TEACHING WITH DIGITAL TECHNOLOGY

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Digital technologies are for education as iron and steel girders, reinforced concrete, plate glass, elevators, central heating and air conditioning were for architecture. Digital technologies set in abeyance significant, long lasting limits on educational activity. (McClintock, 1999, paragraph 10)

INTRODUCTION

Technology has always been a part of schooling; in fact, it was the invention and rapid spread of printed texts that made schooling possible. However, many technologies have failed to find a significant place in classrooms even though they were enthusiastically embraced by educators (Cuban, 1986). In the 20th century, technologies such as radio, movies, and television have suffered that fate. We do not have room to discuss this long history of technological innovations and schooling, so we confine ourselves to discussing digital technologies. We use this term instead of the more common term computer to encompass the wide range of new tools that are introduced in classrooms on a daily basis, including digital video, mobile devices, podcasting, student response systems, computer-mediated communications, and social networking.
applications. Specifically, we will focus on three interrelated issues that are driving debates around digital technologies and education in general.

The first issue is centered on digital technologies’ effect on teaching and learning. Some educators contend that technologies are just delivery systems (e.g. Clark, 1994); others argue that technologies are tools that significantly affect thinking and learning for good or ill (e.g., Kozma, 1991). Somewhere in the middle is a large group of scholars who argue that digital technologies have the potential to meaningfully affect classroom learning, but will do so only to the extent that teaching practices change to make use of their unique capabilities (e.g., Kozma, 1991).

The second issue focuses on how to make the most effective use of digital technologies in teaching and learning. This issue is intimately related to the previous one, and even those who argue that digital technologies have minor or ill effects on learning can argue that students should at least learn about them. Other focal points of study in this area have included concepts teaching, drill and practice of academic skills, tools for thinking and learning, collaborative learning, and knowledge construction. A growing movement among educational technologists favors a ubiquitous computing approach, in which digital tools are available to support teaching and learning anywhere and anytime, and in a variety of ways (van’t Hooft & Swan, 2007).

The third issue in educational technology focuses on teacher professional development, and how best to prepare teachers to teach with digital technologies. In most cases (with the possible exception of online learning), learning to use digital technologies in education seems strangely divorced from advocated and actual uses in classrooms.
Rapidly changing technologies also force teachers and teacher educators to constantly examine how they learn and how they help others learn to teach with technologies.

To put these issues in context, the following timeline highlights major milestones in the short history of digital technologies and education. Even limiting these to digital technologies, however, still leaves far too many for the scope of this book; thus we present only those events with significant implications for professional development.

**TIMELINE**

- **1960s**: PLATO, one of the first generalized Computer Assisted Instruction (CAI) systems was developed at the University of Illinois. PLATO not only popularized the basic CAI drill and practice approach, it pioneered such key educational computing concepts as online forums, email, chat rooms, instant messaging, remote screen sharing and online games. Later taken over by Control Data Corporation, PLATO systems were produced until 2006.

- **1973**: Minnesota Educational Computing Consortium (MECC) created by the state legislature to study and coordinate computer use in Minnesota schools. As the use of microcomputers in schools increased, MECC became a national advocate for computers in schools and corresponding professional development. MECC also was one of the first organizations developing educational software for personal computers, creating such early classics as *Oregon Trail*, *Number Munchers*, and *Lemonade Stand*.

- **1980**: Seymour Papert published *Mindstorms: Children, Computers, and Powerful Ideas*; at the same time Apple computers started making their way into schools. This triggered a grassroots movement among elementary school teachers
in particular for integrating Logo programming and constructionist methods across the curriculum. Learning Logo, however, required extensive training and ongoing support, prompting a call for professional development around technology and technology issues.

- 1985: the Apple Classrooms of Tomorrow (ACOT) project began. ACOT was a decade-long research and development collaborative that brought together public schools, universities, research agencies, and Apple Computer to create computer-saturated classrooms and research the potential of technology for teaching and learning. The project showed that the use of technology in the classroom required a change of a teacher’s instructional role. This resulted in new models of professional development situated within contexts of practice, and emphasizing mentoring and reflection.

- 1989: Tim Berners-Lee invented the World Wide Web, a system of interlinked hypertext documents that can be accessed via the Internet. This was followed in the early 1990s by a series of Internet browsers such as Mosaic, Internet Explorer, and Netscape that made it easy for the general public (including students and teachers) to access the World Wide Web. Besides resulting in the development of a substantial amount of professional development about the Internet and its potential for teaching and learning, more teacher professional development has moved online.

- 1998-2003: The International Society for Technology in Education released its technology standards for students (NETS-S; 1998), teachers (NETS-T, 2000), and administrators (NETS-A, 2003). The NETS are a set of national standards for
appropriate, effective, and meaningful uses of technology for teaching and learning. The NETS have been adopted by virtually every state, and are often consulted for professional development purposes.

- 1997: The Report to the President on the Use of Technology to Strengthen K-12 Education was made public. Prominent among its major recommendations was that special attention be given to professional development. The panel recommended that at least thirty percent of all educational technology funding be spent on professional development, and that teachers be provided with mentoring and time to develop ways of integrating technology into classroom teaching and learning.

- 2000: Computers as Mindtools in Schools by David Jonassen was published. The book’s publication marked widespread acceptance in the educational technology community of the cognitive tools approach to technology integration and a change in the way technology was introduced to teachers at both the pre-service and in-service levels.

- 2000 and beyond: Mobile technology was introduced into classrooms. Devices such as handheld computers and mobile phones began to provide opportunities for learners to connect classrooms and the world, physical and digital environments, and formal and informal learning. Professional development related to mobile devices began to focus on 1-to-1 models of teaching and learning with digital technology.

THE MEDIA AFFECTS DEBATE
Much of what we take for granted in today’s digital culture was invented by Douglas Engelbart (1963), who believed the most important aspect of his work was designing tools for augmenting human intelligence. Was he right? Was he even on the right track? Can technology make a difference in education or life, and if so, what kind of difference? Educators have been debating these types of issues for decades.

**McLuhan and the Medium Theorists**

At one end of this debate are Marshall McLuhan (1964) and the medium theorists (e.g., Bolter, 1991; Meyrowitz, 1996; Stephens, 1998) who believe that media and technologies impact individuals and society apart from whatever content is transmitted. Like Engelbart (1963), McLuhan (1964) saw media and technology as extensions of our senses and minds. He maintained that the medium is the message, that there are dominant forms of communications in cultures that evolve and change, and the dominant form will shape people’s behavior and thinking in a particular era. McLuhan (1964) argued that the habits of mind shaped by constant familiarity with the unique ways in which different media structure information had a more significant impact on human thought than the messages they carried. He maintained, for example, that the invention of printed text led to analytic, linear, progressive habits of mind, which in turn enabled the Enlightenment. He further contended that our society is passing from a print-based era to an electronic era, and that such a passage would change our thinking. For example, in the 1960s, McLuhan argued that because of instantaneous video communications, the world was becoming a global village in which we are more likely to see ourselves as part of an international community. Today, we see how prescient he was.
Scholars who accept McLuhan’s (1964) argument are known as medium theorists. Some think that our move from a print-based to a digital culture is destroying our ability to think critically and logically (Postman, 1985), a position echoed by teachers who bemoan their students’ lack of reading and writing skills. Others are more optimistic and argue that digital technologies support nonlinear thinking (Bolter, 1991), shared experiences (Meyrowitz, 1996), new forms of thought (Stephens, 1998), and student-centered learning (Papert, 1993). A third group, McLuhan among them, thinks that the move from print to digital culture is happening and will continue to affect our thinking, regardless how we feel about it (Tyner, 1998). This point of view has been most recently expressed in calls for changing education to respond to the needs of the Net Generation (Oblinger & Oblinger, 2005).

**Method Over Medium**

At the other end of the media effects debate are those who think technology will never influence learning, a perspective that has been championed by Clark (1994). Clark differentiates between instructional media and instructional methods. He contends that media are just delivery mechanisms for methods, like trucks that deliver food. He argues that, just as different trucks cannot influence the nutritional value of food, different technologies cannot influence the quality of learning. He further contends that simply because a particular technology is not commonly used to deliver a particular instructional method, this does not automatically mean it cannot be used in that manner, and notes that “a number of very different media attributes serve the same or similar cognitive functions” (1994, p. 22).
While Clark’s (1994) arguments have engendered a good deal of criticism because his truck analogy evokes a behaviorist, delivery model of learning that has fallen out of favor, they seem to premise a significant portion of thinking about technology in education today. For example, a great deal of research in online education has been focused on demonstrating no significant differences in learning between traditional and online environments (Russell, 1999). Similarly, the No Child Left Behind legislation mainly funds initiatives designed to deliver content instruction using digital technologies.

**The Potential of Technology**

In the middle of the media effects debate are educators who maintain that digital technologies have the potential to meaningfully affect learning, but they will only do so to the extent that we make use of their unique capabilities. Kozma (1991), for example, responded to Clark (1994) by arguing that specific media attributes make particular methods possible. He contended that differing media can be analyzed in terms of cognitively relevant attributes and described in terms of capability to present particular representations and perform certain operations in interaction with learners, and that this has important implications for educators. We must, he argued, specify the mechanisms through which cognitive processes are influenced by media attributes, and identify appropriate uses for these attributes to support learning. Mayer (2001), for example, has specified both cognitive processes and appropriate uses of multimedia to support learning. That Mayer’s work is supported by decades of experimental research bodes well for the middle position in the media effects debate (e.g., Mayer & Moreno, 2002; Moreno & Mayer, 2002).
Of course, this middle position has important implications for appropriate uses of technology in schools. If the integration of digital technologies into classroom teaching and learning is most useful when they are used to their best effect, then it is very important to determine what that best effect is.

**APPROPRIATE USES OF TECHNOLOGY IN SCHOOLS**

The second hotly debated issue in educational technology is concerned with how to make the best use of technology in schools. Educators experimented with computer-supported learning in schools even before the invention of the personal computer. The early work was characterized as focused on three distinct educational uses of computers: as tutors or teaching machines, as cognitive tools to scaffold thinking and learning, and as tutees, or universal machines to be programmed by students to support their learning (Taylor, 1980). The distinction between using computers as tutors and using them as tutees parallels the media effects debate and has similarly stimulated heated debate within technology education which continues today. However, using technology applications as tools to support thinking and learning is the most commonly accepted position today.

**Computer-Based Instruction**

The use of digital technologies to instruct has its roots in Skinner’s (1958) work on teaching machines. In the 1970s, instructional technologists began experimenting with moving Skinner’s vision to its obvious instantiation on computer systems (Suppes, 1988). What have come to be called Interactive Learning Systems (ILS) are capable of managing the delivery of individualized instruction to large numbers of students at a variety of achievement levels, providing students with instantaneous feedback on their performance, and providing teachers with extremely fine-grained diagnoses of student
abilities. Moreover, several meta-analyses of research comparing learning from such systems with traditional classroom learning have found that students learn more and faster using ILSs than they do in traditional classrooms (Niemiec & Walberg, 1987; Swan, Guerrero, Mitrani, & Schoener, 1990).

The major objection to ILSs and the technology-as-tutor approach in general is epistemological. Many educators argue that such an approach is teacher-centered and does not reflect what we currently know about how people learn. On the other hand, the technology-as-tutor approach appeals to many teachers because it is closest to traditional practices and accepted teaching roles. Indeed, many schools and school districts employ ILSs today; they have strong appeal in our No Child Left Behind era for their proven effects and their ability to directly incorporate learning standards and provide data for decision making. It should be noted, however, that significant teacher professional development is needed as optimal use of ILSs requires teacher use of system diagnostics. Even so, the technology-as-tutor approach has a long history in educational technology innovations down to the present day. Innovations including artificial intelligence tutors (Sleeman & Brown, 1982), hypertext applications (Bolter, 1991), many multimedia programs (Mayer, 2001), and student response systems (Penuel et al., 2005) essentially adopt a teacher-centered approach, as do a good deal of online learning programs, especially in the areas of corporate training and P-16 education.

**Constructivism**

On the other end of the continuum in the appropriate-uses debate are Seymour Papert (1993) and the constructionists. Papert is best known for his creation of the Logo programming language, a powerful computer language designed to be used by children.
His vision for computers in education was focused on learner-centered environments in which children programmed computers rather than being programmed by them. Papert called his technology-as-tutee approach to learning “constructionism,” viewing it as a variant of constructivism which “attaches special importance to the role of constructions in the world as a support for those in the head” (Papert, 1993, p. 142). He argued that by constructing and manipulating “quasi-concrete” representations of knowledge on computers, children would form more robust internal knowledge structures. As in ILS research, a number of studies have reported significantly enhanced learning of mathematical concepts (Clements & Gullo, 1984), physics (diSessa, 1986), geometry (Noss, 1987), and problem solving (Swan, 1989) through Logo-based interventions. Special versions of Logo have successfully been developed for teaching complex systems (Resnick, 1994), geometry (Lehrer & Chazan, 1998), and computational thinking (diSessa, 2000).

However, teaching with Logo not only requires a fundamental rethinking of teaching roles, it also requires intense and ongoing teacher professional development. In addition, learning with Logo takes up a large amount of class time as students need to learn to program in it before significant learning gains can be realized. Thus, after widespread adoption in the late 1980s and early 1990s, particularly in elementary classrooms, Logo programming has faded from classroom use. However, Papert’s (1993) notions of constructionism, computer objects to think with, and microworlds, immersive digital environments designed for student exploration of particular concepts, still have many enthusiastic adherents. A wide range of technology-supported educational innovations ranging from classroom commonplaces like interactive storybooks (Labbo &
Kuhn, 2000), simulations (Reed & Jazo, 2002), and exploratory environments (Stevenson, 2002), to emergent approaches such as serious games (Gee, 2003) and augmented reality (Rogers & Price, 2007) are rooted in constructionist epistemology.

**Cognitive Tools**

The middle ground in the appropriate-uses debate, the technologies-as-cognitive tools approach, is the most widely accepted in schools today, most likely because it not only straddles the instructionist/constructivist debate, but also can be implemented in very small steps. The cognitive-tools approach views digital technologies as tools that support teaching and learning in much the same way that traditional media do. On one end of the digital tools continuum are tools such as multimedia presentations and student response systems that support teacher-centered instruction. At the other end are tools that support collaboration and knowledge construction. In the middle are a range of digital tools that can be employed in either instructionist or constructivist ways – tools such as graphics packages, databases, and communication tools. Moreover, it is widely argued that students be introduced to digital tools simply because they are commonly employed in society today (Partnership for 21st Century Skills, 2003).

Most educators who adopt a technologies-as-cognitive tools approach also argue for constructivist implementations, contending that such uses lead to higher-order thinking and learning (Reeves, 1996). Many also conceive of thinking and learning as distributed, viewing digital technologies as extensions of human cognition in much the same way as Engelbart and McLuhan did. This is the position taken by Jonassen (2000), who refers to digital technologies as “mind tools.” He identifies six categories of digital
tools that, when used by learners to represent what they know, necessarily engage them in
critical thinking about the content they are studying. These include:

- semantic organizing tools, which help learners analyze and organize what they
  know or are learning;
- dynamic modeling tools, which help learners describe dynamic relationships
  among ideas;
- information interpretation tools, which help learners access and process
  information;
- visualization tools, which help learners represent and convey mental images
  and reason visually;
- conversation tools, which support interpersonal exchanges and collaborations
  among students; and
- knowledge construction tools, which support learners as designers.

TEACHER LEARNING AND PROFESSIONAL DEVELOPMENT

The third issue in ongoing educational technology debates is concerned with how
to best prepare teachers to teach with digital technologies. No matter what the approach
to technology use, teachers are critical elements in the technology integration equation.

Challenges

The effects of digital technologies on teaching and learning depend for a large
part on the complex process of professional development: when, what, where, and why
teachers learn to teach with new technologies. There is an often-repeated expression in
education that people tend to teach the way they were taught. If preservice teachers
follow the practices of their professors, their use of technology in education will be
largely based on the examples set for them in their university teacher education programs. To apply technologies effectively in their teaching, preservice teachers must see technology incorporated throughout their teacher education programs, emergent in their university learning and activities, and modeled by their professors and peers in classes and field placements (Doering, Hughes, & Huffman, 2003). Quantity makes a difference. Unfortunately, research has also found that preservice teacher education does not adequately prepare future teachers to teach with technology (Pope, Hare, & Howard, 2002).

To incorporate technology effectively, teachers need to feel comfortable about quickly acquiring the required skills and knowledge. Research indicates that there is a relationship between teacher confidence in technology abilities and the likelihood of technology integration (Nisan-Nelson, 2001). Also, besides the level of computer use, teacher interest in technology for learning is the most important factor that determines technology integration (Keiper, Harwood, & Larson, 2000). As a result, the quality of preservice teachers’ experiences with computer technology is an important factor.

In sum, teacher education programs are challenged to prepare teachers capable of and committed to using technology for teaching and learning. Teachers must be able to use technologies in their curricula to promote learning, improve achievement, and provide students with the skills they need in their future education and workplace careers.

**Responses**

The Preparing Tomorrow’s Teachers to Use Technology Program (PT3) has been one of the national initiatives to respond to the challenge of teacher learning with technologies. Starting in 2000, the PT3 program has provided grants to consortia that
help future teachers become proficient in the use of technologies. More than 400 institutions of higher education have received funding to restructure their teacher education programs so that they can prepare prospective teachers to effectively use technology in their P-12 classrooms. Research shows that PT3 grants have helped teacher educators and teachers to become confident technology users and supported innovative projects integrating technology into teaching and learning (Ludwig & Taymans, 2005).

Among various teacher professional development programs aimed at technology integration, two models are prominent: the traditional training or workshop model and the situated learning perspective. A workshop usually occurs in one or two-day sessions and focuses on technical skill development, incorporating demonstrations and explanations for specific problems, strategies, and solutions. Workshops are efficient and important ways to help professionals acquire technical skills within their time constraints (Berry, 2005).

However, this model has received criticism for not leading to long-term changes in actual practice. Ball and Cohen (1999), for example, noted that decontextualized workshops are “often intellectually superficial, disconnected from deep issues of curriculum and learning… and noncumulative” (pp. 3-4). Moreover, due to their focus on isolated technical skills, teachers walk away from a workshop without seeing the connections between technical skills and their own teaching (Ludwig & Taymans, 2005).

As an alternative, researchers and teacher educators have increasingly argued that effective professional development must be situated in classroom practice in such a way that teachers are active learners who construct their own understandings (Putnam & Borko, 2000). The situated learning perspective recognizes that, especially in a field like
educational technology, teacher learning should be situated within the ambiguity and chaos that is the lived reality of their classroom experiences (Britzman, 2003). Teachers should exert control over the type and content of their experiences and receive follow-up support for what they have learned (Wilson & Berne, 1998).

In the situative model, teacher educators work with teachers in their classrooms and other school settings. Teacher learning is intertwined with their authentic and ongoing practice and what they learn will indeed influence their teaching practice in meaningful ways. This approach values the critical importance of the context in which teachers work and also recognizes that learning happens over time. It recognizes teachers as agents of change and creators of their craft and moves beyond the passive transmission of information more characteristic of the workshop model.

However, there are issues with this approach too, one of which is scalability. Having teacher educators spend considerable amounts of time working alongside teachers is not practical on a widespread basis. In addition, learning that takes place outside of chaotic classrooms affords teachers with opportunities to reflect and think in new ways without being constrained by existing classroom situations. Multiple contexts, therefore, are often recommended for facilitating knowledge transfer from workshops to classroom teaching.

Reflective practice and collaborative inquiry are two of the most important elements for innovative and sustainable teacher learning and professional development with technology (King, 2003). Findings from research about teacher inquiry also reveal that collaborative inquiry groups, team learning, and communities of practice are effective teacher learning models that enable participants to sustain educational reform,
improve practice, and improve teachers’ instruction and students’ learning (Ludwig & Taymans, 2005).

Learning to teach with technology is a substantial endeavor, requiring personal and continuous commitment, and lifelong learning (King, 2003). Rather than just learning how to use the latest software, lifelong learning focuses on a process of ongoing discovery and learning that inspires teachers and teacher educators to become confident technology-using teachers. It should be cultivated in teacher education programs, beginning at the preservice level.

Lifelong learning also means self-directed learning. Self-directed teacher learners actively and continuously seek and find new things to learn on their own, determine how they learn best, and seek out information, resources, and professional development opportunities (Knowles, 1975). Therefore, it is critical for teacher educators to cultivate and support teachers’ interests in self-directed learning. Self-directed learning with technology can be greatly facilitated through professional networks and relationships. In-service and preservice teachers need consistent opportunities to learn to use information technology over time in multiple and authentic contexts (Reeves, 1996).

In that vein, technologies themselves can provide tools to facilitate teacher learning about technology. For example, online learning communities allow teachers to share resources and discuss strategies and approaches even though separated in space and time. At the preservice level, electronic portfolios enhance traditional teaching portfolios by allowing the use of multiple representations to display teaching development with technology (Wiedmer, 1998).

**IMPLICATIONS FOR TEACHER EDUCATION**
No matter whether or how you believe technologies affect thinking and learning, what you think their most appropriate uses in schools are, or what methods you believe will best prepare teachers to use technologies in their classrooms, digital technologies can no longer be viewed as optional, available to only a small segment of the world’s teachers and students. They are essential instruments in a teacher’s 21st century toolkit. Digital technologies are not only becoming commonplace in schools, their integration into classroom teaching is recognized as a vital part of educational planning at all levels.

Indeed, McClintock (1999) argues that recent innovations in digital technology have the potential to dramatically change teaching and learning in three ways. First, the growth of the Internet and broadband, wireless communications can change schools and classrooms from isolated places with relatively scarce access to information to ones with rich connections to the world and all its ideas. He argues that basic pedagogical approaches must accordingly change from disbursing scarce knowledge to enabling students “to use with purpose and effect their unlimited access to the resources of our cultures.” (McClintock, 1999, Paragraph. 12). Secondly, easy access to multimedia allows knowledge construction to assume many forms, and basic educational strategies must be broadened correspondingly to include the intellectual recognition of skills in such areas. Thirdly, McClintock points to digital tools designed to automate lower-level intellectual skills, allowing their users to concentrate on higher-level thinking. He argues that the basic curricular question, What knowledge is of most worth? (1999, paragraph 15) must accordingly be rethought.

WHERE DO WE GO FROM HERE?
McClintock (1999) maintains that his observations are not normative, but rather factual. Innovations in digital technologies have already changed what is educationally possible. To realize that promise, teaching and teacher professional development must significantly change. Digital technologies will remain “oversold and underused” (Cuban, 2001) unless and until teacher professional development changes dramatically to address technology integration as an integral part of classroom practice.

**QUESTIONS TO PROMPT DISCUSSION**

These questions may help you reflect on the issues presented in this chapter.

1. Where do you stand in the Great Media Effects Debate? Are you a medium theorist? Do you agree with those who say technology will never make a difference? Why?

2. How should technology tools be used in schools? Should they be used as tutors, tutees, or cognitive tools? Why?

3. Should preservice teacher education adapt to reflect pedagogical changes inherent in changes in digital technology, or is good pedagogy a constant?

**REFERENCES**


the President of the United States; President’s Committee of Advisors on Science and Technology.


