate of change in the technology continues to create new possibilities for use and the need to find the best ways to implement them.

At the beginning of 2006, 28 of the sub-Saharan countries had developed national IT policies aimed at ameliorating the realization of national development goals (UNECA, 2006). These policies were general in the sense that it was at the discretion of each government ministry to develop appropriate implementation strategies. An IT policy implementation strategy or framework for the education sector is very essential. This is because for sub-Saharan countries IT can revolutionize the learning and teaching processes, open new learning opportunities and access to educational resources well beyond those traditionally available, and impact curriculum development and delivery (Umat, 2000; Coutts et al., 2001).

Although IT revolution holds great potentials in supporting and augmenting existing educational as well as national development efforts in sub-Saharan Africa, several challenges remain. These challenges include the following (Grant, 2004; Tearle, 2003):

- Inadequate IT infrastructure, including computer hardware and software, and communication network (bandwidth/access).
- Lack of skilled manpower to manage available systems and inadequate training facilities for IT education at all levels.
- Resistance to change from traditional pedagogical methods to more innovative, technology-based teaching and learning methods, by both students and teachers/academics.
- Underfunding of the overall educational system, as available funds are used to solve more-urgent and important survival needs of the schools and institutions.
- Overdependence of educational system on government for everything, which has limited schools' and institutions' ability to collaborate with the private sector or seek alternative funding sources for IT educational initiatives.
- Ineffective coordination of the IT-for-education initiatives.

This list is not exhaustive but represents the major problems faced in the development of IT for education in the region; but when adequately addressed, the chances that e-education (which is about connecting learners and teachers to each other and to professional support services, and providing platforms for learning) will thrive in sub-Sahara will increase dramatically.

The challenge of providing modern technologies to sub-Saharan schools in order to enhance the quality of learning and teaching requires a significant investment. In view of the above-mentioned observations the IT policies in education in sub-Saharan Africa must address at least six strategic objectives: IT professional development for management, teaching and learning, electronic content resource development and distribution, access of IT infrastructure, connectivity, community engagement and research and development (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2004, 2005).

Naidoo (2003) noted that attempts to integrate IT into the education system entails the leadership of the government and the education ministry, working together with other relevant ministries. Leadership must have a clear vision of the mechanism that the government intends to use to implement IT. This vision then needs to be integrated with national policies. Walker (1989) observed three preconditions for a successful introduction of new information technologies into an education system:

- An appreciation by the government of the financial, resource, and operational requirements and the resulting consequences.
- A commitment by government to give time and take responsibility for decision-making and implementation strategies.
- A commitment to a policy of an integrated support service encompassing teacher and technician training, curriculum and assessment, together with software and hardware provision.

Such an approach helps to build IT within a broader environmental context of the education system, covering economic and social infrastructure and policies and global market conditions. Also reflecting this broad context, UNESCO (2004) proposed generic elements that any policy on IT in education should cover, which are as follows:

- A careful analysis of the current context that the country finds itself in with respect to the type of society and economy that is being built and the education system necessary to contribute to it.
- Research and analysis of international developments and trends in IT use in education.
- An outline of the key issues that need to be addressed, together with proposed methods of doing so.

From experiences in Asian countries, UNESCO recommends a holistic approach to IT-in-education policy. This policy considers as crucial the integration of other aspects, such as the curriculum, assessment, IT resources, professional development of teachers, research and development, and fund generation.

In the context of education, having a sound policy, as well as an implementation strategy that complies with that policy, could result in a more systematic introduction to and use of IT. Once policy and an implementation strategy for using IT in the education system are developed, the next step is ensuring that the policy is integrated into the general education policy, and other related policies.

Ten elements have been identified that offer critical success factors for the use of IT in the education system and are, therefore, necessary in any IT-in-education policy. The key point is how IT policies are transformed into action, driven by a vision and supported by a blueprint and a roadmap. This contention has been corroborated by two studies on analyzing the experiences with IT application in sub-Saharan schools (Isaacs and Broekman, 2001; Yates, 2001). The ten elements are as follows:

- *Preparing schools to accept IT:* This includes constructing a policy to ensure availability of certain minimum infrastructure requirements, such as electricity, phone lines, school buildings, safe and secure environment, and insurance, for use of IT in schools. This is a heavy investment, and for practicality reasons, many sub-Saharan countries will have to do this in phases.
- *Procuring and installing the technology:* A policy statement that addresses the type of hardware, operating systems, and software conducive to school

environments in the county, or at least a decision-making framework, is necessary. This includes models for efficient, affordable, quality access to the Internet for schools. Such elements would also need to set student–computer ratio targets and technical support mechanisms. Bureaucratic tendencies in the sub-Saharan countries may be a bottleneck in the process.

- *Training teachers to use IT:* Teachers need to understand how to apply IT to support their teaching and administration. Therefore policies should identify ways of improving teacher capacity in the use of IT as well as their specific integration into teaching systems and pedagogical models. The policy should also outline the type of additional staff required to support computers and related technologies in schools. There is not enough expertise in this area but countries may collaborate to train trainers. For example, countries may collaborate to design teacher training models, organize a unit to train trainers from different countries, evaluate the effectiveness of the teacher models, etc.
- *Content development and management:* The added value of IT in schools is best realized when appropriate content is developed and used to enhance and support learning, teaching, administration, and management. This involves the production and consumption of appropriate IT-education content relevant to the local context. Therefore, policy in this area is vital to provide guidance for the development and use of content.
- *Planning for continuous evaluation and research:* Policy on research and evaluation is critical within the context of dynamic and changing IT and its application to the education environments. The constant research and evaluation agenda will ensure that improvements are made to how IT is used in the education system, and these data and analysis will contribute to any review of policy.
- *Integrating curriculum:* IT on its own has limited uses in the education and training system. Its intrinsic value lies in its integration in education to support and enhance learning and teaching in various subjects. Policy alternatives that identify mechanisms and frameworks that encourage this integration are, therefore, important. The world is still struggling to find out how IT can best be integrated into different subject areas, as a kind of augmentation to existing programs. Learning from each other may prove to be a key to success.
- *Computer literacy and Science courses:* Currently, computer literacy courses are offered in ad hoc basis in secondary education in many of these countries. In addition, computer science is one of the programs offered at polytechnics and undergraduate programs in the region.
- *Providing ongoing technical support:* The use of IT in the education system requires different levels of technical support. Policy on using IT in education needs to identify the levels of technical support necessary and outline how those needs would be addressed. For example, technical support based within the school, which requires trained teachers; technical supports via help facilities through contracts with local technicians and companies; technical support based in key schools in rural areas – all could be factored into the policy.
- *Providing ongoing curriculum support:* Ongoing professional development for teachers is crucial to enable increased and better use of IT. Such support would

include how to integrate the use of IT when teaching different subjects. Policy in this area should be explicit so that teachers know what is expected of them and the type of support they can expect.

– *Developing partnerships:* Implementing IT in the education sector requires a substantial amount of money and skilled personnel. Therefore partnerships between government and the private sector, development agencies, school communities, and others become important. The identification of this approach is important to include in any policy document.

The implementation of these success factors on developing IT policy and using it in education vary in emphasis from country to country in the sub-Saharan region. Some countries piloted IT use in schools and trained teachers without an IT-in-education policy, for example, Kenya, Uganda, and Tanzania. Others, for example Mauritius, find it important to have a policy to serve as a framework and guide. Because of better economic advantages, South Africa is ahead in developing and implementing IT policies in its education system. These differences in development stages among countries in the sub-Saharan region are dealt with in the next section of this chapter.

Specific Policies About the Introduction of IT in Education

Studies of IT development in both developed and developing countries identify at least four broad approaches through which educational systems and individual institutions typically proceed in their adoption and use of IT (Anderson and Van Weert, 2002). Sometimes, the number of stages identified varies. However, there is a consensus that the introduction and use of IT in education proceeds in broad stages that may be conceived as a continuum or series of steps. These steps are termed as follows:

– *Emerging:* Initial phase. Administrators and teachers are just starting to explore the possibilities and consequences of using IT for school management and adding IT to the curriculum.
– *Applying:* In this phase, administrators and teachers use IT for tasks already carried out in school management and in the curriculum.
– *Infusing:* Involves integrating or embedding IT across the curriculum, and is seen in those schools that now employ a range of computer-based technologies in laboratories, classrooms, and administrative offices.
– *Transforming:* IT becomes an integral though invisible part of daily personal productivity and professional practice. The focus of the curriculum is now learner-centered and integrates subject areas in real-world applications.

The steps represent a continuum of approaches to IT development. They are similar to the categories discussed by Moonen (2008) in the introductory chapter of this section of the handbook.

Countries in the sub-Saharan region are at different stages of IT policy implementation, in terms of infrastructure, curriculum, content development, technical support, and usage of IT in the teaching-and-learning process. In the typical sub-Saharan schools equipped with IT, computers are often second-hand and cannot run complex software; electricity supplies are unreliable; and access to computer rooms is limited by the competing demands of teachers, students, and administrators. Owing to lack of training and familiarity with computers, teachers do not know how to browse and find Internet materials and are not familiar with educational software. These differences are not only varying from country to country but even within the individual countries. There are uneven developments from region to region, area to area, and even from institution to institution. National priorities and strategies for IT implementation in education differ widely from system to system. However, although there is variation in terms of the structure of education systems and other aspects of the economic and social context, there are also strong similarities in the pathways of change in terms of the goals of introducing IT in education.

In view of the above-mentioned observations, a framework to be able to situate a country in its development of IT-in-education policy is helpful. The framework might also be useful to show the interrelationship of various components of IT implementation and in portraying how complex systems operate. The framework (see Table 1) provided by Moonen (2008) is used to situate the IT-in-education policies of sub-Saharan countries. The status of IT in African countries as described by UNECA (2006) provided information to fill-in the framework.

From Table 1 it is clear that only six countries in the region are without IT policy. These countries have had political crisis, which somehow contributed to the lagging behind in developing national IT strategies. Except for Somalia, which has been without a government for the past 15 years, the other countries have a lot of uncoordinated IT activities going on, initiated mostly by private sector and civil society. There has been growth in the installation of IT systems and articulation of benefits, but limited know-how to access has lead to underutilization in these countries.

Quite a few countries are in the planning stage of preparing IT policies. Some of these countries have been reluctant to act and remain in this phase for too long, for example, Zambia and Botswana. These countries have draft documents which are to be ratified by parliament or other decision-making organs. In Botswana, they have a Revised National Policy on Education that emphasizes the importance of proficiency in computer use by students and their teachers. Also the Ministry of Education has pursued an aggressive roll-out campaign to equip all secondary schools with a fully networked computer laboratory with at least 20 computers and access to the Internet. Teachers are prepared for the integration and infusion of IT into, and across, the curriculum; heads of schools are also trained to support resourcing initiatives. In addition, computer-integration support officers are trained to pass IT skills to their colleagues at school level. IT is taught as a subject and but is not examinable (Chisholm et al., 2004). However, teachers are not satisfied with their training and a systematic approach in training teachers is needed (Batane, 2004).

In the other countries similar initiatives are in progress, though not on such a large scale as in Botswana. Also civil societies and the private sector in these countries have been very active in their own ways to integrate IT in business and education. The problem is only that these efforts are not guided by any policy.

Majority of the countries in the region have an IT policy and have started to implement them either on an ad hoc or small project basis. For example, Tanzania has

Table 1 A summary of IT implementation in Sub-Saharan countries

	No policy yet	Emerging policy	Applying policy	Infusing policy	Transforming education by policy
National/subnational policy document for IT in education	Er, Lr, So, Tg, Gw, St	Ao, Bw, Cm, Cf, Cd, Ga, Gm, Ls, Si, Sz, Zm, Zw	Bj, Bf, Bi, Cv, Km, Cg, Ci, Dj, Et, Gh, Gn, Ke, Mg, Mw, Ml, Mz, Na, Ng, Rw, Sn, Sd, Tz, Ug	Mr, Sc, Za	
Master plan with a time frame			Bj, Bf, Cv, Km, Cg, Ci, Dj, Et, Gh, Mg, Ml, Mz, Na, Ng, Rw, Sn	Mr, Sc, Za	
Budget plan and appropriations			Na, Rw	Mr, Sc, Za	
Organizational structure responsible for implementing the master plan		Ao, Bw, Ga, Gm, Ls, Sz, Zm	Bj, Bf, Cv, Km, Cg, Ci, Dj, Et, Gh, Mg, Ml, Mz, Na, Ng, Rw, Sn	Mr, Sc, Za	
Monitoring and evaluation scheme or mechanism					
Statement of inclusion of women, minorities, and those with special needs in IT policy			Bj, Bf, Cv, Km, Cg, Ci, Dj, Et, Gh, Mg, Ml, Mz, Na, Ng, Rw, Sn	Mr, Sc, Za	
Manner by which the country and schools implement IT for education if no IT policy exists		Ao, Bw, Ga, Gm, Ls, Sz, Zm			

Abbreviations of countries: Ao Angola, *Bf* Burkina Faso, *Bi* Burundi, *Bj* Benin, *Bw* Botswana, *Cd* DRC, *Cf* Central Africa Republic, *Cg* Congo, *Ci* Cote D'Voire, *Cm* Cameroon, *Cv* Cape Verde, *Dj* Djibouti, *Er* Eritrea, *Et* Ethiopia, *Ga* Gabon, *Gm* Gambia, *Gh* Ghana, *Gn* Guinea, *Gw* Guinea Bissau, *Ke* Kenya, *Km* Comoros, *Lr* Liberia, *Ls* Lesotho, *Mg* Madagascar, *Ml* Mali, *Mw* Malawi, *Mr* Mauritius, *Mz* Mozambique, *Na* Namibia, *Ng* Nigeria, *Rw* Rwanda, *Sc* Seychelles, *Sd* Sudan, *Si* Sierra Leone, *Sn* Senegal, *St* Sao Tome and Principe, *Sz* Swaziland, *Tg* Togo, *Tz* Tanzania, *Ug* Uganda, *Za* South Africa, *Zm* Zambia, *Zw* Zimbabwe

started by ensuring teachers colleges get equipped with basic IT infrastructure, and all graduates from the colleges are IT literate and have basic skills to integrate IT in the curriculum (Unwin, 2005; Mendes et al., 2003). The college's curriculum also supports the integration. The government is also in the planning stage to provide all secondary schools with IT infrastructure by 2015. In Kenya, the Ministry of Education has launched a multimillion Information and Communication Technology Trust Fund and committed to providing 2,500 of the 3,500 public secondary schools in Kenya with computers by the year 2008 (Omwenga, 2006). In Nigeria several initiatives by government, civil society, and the private sector are underway towards IT policy implementation for rapid replication of best practices (Mac-Ikemenjima, 2005). Similar stories are evident in other sub-Saharan countries.

Only Mauritius, Seychelles, and South Africa are in the infusing stage of policy implementation. The two islands are more advanced because of their small population and the more-dynamic nature of the ethnic composition of the population. The main resource of Mauritius Island is human capital; the government is committed to make IT the fifth pillar of its economy. The Mauritius government also intends to convert the island into a "cyber-island" (Eastmond, 2006; Lincoln, 2006). IT is used in most schools. Since 2003, IT has been introduced as a subject in primary schools. For Seychelles, the Ministry of Education has developed an IT master plan (Ministry of Education, 2000) since year 2000 with goals and strategies to use IT. The government has put in place policies promoting the use of IT across the system at both organizational and capacity-building levels. The application of IT in educational processes at schools and at higher-education levels has become a main priority for the Seychelles government (Chisholm et al., 2004). IT is implemented in the secondary-school curriculum. Teachers are trained to manage the IT system. South Africa on the other hand is a much bigger country. Because of her economic muscle the level of integration of IT in the curriculum is quite high in a substantial number of schools. The South Africa targets for 2007 in e-education white paper (Department of Education, 2004) include the following: building an education and training system to support IT integration in teaching and learning and improved management and administration, teachers' and managers' confidence in the use of ITs, framework for competencies for teacher development in the integration of ITs into the curriculum; ensuring that schools use education content of high quality, that schools are connected, have access to the Internet and communicate electronically, that communities use and support ICT facilities.

However, funding has always been a perennial hurdle for IT projects or programs in these infusing-level countries as it is in all other countries in the region.

Reflections and Future Steps to Improve the Introduction of IT in Education

Using IT in education may be the answer to alleviating the educational crisis that sub-Saharan Africa is experiencing. The identification of critical success factors related to IT interventions in schools is necessary.

A phased implementation of IT policy in education ensures that the implementation process is manageable and the development of best practices and lessons learned are gradual. It also provides opportunities for evaluations so that the policy can be revised and fine-tuned.

IT infrastructure is the backbone of the IT venture in education. Therefore it is important that sub-Saharan African governments mobilize support from telecommunications and IT organizations and industry to promote affordable Internet connectivity and computer hardware and software. High costs of telecommunications prohibit schools from adopting IT, especially in the rural areas. But, technological innovation and the decreasing costs of wireless and other technologies, combined with progressive policy and regulatory environments, have resulted in the provision of telecommunication services to remote areas in Latin America, Central Europe, and Asia, traditionally thought unserviceable by incumbent telecommunication companies (UNESCO, 2004). In a policy move inline with this increasing number of success stories in other parts of the world, some sub-Saharan African governments have allowed for the introduction of smaller-scale participants into the telecommunications market to provide services in underserviced areas to enable rural areas experience some benefits of ITs. Other governments facilitated the use of broadband communications through the introduction of competition policy with flat and low tariffs, encouraging private sector's investment for new services, including ADSL, and removal of taxes on imported PCs; for example, Tanzanian Government has been doing this since year 2001. These measures encourage implementation of IT policy in education.

Also in order to enhance the reach of IT in education, there is a need to develop practical measures that will be helpful in gauging the extent to which objectives are being met. The following are some of the suggested measures (Lawson and Comber, 1999; Grant, 2004):

– ITs are incorporated into education and institutional administration (includes record-keeping and decision-making).
– Functional access to technology occurs in all schools regardless of geographic location.
– Computers are used in the instruction of all content areas.
– Computers with Internet access are available to all students and teachers during, as well as outside of, formal class time.
– Students graduate with IT skills, which can be employed directly in the world of work.
– Distance education is widely used to make up for shortfalls in physical capacity and reach of the local education system.

With these measures, IT can impact not only education but also the culture and economy of the region.

The sub-Saharan governments need to be careful to avoid past failures of investment in computers and connectivity that have occurred in other regions of the world. These failures relate to the following (Hawkins, 2002; Robertson, 2003):

– An emphasis on quantitative benchmarking based on rough indicators such as pupils per computer or investment in the technological infrastructure.
– The realization that an investment in IT infrastructure solely does not lead to adoption of IT in the learning process.
– IT investment often being made without the necessary complementary developments in teacher training, content, partnership, and organizational and regulatory

frameworks to promote participation of private providers in the development of IT in education.

Some issues may hinder policy implementation. Grant (2004) admonished that the effective implementation of policies and ideas necessitates identifying and forecasting potential challenges in the environment. Some of these challenges and threats particularly pertinent to sub-Saharan situation are as follows:

– Lack of IT expertise among policymakers.
– Lack of coordinated planning.
– High opportunity cost of technology.
– Limited budget allocation for IT maintenance.
– Shortage of teachers with IT skills.
– The dominance of English on the Internet and general computer software, which makes it challenging for sub-Saharan countries whose main language is not English.
– Possibility of widening instructional and achievement gaps among schools.
– Lack of acceptance and support from parents and the community as a whole.
– Lack of legislative and policy implementations that ensure the longevity of initiatives, especially in countries where changes in political administration are likely to disrupt policy implementation.

Having a comprehensive IT policy in each of the sub-Saharan countries is something unavoidable if the region is serious about preparing future generations for a knowledge economy. On contemplating what is required of policymakers, the following ideas are put forward:

– The educational transformations associated with technology are that technology is not a mere ingredient that "boosts" teaching and learning. Rather, it is part of a collective project of educational communities, and the outcomes of that undertaking depend on a multitude of decisions at the local (schools) as well as the national and global level.
– Research input into the implementation process is important but we need to reconfigure the systems of educational research and teaching so that we can respond more quickly and establish a more-dynamic knowledge base on questions of IT use in education. Through research, justification of continued investment of funds for IT in education can then be made, and educators, policymakers, educational researchers, and the public will know what can be gained by using technology in schools, and at what costs.
– IT has the potential to enhance access, quality, and effectiveness in education in general and to enable the development of more and better teachers in sub-Saharan Africa in particular. As computer hardware becomes available to an increasing number of schools, more attention needs to be given to the capacity-building of the key transformers in this process, namely, teachers. Teacher education is paramount in the success of IT integration in the curriculum.
– Currently, there is a strong convergence of support for *the social construction of knowledge* – the idea that learning emerges from an active, collaborative process

of constructing understandings, or knowledge. Hence teacher education needs to focus on integration of well-designed technologies in the context of meaningful, mindful inquiry projects, nonpresentational pedagogies, access to resources and tools, and adequate support for technological maintenance and pedagogical renewal.

– One of the phenomena of recent times has been the enthusiasm with which Africans have adopted cell-phone technology(BBC, 2005; The Times, 2006; USA Today, 2005).Clearly, there is a pressing need to communicate, and the attraction of going from no telephonic communication to a mobile phone has provided a huge impetus to this industry. Prepaid payment methods have fuelled the demand, and growth is still strong. In education a similar trend can happen. Schools in the sub-Saharan region are not equipped even with basic resources as in the Western world. Owing to necessity, Internet and other IT products can prove to be as successful as the cell phone. Policymakers need to seriously think about how to fuel the demand for IT in their educational systems.

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11.8

IT AND EDUCATIONAL POLICY IN NORTH AFRICA AND MIDDLE EAST REGION

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Socioeconomic, Educational, and Cultural Context

The pace of globalization today is faster and more sweeping than in previous times in history, a trend that is forcing education to react. The emergence of Internet and the use of e-learning – in this chapter the term "e-learning" is used to globally describe the use of IT in education – implies that a greater part of the earth's population is now engaged, at least potentially, in a global approach to education and training. The continuing rapid change in the computing infrastructure, the Internet, and multimedia computing and communication have a great impact on the educational system. This evolution in the educational process is a major issue of concern in most developing countries and also in the Middle East and North African regions, which consist of 18 Arab-speaking countries and Israel.

The public and corporate sectors need the most advanced skills and the most updates of equipment and access to training to remain competitive. Government, institutes in the Middle East and North Africa, and policy makers are acknowledging the potential downside of the rapid pace of globalization in relation to the need for integrating IT in their educational and training systems and the impact of globalization on change in skills development.

There are many perspectives to describe the socioeconomic, educational, and cultural context of a region. An interesting perspective, especially related to IT, is the so-called e-readiness index. The journal *The Economist* and in particular its Intelligence Unit (Economist Intelligence Unit, 2006) has published an annual e-readiness ranking of the word's largest economies since 2000. "E-readiness" refers to a country's ability to take advantage of the Internet as an engine of economic growth and human development. E-readiness has several components, including telecommunications infrastructure, human resources, and legal and policy frameworks. An e-readiness assessment can be used as an information gathering mechanism for countries as they plan their strategies for IT development. It can help a society better understand

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what impediments to Internet development exist and what initiatives are needed to overcome them. Currently 68 countries are assessed on their ability to promote and support digital business information and communication technology (IT) services. The ranking allows governments to gauge the success of their technology initiatives against those of other countries. Table 1 reflects the 2005 and 2006 e-readiness rankings of selected Middle East and North African countries.

Based on the aforementioned criteria and ranking in Table 1, it is clear that most Middle East and North African countries lag behind the rest of the world. In addition, the gap between the North African and Middle East countries and other countries in the world has increased over the last decade, fitting the general observation of a (digital) divide between the North and the South (UNDP, 2006a; Lamb, 1987; Mohamed, 2003). Specific data about priorities in public spending (see Table 2) and the diffusion and creation of technology (see Table 3) illustrate the problem. Table 2 illustrates that many countries in the ten countries sampled spend much more money on military than on education.

Table 3 illustrates the enormous growth between 1990 and 2003 of vital means of telecommunications, including mainline telephones, cellular telephones, and Internet users. The growth in the use of cellular phones is phenomenal while the growth in

Table 1 e-Readiness ranking of selected Middle East and North African countries

2006 Rank in region	2005 Rank in region	Country	Overall ranking (of 68)	e-Readiness score (of 10)
1	1	Israel	22	7.59
2	Not ranked	United Arab Emirates (UAE)	30	6.32
3	2	South Africa	35	5.74
4	3	Turkey	45	4.77
5	4	Saudi Arabia	46	4.67
6	Not ranked	Jordan	54	4.22
7	5	Egypt	55	4.14
8	6	Nigeria	60	3.69
9	7	Algeria	63	3.32
10	8	Iran	65	3.15

Source: Economist Intelligence Unit, 2006

Table 2 Priorities in public spending, for selected countries in the region (in % of the annual budget)

	Israel	Kuwait	UAE	Saudi Arabia	Lebanon	Jordan	Tunisia	Syria	Egypt
Public expenditure on health	6.1	2.7	2.5	2.5	3	4.2	2.8	2.5	2.2
Public Expenditure on education	7.3	8.2	1.6	n/a	2.6	n/a	8.1	n/a	n/a
Military expenditures	8.7	7.9	2.4	8.3	3.8	9.9	1.5	6.9	2.8

Adapted from Raphali, 2002

Table 3 Technology diffusion and creation in the region (numbers per 1,000 inhabitants)

	Israel	Kuwait	UAE	Saudi Arabia	Lebanon	Jordan	Tunisia	Syria	Egypt
Tel. mainline 1990	349	156	224	75	144	78	37	39	29
Tel. mainline 2004	441	202	275	154	178	113	121	143	130
Cellular subscribers 1990	3	10	19	1	0	[1]	[1]	0	[1]
Cellular subscribers 2003	1,057	813	853	383	251	293	359	126	105
Internet users 2003 (0 in 1990)	471	244	321	66	169	110	84	43	54

Adapted from Raphali, 2003

the number of users of Internet is substantial, but not across the board. The numbers for Saudi Arabia, Iran, Syria, and Egypt are low, although in the case of Syria the low number of Internet users may reflect the nature of the regimes in some countries that seek to keep their populations isolated from outside influence.

The data in Tables 2 and 3 lead to the conclusion that, although the use of communication facilities using IT is growing very substantially in the Middle East and North African region's countries, the expenditures in the educational sector are probably insufficient to educate the users about how to use these facilities for the benefits of learning. One possible solution to prevent that these countries fall even further behind in using information and high technology is to invest in using technology in education. The importance of this can also be seen in the fact that Arab Gross Domestic product (GDP) as a percentage of the world GDP is fast declining. For example, Oil-rich Saudi Arabia, United Arab Emirates (UAE), Kuwait, and Qatar collectively produce goods and services (mostly oil) worth $500 billion; while Spain alone produces goods and services worth over $1 trillion, Poland $489 billion, and Thailand $545 billion.

No sector of the economy is impervious to the progress of IT, and every sector has the potential to benefit from progress in IT. However, in and of itself, IT investment is unlikely to generate significant productivity gains; it needs to be accompanied by investments in training, organizational design, and collaboration.

Rationales and Factors Influencing a Policy about IT in Education

In recent time, the countries in the Middle East and North Africa evolved from a long history of colonization. At the same time, serious civil unrest is still going on in many countries of this region, which does not create a suitable environment for nurturing education and stability.

Political leaders, employers, and the public are expressing an unprecedented level of concern with the state of education in Egypt. At the beginning of the twenty-first century, the educational system is not ready to generate the skill competencies needed by the globalization of the world economy.

A new willingness to consider fundamental changes and innovative approaches is apparent in the current wave of reform efforts that involve legislatures, business coalitions, teachers, colleges of education, and school administrators (World Education Services, 2007). These educators, policy makers, and citizens are now seriously debating the structural reforms that would have seemed wildly idealistic just a decade ago. Many critics of the current Egyptian educational institutions view technology as an important driver for generating the kind of revolutionary changes called for in the new reform efforts. Having seen the ways in which technology has transformed the workplace, and, indeed, most of the region's communications and commercial activities, the business community, and the public in general are exerting pressure for comparable changes within the education system. One possible solution for enhancement of the education infrastructure is the integration of IT and the shift from conventional methods of teaching to innovate interactive multimedia and teaching methods and techniques (Youssef, 2007). The primary motivation for using technology in education is the firm belief that it will stimulate learning. Research and development educational programs, such as the Egyptian Education Initiative (World Economic Forum, 2006), have emphasized the use of new technologies in learning and management systems, content development, and for applying new pedagogical models. The main objective for the integration of IT is to find better tools and media for enhancement of educational systems. In this respect, several institutes such as the American University of Cairo have developed and integrated e-learning and IT technology for management of courses and electronic communication by the Internet.

The issues raised earlier are relevant to most Middle East and North African countries except for a few rich Gulf countries that are investing heavily in the educational system infrastructure and IT. The following paragraphs describe in a global the initiatives taken by the different countries of the region.

Several initiatives in North Africa and the Middle East have been developed recognizing e-learning and integration of IT in education as a tool for educational development and enhancement. At the start of the twenty-first century, Middle East and North-African countries are starting to embrace IT integration in education and training. However, often no clear policy or strategy has yet been implemented, but initiatives and procedures emerge that harness IT policy development. Examples of programs and pilot projects can be found in Oman (Knowledge Oasis Muscat, 2006); Jordan (Ministry of Planning and International Cooperation Jordan, 2004); Syria (Albirini, 2004); Lebanon (UNDP, 2003, 2006b); Israel (Fisher and Jacob, 2006); Qatar (ICTQatar, 2005); Bahrain (Kingdom of Bahrain Ministry of Education, 2004); United Arab Emirates (Digital Opportunity Channel, 2007); Saudi Arabia (Nair, 2006); Kuwait (Digital Opportunity Channel, 2007); Palestine (Hammad, 2005); and Algeria, Egypt, Libya, Morocco, Sudan, and Tunisia (United Nations Economic Commission on Africa, 2005b).

In addition to the implementation of IT in education through forms of e-learning, many of the countries in the region still require improvements of their general IT policies and strategies. The biggest challenges are weak policy and implementation capacity, opposition from vested interests, and persistent obstacles to adoption of IT. Many countries also lack adequate tools to plan, monitor, control, evaluate, and guide investments in IT and connectivity (United Nations Economic Commission on Africa, 2005a). One possible solution is benchmarking IT data and monitoring trends, themes, and programs supporting IT such as done by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) in Middle East and North African developing countries (UNDP, 2006a,b).

Timely and relevant policy announcements and guidelines help to foster IT penetration aiming at greater socioeconomic gains and growth. Steps like deregulation, encouraging private participation, tax and duty incentives, and wise spending of resources all help to integrate IT with national goals and its fulfillment. Public investment is a critical policy measure in many countries to develop the IT infrastructure.

Specific Policies about IT in Education

The main requirements for e-learning and IT-in-education policy development in the Northern African and Middle East regions are as follows:

- Social and cultural issues (interaction, collaboration, and communities of practice).
- Physical issues (tools, facilities and services, bandwidth, and browser versions).
- Content issues (themes, subjects and levels, pedagogical approaches).
- Political and economic issues (commitment of management and cost) (Nasr and Ibrahim, 2007).

In addition, the attitudes and competencies of learners toward IT need to be determined to be able to develop appropriate and timely IT policies for countries in North Africa and the Middle East.

Several initiatives to provide IT to the Middle East and North African regions have been initiated and supported by governments and international funding agencies. Other initiatives are the Competence Centre, PC for the Community Initiative, Free Internet Initiative, Broadband Initiative, the National eStrategy for Lebanon (UNDP, 2003), and conferences and workshops. These initiatives include the creation of Smart Schools Networked Learning in Egypt, where IT was introduced in schools (Halouda, 2005) focusing both on infrastructure and applications in order to qualify teachers to obtain the International Computer Driving License (ICDL) and to improve teaching and educational methods.

By using the framework proposed by Moonen (2008), clusters of counties in the Middle East and North African regions can be situated with respect to the implementation of their IT-in-education policy, taking into account the initiatives referred to in the previous sections of this chapter. Table 4 presents the status of implementation of IT policy of the various clusters of countries.

Reflections and Future Steps to Improve Policy about IT in Education

It can be predicted that e-learning will emerge as part of the future utility services provision for education, just as utilities for electricity in educational campuses and institutes. For example, in Al-Wakra Independent School for Girls in Qatar, book

Table 4 A summary of IT implementation in the Middle East and North African regions

	No policy yet	Emerging policy	Applying policy	Infusing policy	Transforming education by policy
National/subnational policy document for IT in education			NA, AC	G, IS	
Master plan with a time frame			NA, AC	G, IS	
Budget plan and appropriations					
Organizational structure responsible for implementing the master plan			NA, AC	G, IS	
Monitoring an evaluation scheme or mechanism			G, IS		
Statement of inclusion of women, minorities, and those with special needs in IT policy					
Manner by which the country and schools implement IT for education if no IT policy exists					

NA – North African countries (Egypt, Libya, Sudan, Algeria, Tunisia, Morocco); GC – Gulf Countries (Kuwait, Qatar, Bahrain, United Arab Emirates, Oman); AC – other Arab Countries (Lebanon, Iraq, Syria, Palestine, Saudi Arabia, Yemen, Jordan); IS – Israel

learning has been replaced by eSchoolbag learning. Portable and filled with information covering various subjects, these portable computers (Tablet PCs) let students take notes digitally, and then share and edit the information electronically.

The tablets are not just electronic notebooks. They are packed with materials on science, math, and English mapped to Qatari curriculum standards. They can be customized by teachers to fit individual student's needs.

Students can use the Tablet PCs to work independently in the classroom and at home, deepening their understanding of subjects. eSchoolbags also allow students to interact with teachers day or night.

The Infocomm Development Authority of Singapore – an e-learning pioneer – is working with ictQATAR to introduce eSchoolbag in Qatar's schools, as well as train instructors in technical and teaching skills.

In this respect, we will see e-learning and IT integration in education provided on digital TV networks on demand, and the customer can subscribe to a set of topics and disciplines that will be accessible through a Personal Learning Environment (E-learning Guild, 2006; Medhat, 2005). More innovation will be demonstrated as the Internet, digital broadcast media, and video telecommunications become more integrated.

To prepare for the integration of e-learning, Egypt, for example, is adopting a Scandinavian model indicated as one of the best performance examples of e-readiness (Ministry of Communications and Information Technology in Egypt, 2006). The model is based on innovation and leadership as the result of the ability to embrace change, shift priorities, and the courage to make tough choices. The Middle East and North African countries must realize that innovation is a societal phenomenon, a collective task, largely carried by the private sector. Taking the Scandinavian model as an example, the following are the key lessons learned: education, skills development, and lifelong learning must be at the center of an innovative economy.

In conclusion, it is important that the technology infrastructure does not become a key inhibitor for pursuing e-learning. At the same time, any infrastructure investments should be balanced with digital content development, and staff training to enable teachers to use e-learning materials related to their learners' needs. In addition, learning content that is generated needs to be stored, registered, evaluated, and integrated into an e-library (Digital Empowerment Foundation, 2006).

North-African and Middle East governments, professional bodies, and educational networks in the region could do more to promote e-learning solutions as part of their national skills development and lifelong learning strategies. In addition, there are clear strategic opportunities for collaborative developments of best practice to minimize the amount of overlap and maximize cooperation between organizations, governments, and institutes, in content development at the various educational levels.

The Middle East and North African educational institutes are entering a new world that is global, entrepreneurial, and competitive. Accordingly, instituting the appropriate policy, vision, and leadership, and investing in the future, the Northern Africa and Middle East regions maybe will be able to follow and participate in the technological shift and globalization.

E-learning allows educators and institutes to move from the industrialized model of the instruction to an "any time and place" model of learning. A school that is contained by time and space will be an old model and unable to compete in the globalization of the educational process that is based on a 24 × 7 learning model. In this respect, it is important to emphasize that laws, procedures, infrastructure, and attitudes are needed to support a knowledge economy.

To stimulate new initiatives, most schools face formidable challenges with regard to taking IT to every village (e.g., Garari and Shadrach, 2006) about the Indian experience. This experience is not very different from the typical development projects in the Middle East and North African regions. Some of these challenges include the following:

– Integrating IT in the very life of the school, as an essential part of an educational solution and not just as a technology centered project.
– Creating awareness amongst policymakers and convincing them about the usefulness of investing in education through IT.
– Developing beyond donor dependency and creating integrated national programs that are affordable and sustainable in the face of education budgetary cuts, how to read and write, and basic health education.
– Monitoring whether IT interventions in schools really add educational value to learners, teachers, and school management.
– Stressing the importance of policy, vision, and regulation reform in IT with focus on the poor.
– Acknowledging the importance of entrepreneurs and their initiatives for development of education and leading the change.
– Realizing the importance of professional managers, advisors, and experts for planning and execution of policy.

The steady rise in IT in education in developed countries is attributed to high incomes and normal population growth rate. Some developed countries in the Middle East and North Africa with huge population growth may not be able to realize a steady rise in IT penetration in education. To encourage the use of IT in education the adoption of an IT policy, which outlines the overall direction and guides subsequent action, is of paramount importance.

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11.9

POLICY FROM A GLOBAL PERSPECTIVE

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Introduction

In the previous chapters of this section, an overview has been given about major policies introducing and implementing IT in different regions of the world, mainly focusing on the school sector. The only region not included is the former Soviet Union and parts of Eastern Europe.

In the introductory chapter by Moonen (2008) and the next chapter about comparing policies by Kozma (2008), a general framework has been developed to describe policies developed in countries around the world. Eventually a specific matrix (see Moonen, 2008) was chosen to serve as organizational support to position different clusters of countries with respect to the introduction and implementation of IT in the school sector.

In this concluding chapter, the matrices developed for the regions of the world by the different authors of the regional chapters in this section are combined to get a global perspective about the use of IT in the school sector around the world. In this matrix, clusters of countries per region are categorized. Moreover, remarks made in the preceding chapters in addition to some personal observations are converged toward a conclusion about the success or failure of the policies developed, and for suggesting a path toward the future.

It is obvious that the level of introducing and implementing IT in schools depends on the level of economic development in and within the different regions. In the developed countries, mainly in Europe, North America, and in parts of the Asia–Pacific region, introducing and implementing IT has reached a point where the concept of IT-supported learning in education has been replaced by the concept of e-learning or by a comparable concept such as online learning or virtual learning environments (VLE). This change in terminology is not only a change in words but underlines implicitly the change from a focus on implementing hardware and software infrastructure toward a focus on communication and incorporating IT in the

J. Voogt, G. Knezek (eds.) *International Handbook of Information Technology in Primary and Secondary Education, 1171–1178.*

teaching–learning process. The latter also implies that the explicit policy focus on IT and education is fading. Using IT in education is becoming more implicit and incorporated in a broader policy context, especially around needed qualifications and competencies of citizens in a knowledge society (Anderson, 2008; UNESCO, 2005). This is most explicitly visible in the European region (see Delrio and Dondi, 2008).

It is also remarkable that in the different chapters of the Section, not much emphasis is given to explicit results, effects, or impact of the policies described. This is not a lack of focus by the authors, but because of a lack of convincing evaluation and assessment results. This is confirmed by a recent study by Bruns and Ungerleider (2003) as they conclude in their research of over 800 studies that "Simply put, we don't know enough about the impact of the use of ICTs in elementary or secondary schooling" (p. 47), further implying that there are too few studies of sufficient rigorous design to permit informed policy choices.

It remains, therefore, a question if this shift from explicit to implicit policy with respect to IT and education in the developed countries is being made as a reaction to the lack of satisfying results after many years of explicit IT policies to improve the teaching–learning process. This aspect is particularly highlighted in the description of the North American case, especially in the United States, where Patrick (2008) comes to the conclusion that the inclusion of IT in education will only be perceived as a success when it transforms the educational system, allowing education to deal appropriately with the needs of the twenty-first century.

The situation is much different in the other, less-developed countries around the world. Also because of economic circumstances, the drive to use IT in education has often just started. In many countries, this means a clear focus on implementing hardware and software infrastructure and dealing with teacher training issues. Moreover, also in those cases there is a lack of convincing evidence about the impact of those policies on the daily practice in schools.

Combined Overview

In Table 1, the results appearing in the matrices in the earlier chapters of this Section are combined. To improve the overview aspect of the results, the following symbols are used: each region of the world is symbolized by two letters; the first letter indicates the region (A = North America, E = Europe, P = Asia–Pacific, S = Sub-Saharan Africa, M = Middle East and North Africa; summary data were not reported in the regional chapter for the Latin America and Caribbean regions); the second letter refers to the evolutionary status of countries in a region with respect to implementing IT in education (L = Lower, A = Average, H = High). When combining the results of the matrices in the different chapters, the following results appear.

This overview indicates that only in the North American region and some countries in the Asia–Pacific region, there are existing policies explicitly striving to a transformation of the educational system. Given the comments in the previous paragraph, the question remains if a transformation effort has already become a success, or if the wish for a transformational effort is being implicitly supported and advanced. Most

Table 1 Synthesis of regional policies, by dimension and level

	No policy yet	Emerging policy	Applying policy	Infusing policy	Transforming education by policy	Definition
National/subnational policy document for IT in education	SL	PL, SL	EL, PL, PA, SA, MA	EA, EH, PA, PH, SH, MH	AH, PH	A policy document that provides for the mandate, goals, objectives, strategies and activities, organizational structure by the government (Ministry of Education) regarding IT use in education
Master plan with a time frame		PL	EL, PL, PA, MA	EA, EH, AH, PA, PH, SH, MH		A blueprint that transforms the policy into action as scheduled including who, what, where, when, how to achieve objectives
Budget plan and appropriations		EL, PL, PA	EA, PA	EH, AH, PH, SH		Budget allocations as included in the national and subnational or local budgets. It also looks into other sources of funds apart from government funding
Organizational structure responsible for implementing the master plan		EL, PL, PA, SL	EA, PA, SA, MA	EH, PH, SH, MH		Refers to organizational structure with item positions, job descriptions, and salary scale as either department, unit, or sector in the ministry with the primary function of implementing policy of IT for education based upon master plan. This structure could be either permanent, sub-contracted agency, or a committee

(continued)

Table 1 (continued)

	No policy yet	Emerging policy	Applying policy	Infusing policy	Transforming education by policy	Definition
Monitoring and evaluation scheme or mechanism		EL, PL, PA	EA, PA	EH, AU, AM, PH		Detailed plan to monitor and evaluate progress of implementation of activities based on master plan as evidenced by monitoring and evaluation schedules, instruments, plan of data gathering and analysis of monitoring and evaluation data and presence of reports
Statement of inclusion of women, minorities, and those with special needs in IT policy		PL	EL, PA, PH, SA	EA, EH, AU, SH		A special statement in the IT policy on education for inclusion of these special groups
Manner by which the country and schools implement IT for education if no IT policy exists		PL, SL	EL, PL	EA, EH		Often, countries are implementing IT activities or projects and using ITs in schools even if there is no national IT educational policy
Definition	No policy	Governments are thinking about it or planning it	Small scale (more or less ad hoc, or on a small project basis) implementation	Large scale (in a planned systematic way) implementation	Implementation is transforming fundamental structure of education	

The first letter stands for Region (A, North America; E, Europe; P, Asia-Pacific; S, Sub-Saharan Africa; M, Middle East and North Africa; summary data were not reported in the regional chapter for the Latin America and Caribbean region); the second letter refers to the evolutionary status of countries in a region with respect to implementing IT in education (L, Lower; A, Average; H, High) probably, the latter is the case, which can also be experienced in the European region where explicit policy about IT in education fades as the overall embedding of IT in society occurs.

As is indicated in the matrix, most countries of the world are actively pursuing policies in support of the use of IT in education. A logical sequence of events is followed: After initiating a policy, the next step is to provide hardware and software, or more generally, technical IT and communication infrastructure. When the infusing stage arrives, the policy has to deal more explicitly with pedagogical factors. Issues become much more complex and at the same time, much more intangible in terms of measuring their impact. Not surprisingly, countries that are "high performing" in the IT-implementation sequence are often experiencing an implementation "dip," as it is known in the pedagogical literature (Fullan, 2001). Trying to get out of the dip often leads to looking for new ideas, or in the case of IT implementation, looking for new technological functionalities. Combinations of such arguments then lead to the appearance of e-learning and/or its companion terminologies.

Another argument explaining the current situation is the lack of some of the essential ingredients necessary for a transformational change of the educational system. Reference is then made to the need for a policy that incorporates all of the aspects mentioned in the vertical dimensions of the matrix, or in more detail, the activities, described by Kozma (2008) as operational components of IT policies, and by Tilya (2008). Mentioned are activities such as infrastructure development, teacher training, technical support, pedagogical and curricular change, and content development. However, such comprehensive approaches have been applied in the past, not bringing the success that was expected either. A typical example is the IT-in-education policy developed in The Netherlands. In The Netherlands, a comprehensive policy plan called the Informatics Stimulation Plan (INSP) (Plomp et al., 1987) was introduced and implemented over a period of many years starting in the 1980s. The plan was supported by a very generous financial scheme. In the plan, five clusters of activities (infrastructure development, school sector-specific activities, in-service and preservice teacher training, and research) were created. After its expiration after five years of operation, the INSP was followed up in the 1990s and in the beginning of the new century by new schemes emphasizing the integration of IT into the school curriculum, teaching, and learning. After 20 years of explicit and comprehensive IT stimulation in the school sector in The Netherlands, a research report (Kennisnet ICT op school, 2006) about its impact indicates that much attention is still very much focused on technical aspects such as acquiring hardware, educational software, and content. The report concludes that there is a need for vision and competent teachers who are sufficiently equipped to use IT facilities in a pedagogical responsible way.

Although policy-supported schemes in many European countries had considerable impact on how schools' technological infrastructure changed over the years, the transformation effect on the pedagogy, and particularly the teaching–learning process within the boundaries of the school system, has not changed dramatically, or only on a small scale creating even then much discussion. Again, a typical example is from The Netherlands. In The Netherlands, much discussion is going on around what is called a "het nieuwe leren" ("the new learning"). The new learning approach is based upon stimulating the self-directed activities of pupils in combination with a more specific emphasis on competencies. Often this new learning occurs within a project-based approach supported by IT (and in particular the Internet and its search capabilities). The new learning approach is certainly a road toward transformation of the current educational system. This new approach started years ago in The Netherlands in the upper part of secondary education and was named "het studiehuis" ("the study house"). However, after years of experimenting, many critical comments were raised (particularly from students), resulting in a slowing down and therefore reduction of the transformational impact of the study house (Gerrits and du Pré, 2005; Veugelers, 2004). Later a similar new learning was stimulated on a much broader scale in the preparatory professional education sector (MBO). However, to the surprise of many, much opposition was raised by a broad combination of pupils, their parents, and parts of the teaching profession. The protest was so strong, and became even so political, that the Dutch State secretary of Education had to officially postpone the introduction of the new learning approach in this sector until there was evidence that through the new approach pupils will still attain the goals of the educational system (Doorduyn, 2007). Thus, although it can be argued that introducing and implementing IT in schools will only become a success if this leads to a transformation of the educational system, there is at the same time some evidence that a transformation of the educational system is very difficult, as was proven in the past with reference to many pedagogical reform movements. And there is also the argument explained in the first chapter of this Section: a policy can only become successful if it applies to what is called a "core" technology of teaching and learning in a given context (Collis and Moonen, 2001). Regardless of the overwhelming availability of IT technology in society, IT has not yet become "the" core technology in education. IT remains a wonderful and exciting "complementary" technology in the educational system. Therefore, a policy to stimulate transformational changes in education based on the implementation of IT has, as yet, no chance of succeeding.

A New Policy?

Given the long period of time, many European countries have gained experience with the planning and implementation of IT policies in education and the rather disappointing explicit results with respect to the pedagogical renewal of the educational system as a whole; maybe, this experience can be a reference point for other regions about what to expect, and what road to follow in developing their own policies.

The previous comments mention the lack of dramatic pedagogical transformational changes "within" the existing school systems. On the other hand, it is amazing how youngsters, all over the world, make use of technology to do what they like to do and also learn. Typical examples in the developed countries are provided by what is called the Web 2.0 tools and processes, with specific applications such as MySpace or YouTube. No pedagogical or instructional approach seems to be necessary for the young people to get ready for intensive use of these applications. No formal learning activities are necessary and are not available. Informal learning supported by technology and peer contact is doing the job. Only the widespread and user-friendly availability of IT is sufficient. No formal policy has been developed to stimulate these new attitudes. It is the availability of the technological infrastructure, its user-friendliness, its cheap price, and its philosophy of user control and contribution that is making it happen. These comments mainly refer to the pupils. Although many teachers are aware of these developments, there is still a serious lack of professional development in the teaching profession to facilitate these user-centered processes. Also within the teaching profession, informal learning through personal teacher networks instead of formal teacher training courses should become dominant (Inspectie van het Onderwijs, 2006; Pelgrum and Law, 2004). Also Valcke et al. (2007) conclude that "ICT policies are not well developed and reveal a partial match between policies, needs, and the actual in-service training."

Therefore for a sensible policy to improve the impact of IT on education, three main policy lines could be developed. First, basic knowledge and skills about IT should become available in basic education. Depending on the level of development of a country, teaching about it or supporting its use in daily school practice should be stimulated. Second, policy should support the creation and facilitation of informal teacher networks. Teachers (young and old) should be or become equals in attitudes and skills toward IT with their pupils. Third, policy should facilitate the use of IT by the new generation of pupils by providing Internet access as much as possible, not only in schools but in many different kinds of public institutions such as libraries, sport facilities, and homes.

Such a policy can only succeed if the necessary technological infrastructure is available and affordable. This is certainly a problem for less-developed countries that want to introduce IT in the educational system. The One Laptop per Child Project (OLPC) that aims to provide very cheap laptop computers to less-developed countries could be a step in the right direction (http://www.laptop.org). Also Microsoft has announced (International Herald Tribune, April 20, 2007) that it will sell a relevant Microsoft software bundle including Windows XP and Office Home and Office 2007 in developing countries for US $3. Policy makers in developing countries, therefore, should continue to focus on providing a sufficient technological infrastructure. They should be less concerned about the pedagogical/instructional and transformation approach intrinsically and rationally connected with the introduction of IT in education until their technical access problems are reasonably solved. The current experiences in the developed countries with transformational movements indicate very serious, almost existential problems arising from explicit goals for transformation through pedagogical change and the use of IT. It seems to be wise for policy makers to wait for a new balance to occur between informal and formal learning, based upon continuing technological developments, before expecting a transformation in learning that makes use of the affordances of IT to occur.

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SUBJECT INDEX

GLOSSARY

Adaptive tutoring software A system that accommodates multiple users by changing the displayed content depending on factors such as age of the student or answers to assessment questions.
ADSL – Asymmetric Digital Subscriber Line Data communications technology that uses copper telephone wires to transmit voice and data simultaneously. It is an "always on" connection that is faster than dial-up services.
Affordance Some property of an object that indicates how it could or should be used. For example, the knob on a door can be twisted, pushed, or pulled, and the shape of that knob is an affordance that gives users clues as how to use it.
Animation A technique in which static images are placed consecutively. When the images are shown in quick succession, the technique offers the appearance of continuous movement.
Applet A small program written in Java and intended for publishing on an HTML page. The program is not operating system dependent and increases the functionality of the webpage.
Artificial intelligence A field of study examining the capability of computers to perform intelligent behaviors such as voice recognition or the ability to reason.
Assistive technology Refers to any item, piece of equipment or product system, whether acquired, commercially modified, or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities. Examples include specially designed computing equipment, specialized software, augmentative communication devices, and motorized wheelchairs.
Asynchronous communication In educational telecommunication modes, this involves the use of time-independent transmission of information. Examples involve such things as email, electronic bulletin board postings, voice mail, streaming video recordings, blogs, or podcasts.
Audiographic Telephone used in combination with a form of graphic communication.
Augmented reality (AR) The combination of the real world and computer-generated data to create an experience that could not be replicated by either environment individually. Typically, users have special equipment such as a heads-up display, goggles, or a special computer.

Authoring software tools Software that allows users to create or edit multimedia files, documents, presentations, or applications. Examples include Adobe Dreamweaver for web pages, Microsoft PowerPoint for presentations, Adobe Photoshop for digital images, and Adobe Encore for video.
Avatar A user's graphical representation in a virtual world. The avatar does not have to resemble the user.

Bandwidth A measure of capacity and speed of data transmission typically quoted in megabits per second (mps). It is analogous to a highway with a certain capacity for vehicle traffic, which when exceeded slows considerably.
BASIC An acronym for Beginner's All-purpose Symbolic Instruction Code. It is a computer language that is easy to use and learn and is the language of larger programs such as Oracle and Microsoft Visual Basic.
Beaming Transfer of data from one handheld device to another via an infrared port on each device. By aligning infrared ports on two devices, users can beam data to each other.
BITNET Originally, "Because It's There Network" and later became "Because It's Time Network." A cooperative US university network, founded in 1981 at City University of New York (CUNY) and Yale University.
Blended learning The combination of multiple delivery modes that are designed to complement each other and promote learning.
Blog Term given to a website set up for posting of information, journal, and documentation to which readers are able to comment/respond (also web blog)
Bluetooth A technology industry standard or specification for wireless communication between devices. The devices must have the Bluetooth capability and must be in close proximity to each other. Bluetooth connections are typically only up to ten meters.
Broadband Derived from the terms "broad bandwidth." Broadband describes communications technology that allows for multiple channels of voice and data transmissions over the same medium. Transmission capacity with sufficient bandwidth to permit combined provision of voice, data, and video, with no lower limit. Effectively, broadband is implemented mainly through ADSL, cable modem, or wireless LAN (WLAN) services.
Browser A software program that allows users to navigate to, view, and interact with Internet and World Wide Web resources. Examples include Internet Explorer and Mozilla Firefox.
Bulletin board Generic web-based, asynchronous sites used to organize courses, projects, or general information. Various options include the following: discussion conferences, links to websites, internal/external email, document posting and preparation, posting of agendas, submission of class assignments, and other options depending on the system used (also bulletin board system (BBS), electronic bulletin board (EBB)).

CD-Rom An acronym for Compact Disc – Read-Only Memory. A CD-Rom is an optical disc that stores computer data that can be accessed when using a CD-Rom drive on a computer.

Cellular networks A network of radio cells that together can offer telephone coverage to a broad geographic area. Each cell consists of a radio transmitter and receiver, sometimes called a base station.
Cellular phone A wireless portable electronic device for communication that uses a network of specialized base stations (also mobile phone).
Chat A conversation between two or more persons over the Internet. The conversation is synchronous as all parties must be on the Internet to participate in the chat. Most chat is text-based, but recent technology is also allowing for audio and/or video chatting (also text chat).
Chat room A virtual space on the Internet where people can meet synchronously to chat. Many chat rooms have themes or topics of interest to participants who sign on.
Classroom network A hardware and software configuration in which students can signal answers to instructor questions, and the results are aggregated and shown graphically. Typically, each student is given a remote control type device. Multiple choice type questions are devised in advance, and when shown on the screen, students use the remote control to signal their answers. These systems encourage interactivity in the classroom environment and allow instructors to target areas where student understanding is weak (also classroom communication systems (CCS)).
Communication networks An interconnected group of computers.
Computer-assisted instruction (CAI) A learning environment where a computer is used as the principle medium of delivering instruction to students. This instruction can consist of lecture materials, tutorials, assessments, and more (also computer-based learning).
Computer-based design and manufacturing Using computer hardware and software to take an initial concept through the design and manufacturing process. These concepts can be also separated so that computer-based design is accomplished using separate hardware and/or software from the computer-based manufacturing hardware and/or software.
Computer-Based Educational Telecommunication (CBET) This term grew out of the time when educational telecommunication took place via telephone or satellite.
Computer-based training (CBT) Similar to computer-assisted instruction except that CBT is used in the corporate training world whereas CAI is used in the education world. Essentially, a computer is used in the process of training individuals to accomplish work goals.
Computer games Any computer generated and/or controlled virtual space in which users interact to achieve a goal. Some computer games have evolved so that users interact with each other in the virtual space whereas other games put the player against the computer.
Computer-Mediated Communication (CMC) Any means by which two or more people communicate, each using a computer (also IT-mediated networks).
Computer-Supported Collaborative Learning (CSCL) A computer network system that supports groups working toward a learning goal. Typical technologies include communication technology, file sharing or file access.

Computer-Supported Cooperative Work (CSCW) Similar to CSCL, except that learning is not necessarily the goal of the group work. It is used typically to reference work in the business world whereas CSCL is used in the educational world.
Connectivity The capability to provide, to end users, connections to the internet or other networks.
Console game A game that is played using a console system connected to a television. Examples of console systems include Nintendo Wii or GameCube, Sony Playstation, and Microsoft Xbox.
Cyber bulling Harrassing, threatening, humiliating, or intimidating others using modern communications technologies.
Cybercrime Any crime involving the misuse of ICT technology.
Cyberspace A term used to describe the information networks of connected computers and the users who gather and connect virtually using that network.

Data-logging Using a computer along with sensors or probes to collect and analyze data. Commonly used in scientific experiments.
Data-mining The process of analyzing data, typically large databases of information, to surface trends, identify relationships, or develop new hypotheses.
Deep web Also known as the invisible web or the hidden web, the deep web is any content not accessible through traditional search engines. Examples include documents in online databases or dynamic web pages accessed from database queries.
Digital Using digital signals (zeros and ones) to broadcast and receive video and audio.
Digital divide The gap between people who have the knowledge, skills, and access to utilize information technology and the people who do not. The gap can be attributed to many reasons, including economic, geographic, educational, or social reasons.
Digital immigrants A term coined by Prensky in 2001 to describe people who did not grow up using digital tools (see also digital natives). According to Prensky, digital immigrants think differently from digital natives and process information differently. For example, digital immigrants look for text first and then seek out graphics for clarification.
Digital library Internet accessible books, journals, and periodicals that have been digitized (also E-library, virtual library).
Digital natives A term coined by Prensky in 2001 to describe people who grew up using digital tools (see also digital immigrants). According to Prensky, digital natives think differently from digital immigrants and process information differently. For example, digital natives seek graphics first to understand concepts and then look to text for clarification.
Digital portfolio (also electronic portfolio) A collection of work for a purpose that uses an electronic media for collection and/or display. Digital portfolios can be online, such as a web-based portfolio, or offline, such as a PowerPoint portfolio.
Digital TV networks A distribution network for digital television, which provides programming for several channels.

Digital video Moving pictures and sound that are recorded in digitized form (i.e., zeros and ones). These images are thought to be of superior quality and are typically easier to edit and manipulate than analog.
Discussion board (also discussion list) A forum on the Internet used for discussion purposes where users asynchronously post and read comments from other users. Discussion boards use threaded discussions (see later) to organize messages.
Distance education Distance education describes a set of teaching and learning strategies (or education methods) that can be used to overcome spatial and temporal separation between educators and learners. Further, since economies of scale can be achieved through enrolment of larger numbers of learners than is possible in a face-to-face context, distance education is often presented as a cost-effective solution to the challenges of increasing access to education.
Distance learning Traditionally these terms relate to provision of curriculum to a dispersed audience. Original modes involved relatively slow correspondence courses and faster electronic modes such as radio or satellite transmission of courses. Contemporary modes are increasingly computer-based systems linked through the internet (also D-learning).
Distributed learning community A group of instructors, students, and experts that can be located in different places and come together virtually for learning.
Distributed learning environment An instructional method where the instructor, the students, and the content can be located in different places. Broader than distance learning, a distributed learning environment can also be used in traditional classroom courses when resources are found outside the classroom.

E-learning Learning that is facilitated or delivered through the use of computer or communications technologies, including computer, Internet, CD-Rom, or television (also Web-based instruction, Web-based education, multimedia learning).
E-learning policy Government policies, strategies, or guidelines that relate to e-learning or information technology in education (also IT-in-education policy, E-strategy).
Electronic Field Trip (EFT) The combination of synchronous and asynchronous communication techniques to provide virtual and real-time classroom experiences that are prohibitive in terms of costs, time, or logistics of normal field trip travel activities.
Electronic Performance Support System (EPSS) An application that is embedded within other applications and provides on-demand training in the form of context-sensitive help and job aids.
Email (electronic mail) Asynchronous messages exchanged between computer systems to individuals with unique email addresses.
Emerging technology A technology in which the basic theory and principles are understood but the potential is unfulfilled. A new technology that has been introduced recently but has not had widespread use yet.
ENIAC An acronym for Electronic Numerical Integrator and Computer. ENIAC was the first electronic computer that used vacuum tubes.

E-rate A program that benefited schools and libraries by offering discounted telecommunication products and services. The program was funded by the Telecommunications Act of 1996.

E-readiness Being ready to use technology appropriately.

European Pedagogical ICT License (EPICT) A comprehensive in-service training course for teachers to learn and understand the European standards for ICT integration in education.

Extranet A part of a company's intranet that is shared with those outside the company. An extranet is a private network utilizing Internet protocols that can be shared with interested parties such as suppliers or customers.

Facebook Also see MySpace. A social networking site where users can create web pages with personal information and connect and communicate with other users.

Freeware Software that is free to download and use, but remains copyrighted by the author.

Generation Y Also called Millenial Generation or the Internet Generation; it typically includes people born from the year 1978 or later.

Geographic Information System (GIS) Computer hardware and software that is used to collect, store, and display data in a geographic context. For example, demographic data can be overlayed on a map of a city to identify areas for a new Senior Citizen Center.

Global Positioning System (GPS) A GPS uses satellites and receiving devices to calculate positions on the earth. It is used typically for navigation.

Google Earth A desktop application that uses satellite photos of the earth, maps, and a search feature and allows users to navigate to and search for places on the earth.

Google image The google search engine specifically for images on the Web.

Google maps Satellite interactive maps providing directions and keyword searches.

Graphing calculator Also called a graphical calculator. A handheld calculator that can also plot graphs, solve equations with variables, and be programmed.

Groupware Collaborative software that allows groups of people to work collectively to accomplish goals. Groups can use groupware to share documents or information.

GUI design GUI is an acronym for Graphical User Interface. A GUI design uses graphics such as icons and pointers to make navigating software easier.

Hot spot A wireless access point that offers wireless Internet access, typically in a public place such as a library, coffee shop, or airport. A hot spot can offer free or paid service.

HTML An acronym for Hypertext Markup Language. It is the programming language used to create Web pages for the World Wide Web.

Hypermedia A combination of hypertext along with multimedia such as graphics, audio, and video. Hypermedia platform is nonlinear, allowing the user to decide how to progress.

Hypertext Words or text on web pages that are specially coded to link to other related web pages. Typically, hypertext is underlined and displayed in blue font. Users click on the hypertext word to bring up the related web page.

Information age A time period marked by increased and exceptional reliance on and access to information. Most experts agree that the Information Age began at the end of the twentieth century.

Information highway A global high-speed computer network that transfers information, graphics, text, audio, video, and more. Many times, the phrase is synonymous with the Internet (also Information superhighway).

Information literacy Also computer literacy, digital literacy, e-literacy, e-skills, technological literacy, new literacy – all knowledge and skills that are necessary to participate in an information society; sometimes also used as name for a school subject; sometimes also more narrowly defined as skills that are necessary to effectively use technology, e.g., finding and evaluating information on the Internet.

Information society A society where information is created, manipulated, managed, and distributed by information technologies (also information-driven society).

Information Technology (IT) The hardware, software, and network technologies associated with creating, displaying, and communicating information (also computer technology, technology, information and communication technology (ICT), informatics technology).

Infrared interface Infrared ports allow devices to transmit data using infrared light waves. Both devices must have the appropriate ports and those ports must be aligned for the transmission to occur.

Instant messaging (IM) A program that allows users to communicate with text synchronously. Users establish contacts with others and are alerted when these contacts are online. Users can then communicate in real time over the Internet.

Integrated Learning Systems (ILS) Integrated Learning Systems (ILS) are computer-based systems for the delivery of curriculum material, via an individualized program of study. A complete package of software for instruction that includes the lessons, assessment, and record keeping.

Intelligent agent (also digital agent) A software program that is designed for a particular purpose, that runs in the background, sometimes without the users' knowledge, and reports results back to the owners or developers.

Intelligent Computer-Assisted Instruction (ICAI) Computer-Assisted Instruction that takes advantage of artificial intelligence to enhance the instruction. Intelligent Computer Assisted Instruction can include natural language, for example.

Intelligent tutoring system (ITS) A system that adapts to the learners' preferences to deliver instruction.

Interactive story books A story that is created with multimedia so that users can interact with the words and pictures. Interactive story books can read words or describe pictures when clicked. In addition, some story actions can take place when clicked.

Interactive video A videodisc that is played on a computer. The user controls certain actions and can make certain decisions as the video plays.

Interactive white boards A special whiteboard that interprets a projected computerized image. By touching the image on the whiteboard, users interact with the computer in a way similar to the mouse (also smartboard, digital schoolboard, electronic whiteboard).
Interface The look and layout that users view and interact with when using technology. Interfaces allow users to interact with technology without using programming languages.
International Computer Driving License (ICDL) Begun in Australia, the ICDL includes testing to certify computer knowledge for individuals and employers. The standards are accepted in over 140 countries.
Internet A global network of computers that communicates via common communications protocols.
Internet addiction A compulsion to Internet use.
Internet browser Software that is used to view Internet pages, including text and graphics (also browser).
Internet predators An individual who lurks and stalks others on the Internet, usually in chat rooms or on social networking sites. These individuals attempt to get to know other users and then prey on them.
Internet Provider (IP) or the communication link that allows a computer user to link to the Internet for accessing World Wide Web resources or for communication. Both public and private IPs exist with the latter requiring paying a subscription to use the service.
Internet relay chat (IRC) A chat forum designed mainly for group communication over channels in which anyone on a channel can read all text on that channel. It can be used for one-to-one communication also.
Interoperability A set of rules that are established to allow two software programs (applications) to talk to each other. These rules define how one software program asks another software program for information and defines how the second software program will respond. This set of rules is referred to as an interface. If a software program writes to the interface, it should be able to communicate with other applications and the operating system. A software program that writes to an interface is one that has used the standard set of rules to ask for or provide information. These sets of rules are generally referred to as Application Programming Interfaces (APIs). http//www.accessibilityforum.org.
Intranet A network that uses Internet protocols but is secured for private use, usually by corporations or organizations.
IVR (Interactive Voice Response) Technology in which individuals use telephones to acquire information or input information into a database using voice or touch-tone keys. For example, banks use IVR systems so that customers can access their accounts.

Know bots Short for "Knowledge Robot." A know bot searches networks such as the Internet to gather information in response to a request and then displays the information to the user.
Knowledge management system (KMS) A web-based system for managing knowledge in organizations, supporting creation, capture, storage and dissemination of information.

Knowledge society Refers to economic systems where ideas or knowledge functions as commodities (also knowledge-based society, knowledge economy).

LAN An acronym for Local Area Network. A LAN is a network of computers in a small geographic region (usually within a few square kilometers) that is connected to share data, applications, and peripherals.

Laptop A small, portable computer that can fit on a lap. Newer laptops typically offer wireless connectivity to the Internet.

LCD projector A projector that utilizes liquid crystal display. The machines are connected to a computer that projects the display onto a screen for more public viewing.

Learning circles Learning circles are highly interactive, project-based partnerships among a small number of schools located throughout the world. Learning circles promote theme-based project work integrated with the classroom curriculum. The learning circle model evolved out of a research project at the University of California, San Diego in the mid 1980s.

Learning management systems (LMS) Web-based, asynchronous sites used to organize courses. Course participants register and can post completed assignments and communicate with classmates and instructors. Commercial systems (e.g., Blackboard, WebCT, TeleTop) involve modes of assessment and grade posting. In contrast, systems like BSCW, Moodle, and Nicenet are free and less complicated, but may lack features such as attaching documents (also Course management system (CMS), Learning Content Management System, Instructional Knowledge management system).

Learning object The term learning object refers to an object or set of resources that can be used for facilitating the achievement of specific learning outcomes. Individual learning objects can be extracted and reused in other learning environments and educational contexts.

Learning object repository A digital storage space used for learning or instruction-related content as well as the metadata for content (also digital repository).

Lifelong learning Learning that occurs throughout one's life, including formally and informally. Typically considered a state of mind, such that lifelong learners are inquisitive and constantly trying to better themselves.

Lifelong learning skills Traits associated with lifelong learners such as creativity, problem-solving, persistence, and ethical behavior.

Listserv An automated email list server. Users can subscribe to a listserv, and then all email messages sent are delivered to all other members of the group. Listservs are typically organized around interest groups so that emails are personally or professionally meaningful to the group.

Logo A programming language developed by Seymour Papert at the Massachusetts Institute of Technology. Logo was created to make complicated math concepts accessible even to very young children. It has also been shown to develop problem-solving skills.

Massive multiplayer online games (MMOG) A video game which is capable of supporting many players simultaneously. By necessity the game is played on the

Internet (also Massive multiplayer online role playing games, Massive multiplayer online persistent world).
Metadata Data that describes other data. Web pages use metadata to describe the contents of the page. This data can then be used by search engines for example.
Microworlds A commercialized version of the Logo™ programming language.
Mobile blogging (moblogging)) Content is posted to a blog from a mobile device such as a personal digital assistant or a cellular phone.
Mobile learning (M-learning) Learning that takes place wirelessly on devices such as cellular telephones, personal digital assistants, or wireless laptop computers.
Mobile technology Devices that allow users to access information wirelessly and can be moved from place to place.
MP3 player A typically small, portable device that plays digital audio files encoded as an mp3.
Multimedia Presenting information with a combination of text, graphics, audio, and video.
Multimedia case studies A case delivered to learners in a hypermedia environment usually with a video case (to better capture the complexity of teaching and the simultaneously occurring events in the classroom) as the heart of the case. Multimedia cases are particularly being used in preservice teacher education.
Multimodality Communications that occur using more than one mode. For example, communications using voice, text, and images would be considered multimodal.
Multiple agent Pedagogical agents that contain different information and learning scaffolds. Students can return to these agents for different types of information.
Multiuser Dungeon (MUD) A role-playing game over the Internet that is text-driven, with players assuming the identities of fictional characters and interacting with other users/characters.
Multiuser object oriented A type of multiuser dimension or 3D world that is based on an object-oriented language. In the virtual environment, users can use object-oriented programming to change or expand the environment.
Multiuser virtual environment (MUVE) A three-dimensional world created using computerized graphics and sound. It simulates real-time interaction with many users simultaneously (also 3D online learning environment).
MySpace A social networking site where users can create web pages with personal information and connect and communicate with other users.

Netizens A frequent user and active participant of a community on the Internet.
Netspeak The language, usually abbreviated, used in electronic text communication.
Networked learning Learning that takes place with connections between learners, between learners and instructors, and between learning communities and learning resources.
Networked multimedia environment An environment with multimedia elements such as graphics, animation, and video that is connected to a network such as the Internet.

Newsgroup A discussion board that is related to a specific topic such as recreation activities, science news, or computer-related news.

Object-oriented programming A type of programming language that uses objects, or packages of data and functionality. Popular object-oriented programming languages include Smalltalk and Java.

One-laptop-per-child (OLPC) An initiative by Nicholas Negroponte of the Massachusetts Institute of Technology's Media Lab to provide low-cost laptop computers to children in developing nations. The laptops would be used for education and are targeted to cost US $100 each.

One-to-one computing Providing each student and teacher with a laptop, notebook or handheld computer to use continuously at school and home.

Online learning A subset of e-learning communities, also virtual learning communities or cyberspace classrooms in which all instructions are delivered through the Internet.

Open educational resources Technology-enabled, freely accessible provision of educational resources for use and potential adaptation by a community of users. Use of open educational resources is for noncommercial purposes. Resources are typically made freely available over the Internet (also open courseware).

Open learning The concept of open learning is based on the principle of flexibility to increase access to education and often forms part of broader equity efforts in society. This approach allows learners much more freedom to determine what, how, and when they want to learn, than do traditional approaches to education. The aim is to provide learning opportunities to a diverse range of learners both originating from, and learning in, different contexts.

Open School An Open School is an educational institution delivering primary and/or secondary education, providing courses and programs predominantly through use of distance education methods.

Open source Example Moodle, Open Office – Software that is freely available to use and that allows others to view and alter the source code. Applications that are open source are typically developed collaboratively with large groups of volunteer developers who work together in a loosely defined network.

Personal Computers (PC) A computer whose capabilities make it useful for individuals, intended to be operated directly by an end user.

Personal Digital Assistant (PDA) Also called a handheld or a pocket PC. A PDA is a small computer that can fit in one's hand. It holds many traditional PC software applications, but with fewer features. Some handhelds can accept handwriting on the screen as an input method. Most also allow connections to small keyboards for input (also Handheld, Palmtop, Pocket PC).

PLATO An acronym for Programmed Logic for Automatic Teaching Operation. PLATO is generally known as the first attempt at computer-assisted instruction.

Podcasting Use of computer and multimedia formats for posting/sharing asynchronous communication.

Portal A website that serves as a starting point for other web-based services, such as email, search engines, etc. (also Web-portal).
PowerPoint Presentation software that is a part of Microsoft Office. PowerPoint allows users to create slides as well as handouts and outlines.
Productivity software Software such as word processing, spreadsheets, database systems, and desktop publishing designed to help individuals work more efficiently.

Radio frequency identification (RFID) Technology that transmits information in the form of radio signals from tags to readers. Transmission does not require contact or even line-of-sight.
RSS An acronym for Really Simple Syndication. RSS is typically used with blogs and podcasts and allows users to subscribe to their favorite sites and receive content as it is updated. Typically, subscribers use an aggregator to gather all new content for the user and display it in one place.

Satellite broadcast interactive TV Television that is at various levels of interactivity and is broadcasted over satellites. Levels of interaction include commonplace actions such as using a remote control to turn the television ON and OFF, and less common actions such as changing camera angles or altering the storyline in a television show.
SchoolNet A Canadian program to promote ICT use in education.
Screen reader A software program that reads the words on a computer screen loudly to the user. Typically, screen readers are used by those who are visually impaired.
Search engine A Web-based program that allows users to enter keywords and receive a list of possibly relevant Internet sites. Examples of search engines include Google and Yahoo!
Second Life A virtual world created by Linden Lab in which users can socialize with other users and build and create the environment in which they interact.
Server A host computer that is networked to other computers. Servers can have many purposes, such as Web server, print server, and application server.
Sharable Content Object Reference Model (SCORM) Standard for metadata standards, e.g., ARIADNE CENISS, Dublin Core, EdNa, IEEE LOM, IMS, PROMETEUS (http://www.cetis.ac.uk).
Sibling technologies Any communications technology which supplements telephone communication.
SIMCALC A computer and graphing calculator based application that allows students to explore algebra and calculus concepts.
Simulation A computer program that imitates reality. Students use simulation software to gain experience with real situations but without the same risks.
Slow Scan Television (SSTV) Sometimes called “freeze frame” TV. These devices allow an ordinary telephone line to transmit slow scanned video images from one site to another.
Smart card A plastic card approximately the size of a credit card that holds information such as customer account information or cash balance. Smart cards can be used for prepaid telephone calls and credit cards with prepaid limits.

Smartphone A handheld device that integrates mobile phone capabilities with personal digital assistant type capabilities.
SMS (short message service) A service for sending short text-based messages between cellular telephones (also text message).
SMS gateway (also SMS-portal) The SMS gateway translates one SMS protocol to another, which allows wireless carriers to connect with each other and exchange messages.
Social bookmarking Similar to bookmarking a Web page within a browser except social bookmarking; allows users to save and categorize their bookmarks with tags and then share them with others (e.g., http//www. blinklist.com).
Social software Web-based software programs that allow users to socialize with each other in some manner.
Speech recognition The ability of a computer to understand and respond to spoken words. Speech can be in the form of commands or data input.
Speech-to-text Using speech recognition software, computers can use spoken input and translate the words into text.
Spreadsheet A software application that uses rows and columns of numbers and text for manipulation and reporting.
Stand-alone computer A computer that is not a part of a network of computers.
Student response system A technological tool that consists of hardware and software to request and receive student input during teacher-led lecture or discussion. Each student is given a handheld remote control type device. The teacher asks specific multiple choice or true/false type questions with which the students respond via the handheld remote. Results are tallied for the teacher immediately (also clicker technology).
Synchronous communication In educational telecommunication modes, this involves use of real-time transmission of information. Examples involve face-to-face communication, teleconferencing in audio, video, and text chat formats.
Synthesized speech Computer-generated simulated human speech.

Tablet computer A computer that uses a touch screen for input. Some tablet computers also have traditional input devices such as keyboards.
Talking book software Software that replicates books, adding multimedia and interactivity. Talking books typically offer stimulating pictures along with the story, can read the text, and sometimes can respond to human voice.
Teachable agents Technology that requires students to instruct teachable agents that explore simulated worlds and solve problems that require knowledge from the student.
Technological pedagogical content knowledge (TCPK) The framework aims for teachers to combine knowledge of technology, pedagogy, and specific subject area content to design meaningful lessons.
Telecommunication Transmitting information through wires or optical channels for voice or data communication.
Telecommuting The practice of working in a place away from a traditional office building, such as home, and communicating via telecommunication.

Telesharing Exchange or sharing of information over the Internet. Telesharing is a subset of telecollaboration.
Thin clients A networked computer in which all data storage and computing are performed by the server. A thin client may not have a hard disk drive and thus relies on the server for all needs.
Threaded discussion Typically in the context of an electronic bulletin board. Users post comments and other users can respond to those comments, thus creating a thread of discussion.
TICCIT An acronym for Time Shared Interactive Computer Controlled Information Television. A training experiment of the United States Army that investigated the effectiveness of computer-aided instruction.
Total cost of ownership (TCO) All the costs associated with the use of computer hardware and software including the administrative costs, license costs, deployment and configuration requirements, hardware and software updates, training and development, maintenance, technical support and any other costs associated with acquiring, deploying, operating, maintaining, and upgrading computer systems in organizations.
Touch screen display A computer display that uses human touch for input. Users interact with touch screen displays by touching the screen rather than using a mouse or keyboard.
Twenty-first century skills Skills, such as global awareness, entrepreneurship, technology skills, critical thinking, and problem solving, that experts believe will be important traits for students in the twenty-first century.

Ubiquitous computing Computers or computing that is ever-present in the environment, but not typically seen or noticed. For example, computers could be embedded into everyday objects so that they are not seen but are effectively used (also ubiquitous learning (ubi-learning)).
URL An acronym for Uniform Resource Locator. A URL is the address that users type into a browser to find a resource on the Internet. For example, http:///www.google.com is a URL.
USB stick A small memory device that uses flash memory and a USB interface to connect to a computer (also a flash drive or jump drive).

Value on investment (VOI) The systematic measurement of the alignment of a school's human, information and organizational capital linked to a school's strategy and performance to determine strategic readiness and the value of these intangible assets to the school.
Videoconference A synchronous meeting between two or more groups of people using video monitors. Videoconferences can also include document sharing.
Virtual classroom An online environment that allows students and instructors to interact synchronously or asynchronously for learning.
Virtual learning community A community of people connected via technology with the shared purpose of learning together.
Virtual learning environment (VLE) A web-based space that is specifically designed for learning and has social and collaborative aspects. Many learning man-

agement systems are examples of VLEs (also electronic learning environments E-learning platform).
Virtual reality A virtual world that is combined with real elements such as sound and/or movement to give users the sense that they are present and fully participating.
Virtual-reality-based learning systems A learning environment that takes place using virtual reality environments.
Virtual school A school where learning takes place online, without buildings and classrooms. Normally used for distance learning/education for students in elementary and secondary, K-12, schools (also CyberSchool).
Virtual world A two-dimensional or three-dimensional computer-simulated environment that users explore with avatars. Some virtual worlds allow for many simultaneous users, others do not.
Voice over Internet Protocol (VoIP) This mode of communication makes possible audio, video, and text communication in a way that is analogous to a telephone conference call or bridged audio–video teleconference.
Voice user interface The interface that allows technology to understand and respond to the human voice.

Web 2.0 A term used to describe the next generation of websites that allows for more user-created content. Examples of web 2.0 include wikis and blogs.
Web authoring tool Software that allows Web pages to be created using a Graphical User Interface (GUI) interface and which then generates the necessary HTML code for the user. Examples of Web authoring tools include Macromedia Dreamweaver and Microsoft FrontPage.
Webcam (web camera) Simple computer-based camera that is used for videoconferencing with a personal computer or capturing video images for asynchronous posting/emailing.
Webcasts Transmitting audio or video broadcasts using Web-based technologies. The broadcast can be live or delayed.
Web communities A group of like-minded people who share ideas and interests online using various communication technologies.
Webquest A learning activity in which students use Internet resources to research and solve problems. It was created by Bernie Dodge.
Widgets An element in a graphical user interface (GUI) such as a pull-down menu or a button that allows users to interact with the computer.
Wiki A website that allows all users to add, update, or edit content on the page. Wiki is a Hawaiian word meaning quick.
Wikipedia An encyclopedia on the Web that is written collaboratively with users around the world. Any user can edit or change an article.
WIMAX An acronym for Worldwide Interoperability for Microwave Access. It is wireless technology whose coverage is greater than wi-fi technology.
Wireless network Networks that do not rely on cables or wires to connect computers. Instead, computers connect via radio waves to transmit data.

World Wide Web (WWW) A network of hypertexted documents written using HTML that can be viewed with a web browser. The WWW was important because information could be displayed graphically and hyperlinked and thus opened the Internet to more users.

YouTube A popular website that allows users to upload videos for public or private viewing.

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