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Chapter 13

Learning and Teaching with Educational Technologies

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This chapter considers what we have learned about learning and teaching with educational technologies over the past several decades. While there are compelling data and arguments on the positive effects of these tools, there are also well-documented difficulties with implementing such innovations. The social contexts of the uses of technology are crucial to understanding how technology may influence teaching and learning. The classroom influences, in particular the teacher, are seminal. Much more attention needs to be focused on the teacher in research and practice on educational technologies. I provide the metaphor of

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an on-line "School Depot," which could serve national needs in support of teaching and learning with educational technologies.

All across America, students and teachers (and increasingly parents) are finding excitement in new technologies for learning and teaching. Stories abound of troubled students who suddenly spring to life as their peers recognize the talents these students express in graphics programming, or in video editing, or in building simulations. Conferences of computer-using educators are abuzz with talk of connectivity to the "information superhighway," of how no school can survive without direct Internet access and TCP/IP, gopher and World Wide Web information servers, and about the relative merits of different computer operating systems or computer chips such as the PowerPC and the Pentium. Schools and parents are buying multimedia computers with CD-ROM players at a rapid pace. Deals among media conglomerates in interactive information services are front-page news virtually every day. What is all this chatter about? What is going on here? And how might it bear on education? Is this just another hyped-up technology infatuation for education, like filmstrips or Skinner machines, which will not really make much of a difference for what or how students learn and teachers teach?

"Educational technologies," in the broad sense of the term, are any resources, including methods, tools, or processes used for handling the activities involved in education. In this sense, the presence of a teacher, written materials such as books or physical materials such as alphabet blocks, the use of display media such as chalkboards or overhead transparencies, the techniques of lectures or hands-on laboratories, or even the use of assessment instruments are all "educational technologies." In practice, though, after World War II the phrase had a more restrictive meaning, referring to technologies such as filmstrips, slide projectors, language learning laboratories using audiotapes, and television. Since the advent of personal computing in the early 1980s, "educational technologies" has come to refer primarily to computer-based learning, to the use of interactive videodiscs and more recently CD-ROMs, and, within the past few years, to learning environments established with computer and communications technologies, such as computer networks. In short, "educational technologies" has commonly been used to refer to the most advanced technologies available for teaching and learning in a particular era.

Given the diversity of educational technologies incorporated in this thumbnail history, it will not be feasible to provide even a cursory review of research on what is known about learning and teaching with them (see CTGV, 1995). I will primarily aim to offer a characterization of ways of *thinking* about the roles of educational technologies in the educational enterprise. For that is the primary purpose of this book-to provide useful guidance for educational policymakers, practitioners, and parents-toward establishing effective conditions for improving learning and settings for learning, such as schools.

I will describe the diversity of ways in which such technologies have been used for learning and teaching, in which their design has been guided by different perspectives on learning, and by which assessments of the "effects" of their use have been made. It is also important to view such considerations against a backdrop of rapidly changing conditions in how accessible computational, software, and networking resources are to schools, and what properties these technologies are coming to have (e.g., greater speed of interactivity, wireless connectivity, more frequent use of graphics, animation, and video).

There is another important reason to consider technologies in education, beyond their potentials for improving the provision of education per se. Over the past fifteen years, computers and their affiliated media and communication technologies have become a fundamental fact of life in this country. They increasingly undergird how citizens and institutions work, learn, and play, and are ubiquitous in our living space. The Secretary's Commission on Achieving Necessary Skills (SCANS) of the U.S. Department of Labor says that "those unable to use... [technology] face a lifetime of menial work." Such technologies are thus essential to education for the future, and it is the responsibility of education to find designs for their effective use, or our schools will fall drastically out of step with society.

A recent study from the U.S. Congress's Office of Technology Assessment (OTA, 1995) estimates that in spring 1995 there were

- About 5.8 million computers in United States schools for use in instruction for about 50 million pre-college students.
- At least one television and videocassette recorder in every

school, and 41 percent of teachers with a television in their classroom.

- Only one in eight teachers with a telephone in the classroom, and 1 percent of teachers with voice mail.
- Only 3 percent of all instructional rooms connected to the Internet, though 35 percent of public schools have some kind of Internet access.

I believe that such technologies are neither sufficiently nor effectively used in American schools today. On the high end of estimates in the 1995 OTA report, the average K-12 student spends only about two hours a week using a computer, and only one-third of our teachers identify themselves as "computer-using." A large proportion of the school computers (e.g., Apple IIs) are outdated, and cannot handle most software available today.

I begin this chapter by presenting a framework for thinking about the uses of educational technologies. Second, I provide a taxonomy of different uses of computing in education, discussing the theoretical foundations for those uses that define what outcomes the technologies are expected to provide, and under what conditions they have had such outcomes. I then proceed to highlight the fundamental influence of the social context of educational technology use in determining any outcomes that might result from such uses. Third, with these concerns about social context in mind, I introduce the concept of an on-line "School Depot" to serve educators' appropriation of educational technologies for improving teaching and learning (by analogy to the home-renovation superstore chain, "Home Depot"). What are some of the practical aspects of establishing a culture of improvement in school environments that plan to substantively integrate educational technologies?

A Framework for Educational Technologies

Technology in classrooms provides an extraordinarily complex nexus between institutional and societal change, and presents intricate challenges to the scientific and social analysis of learning. Educational technologies are neither simply a way of automating existing educational practice for efficiency nor a means of innovating and reforming practice through the technologies alone.

It is useful to make an analogy to a basic tool to illustrate a fundamental and often neglected point about educational technologies. Consider a particular type of hammer that was designed to support particular activities-say, nail hammering (with a flat hammer head) and removal (with its claw side). The designer's intentions, as expressed in this tool, do not guarantee that the user of the hammer will use the tool in the ways that the designer intended. But the properties of the tool-such as its size, shape, surfaces, weight, and materials-furnish means to use the tool in the intended ways. The user may force this tool into uses ill-matched to its design, such as breaking rocks. The user may also come to invent positive uses of the nail hammer that the designer never intended, such as making the claw end serve to pry up loose boards during house renovation, or to loosen up soil before planting seeds in the spring.

In a like vein, the user of educational technology in the classroom receives *some* guidance from the designer in matching activities using that technology to its properties. But the properties of these educational technologies, just like those of the nail hammer above, do not ensure their use according to the intentions of the designer. And, in like vein again, the users of educational technologies may invent positive, and not only negative, uses of the educational technologies, which were unanticipated by its designers.

In light of this tool analogy, I will now characterize components of a socio-cultural framework for thinking about the uses of educational technologies.

Design Ideology

The first component is made up of the primary design influences for the technology. For example, what views of learning, the learner, knowledge, and outcomes, served to guide the design of the technology? On what we may call here the "design side" of the educational technology, the technology-as-artifact comes as a carrier of expectations. The properties it will have are expected by the design ideology to guide its "appropriate use" in educational activities.

Design Properties

The second component involves the properties that are said to be part of the technology itself-its "functions"-which are usually characterized by its designers. What properties of the technology are expected to enable fulfillment of the designer's intentions in the uses of the technology?

Design Interpretation

The third component involves the social, interpretive environment in which this technology is introduced and used. On this "use side" of educational technology, the technology comes into the setting, to the students, teachers, principal, and other administrators, as something that is *interpreted,* like a text-and not with just one meaning, but many. In other words, the intended design of the technology may not be obvious from its properties. How it comes to be talked about, thought about, and used will determine what consequences the technology will have for learning and teaching. A great diversity of influences affects how this object will be conceived of, and what it will be associated with (e.g., vocational education, drill and practice of basic skills, carrier of powerful ideas, or powerful multimedia motivator for the economically disadvantaged). These influences include

1. The promise computers are supposed to hold as harbingers of a new world of education, "attracting," "empowering," "personalizing," and "motivating" youth and "professionalizing" teaching. Teachers and administrators alike may see computers positively or negatively, depending on how the technology may fit with, help evolve, or obstruct the work conditions and power relations in their own institutions.
2. The positive media images of the value of computers as an index of modernization, efficiency, and the likelihood of jobs for those who master their uses; or the negative images of computers as de-skilling workers, reducing face-to-face interactions and hands-on learning, and promoting surveillance.
3. The genres of media-pop culture such as MTV, feature films, broadcast television, and videogames in new multimedia uses of computing.

Some positive aspects of the "use side" of design are that computers may enable teachers to shift their roles in supporting student learning from "sage on the stage" to "guide on the side," and empower their teaching activities. They may allow teachers to model for students educationally desired forms of activity and thinking too constrained by previous classroom tools.

Some negative aspects of the "use side" of design are that teachers are aware of potential threats of "integrated learning systems" (a form of centrally managed, closed network of computer-assisted instruction) to their autonomy in selecting means for meeting student learning objectives. Teachers may be concerned about new kinds of required accountabilities. They may be worried about their teaching becoming dependent on resolving the computer-related technical support issues. Also, with some of the uses of educational technologies I describe below, the new questions students raise for teachers in open-ended learning environments may challenge the limits of the teachers' knowledge and authority in ways they find difficult to handle. Teachers who are under supported in training and release time and disempowered from using their own judgments about how to appropriately employ computers for augmenting their teaching may feel taken over by these technologies rather than empowered by them.

For students, too, the interpretive frameworks for computers will shape their use. For example, students' identity formation involves their affiliation with specific social groups, which is a process particularly salient in the adolescent years. This will mean that there are signal values of technology acceptance or rejection. Whether or not students react with enthusiasm to these tools will have broad influence over their uses in and out of the classroom.

The Opportunities and Obstacles of Educational Technologies

How have technologies been used for learning and teaching? On one extreme, technologies have been used to "automate," or make "more efficient," traditional methods of instruction, such as by providing drill and practice in basic multiplication facts. On the other extreme, technologies have been used to provide experience with the same productivity tools that are used in work (such as word processors, spreadsheets, and database programs) and in research (such as in the use of microcomputer-based labs for collecting data such as temperature and graphing its changes over time, or in scientific data analysis programs). *The guiding contexts of different uses of technology have thus been very different.* In one context, technology use promotes "business as usual"; in the other, it involves accelerating student access to learning through complex, authentic tasks in order to achieve the higher standards targeted in educational reforms.

I will next present a helpful taxonomy of uses of educational technologies (from Means et al., 1993). Each category of design for technologies has been guided by different theories of learning, or to use the language above, different "design ideologies." Different design properties have emerged from these ideologies, and different interpretations of these categories of technology are found in their uses. Correspondingly, different kinds of assessments have been made of the "effects" of using such educational technologies.

Technologies for Tutorial Learning

Through computer-assisted instruction (CAI), tutors and drill-and-practice programs have been used as "instructional delivery" vehicles for a great diversity of subjects. Common CAI programs teach spelling and basic mathematical skills such as adding, and highlight memorization of facts and theories in subjects such as science and social studies. At the core of this use of technology for education is the traditional model of education as the "transmission" of knowledge from the teacher to the student whose memory will be tested in order to measure achievement. CAI has appealed to educators because of such design properties as brief and branching lessons, well-defined feedback, careful student performance records, and good fit to this traditional pedagogy. Today's CAI programs are often bundled in "integrated learning systems" for managing individualized instruction. They provide for little flexibility in design interpretation-since the very point is a controlled learning experience "delivered" by computer.

Studies of the outcomes of computerized instruction document that on conventional achievement tests, students who receive CAI do as well as or better than students taught with traditional instruction (e.g., students who receive CAI demonstrate increased test item accuracy).

Critiques of this work have emphasized either methodological flaws or misguided educational theory. Critiques that emphasize methodological flaws argue that superior effects from CAI as compared to live instruction are not due to the computer, but to the teaching method embedded in its use (Clark, 1994). Critiques that emphasize misguided theory acknowledge that there is a place for such skill training in K-12 education-but as a broad model for education, the transmission approach is problematic (CTGV, 1995; Means et al., 1993; OTA, 1995). The transmission approach fails to prepare students for a more competitive workplace in which open-ended inquiry, more complex tasks, and collaborative activity are common. Furthermore, it may waste students' time by having them practice skills that are irrelevant due to universal access to computation (e.g., CAI lessons on multiplying fractions instead of an emphasis on calculator use and estimating results from calculations).

Technologies for Exploratory Learning

The use of computers to provide electronic databases, programming languages, simulations, and other kinds of "microworids" for student-directed explorations has become increasingly common. Interactive video is an increasingly frequent application with videodisc and CD-ROM players in the classroom. Videos often depict rich phenomena and events in such subjects as science, history, and social studies of contemporary life.

A design ideology different from the transmission model guides the design and use of such learning tools. Designers of these tools and the educators who use them seek to provide opportunities for the learner to engage in complex comprehension, reasoning, and authoring tasks that are similar to such tasks in the real world. Learners "construct" new knowledge by engaging their present understanding when thinking about the content provided by these more realistic problems and are motivated to understand a subject by pursuing their own questions about it. Basic skills are learned as larger problems are considered; that is, basic skills become useful rather than decontextualized procedures. Information technologies transform students into discoverers and authors of new information and meaning. Simulation technologies offer students insights into complex systems, including such topics as fractal mathematics, chaos, urban planning, and ecology.

Design properties of such technology that attract educators and learners include rapid electronic access to vast repositories of information (in on-line encyclopedias and databases), and modeling functions that enable learners to frame and test hypotheses about how real-world systems work (e.g., urban planning in SimCity).

Because of the focus on multidisciplinary inquiry, open-ended explorations, and more complex tasks, it is rare for narrow measures of traditional student achievement to be taken when such exploratory learning environments are studied. Instead, assessments of student learning have tended to include "case studies" of students' work (e.g., portfolio outcomes), or have held up the valued learning outcome of the students' use of these systems itself as an index of prima facie importance. As for design interpretation, without substantial support for professional development, teachers might view these exploratory technologies as difficult to connect to the core curriculum for purposes of accountability.

Technologies as Applications

Looking to how computers were used in society, education came to adopt the "tools" provided by computers at work and in other contexts. In the early 1980s, this strategy meant word processing for writing, spreadsheets for mathematical modeling and science, and databases for building up and searching information during research inquiries in many subject domains. Today, it also includes desktop publishing, authoring multimedia documents, CAD (computer-aided design), scientific visualization of complex data, animation, and digital video editing. The design ideology of such tools is to provide "cognitive technologies" that enable more complex activity, with less error and effort, than can be achieved without the technologies. The pedagogy underlying using such applications has been "learning by doing," often associated with John Dewey's work early in this century, but reborn in recent work emphasizing "situated learning" and instructional strategies such as "cognitive apprenticeships." To enable students to learn through participation in complex activities, this educational orientation seeks to harness the power of tools and human supports that characterized learning before schools were even invented. Such tools also lend themselves well to multidisciplinary tasks (e.g., writing and science investigations), and can be "integrated" throughout the subjects of the school curriculum. In one dramatic example, scientific visualization tools allow pre-college learners to use the same techniques and data as those used by professional scientists.'

The difficulties with this approach often come from this very freedom of design interpretation-it is not a simple matter for teachers to integrate such "flexible" tools into the curriculum. More important, such uses of computers make evident that new technologies should change curriculum, for their use is changing what learners need to know (Pea, 1993). The activity of drill and practice in multiplying and dividing fractions makes very little sense given that calculators are now commonplace. The technologies shift the burden of computation to the computer, and make the human's role one of meaningfully using mathematics to reason about situations. Time in mathematics education is far better spent, according to curriculum experts in the field of mathematics teaching, on helping students achieve facile use and understanding of how the symbol systems of mathematics may be used to model the world and think about it. While this "shifting ground" of learning goals with developments in technology is an important lesson, it is also a ground for controversy. Any time instructional goals are changed or technology is made instrumental to the achievement of learning objectives, there are disputes about the appropriateness of students' using technology to do part of the problem-solving tasks presented in education.

Another difficulty is that the wide range of useful application programs can mean that students and teachers need to learn to use quite a few distinct software programs. In a worst case, some

'See the World Wide Web server on the Learning through Collaborative Visualization (CoVis) Project at http://www.covis.nwu.edu schools "teach" students how to operate different word processors, rather than teach them to use a word processor to write better.

We also often find instructional time devoted to teaching students how computers work, because in using computers as tools, fundamental concepts and processes in information technology and sometimes in computer science need to be understood. The 1980s fashion for separate courses in "computer literacy" has now thankfully faded. Many teachers weave in such instruction as students develop proficiency in specific uses of computers. Nonetheless, recent studies document that worldwide a predominant use of computers in education is to teach *about* computers rather than *with* computers. Up to half of the computer use in upper secondary schools is computer education rather than computer use for academic subjects (Becker, 1993). And in U.S. schools, only small proportions of computer access time are devoted to subjects such as mathematics, science, and writing, in which computers are fundamental to adult work.

Furthermore, learning to program a computer for its own sake rather than for particular purposes of modeling or inquiry in science or social studies is viewed as less significant than it was in the 1980s. This shift is in part due to a recognition that programming is unlikely to serve as a general-purpose way of teaching thinking skills, because the considerable knowledge specific to a given programming language or an application area renders the "general" aspects of cognitive skill affiliated with programming rather small.

Appraisals of the tool applications of computers in education have tended to highlight the value of students' learning to use such tools for life outside school. As students use computers for electronic library research, on-line data collection, and writing and preparing desktop publications in collaborative learning groups, they are learning crucial inquiry, analysis, and synthesis skills and are applying these skills to many different subjects.

Technologies for Communication

With the integration of computing and communications has emerged widespread interest in using computer-based communication technologies for education. Perhaps the greatest passion is for students to have connection to the Internet, the huge network of networks that connects computers around the world. The primary design ideology behind telecommunications is to enable and even supersede the capabilities of face-to-face interaction. Initiated in the defense community and its use broadened by university researchers, the Internet is now the backbone of electronic communication, and, increasingly, commerce, for over fifty million computer users.

Design properties of such communication technologies as electronic mail, conferencing systems, file transfer, and World Wide Web standards for multimedia file storage, display, and retrieval enable students and teachers to write and send messages to one another, download information and programs from remote computers, and participate in such exciting educational paradigms as collaborative learning, teleapprenticeships in particular knowledge domains, and telementoring relationships (e.g., with a scientist advisor to work on an investigative project). The ability to go beyond the school walls in order to tap distributed expertise and databases is perhaps the greatest motivation for educators to this use of computing. Network technologies promote local and global collaboration and exchange of information among students, schools, and society.

Educational projects involving such communication technologies have tended to provide textured accounts of their patterns of use by students and other participants, and to highlight students' extensive writing and reading in such electronic exchanges. Of all four categories presented here, telecommunications perhaps represents the greatest flexibility for design interpretation in the educational setting-with the greatest challenges to teachers to make effective use of the technologies.

Synthesis of the Opportunities and Obstacles of Educational Technologies

Across these different guiding perspectives on learning and these varying intervention contexts for uses of educational technology, tremendous potentials for enriching learning experiences and teaching outcomes have been demonstrated. Of particular interest are those uses of educational technologies that are well matched to the higher standards of complex thinking and problem solving sought in today's workplace, even though they are ill matched to the traditional "transmission" model of education common in today's classrooms. Yet persistent problems have emerged when researchers and practitioners seek to implement educational improvements with new technologies on a broad scale. For example:

- Teachers have difficulties linking new technologies to local curricula. And right now, they do not have time to effectively integrate tools into instruction (OTA, 1995).
- There are large differences in how teachers use innovative educational technologies, with corresponding differences in students' learning outcomes. These effects were not so apparent in "teacher-proof" uses of technology to train students in basic skills, because teachers relinquished control to the computer for arranging curriculum and guiding student progress.
- When researchers disappear, classrooms often revert to traditional forms, even when new technologies remain in place. Teachers "close their classroom doors and teach as they were taught" (Smith and O'Day, 1990).

Many of the research studies in educational technology are efforts based on the best learning theory and research findings available. Thanks to the largess of federal funding agencies and private corporations, this research has often included the best available technologies and technological support staff. Under these "design experiment" conditions, it may not be surprising that important improvements in learning were achieved, that students' proficiencies in inquiry improved, and that impressive projects were produced (Hawkins and Collins, forthcoming).

Yet these ideal circumstances for educational "design experiments" will not and cannot be replicated in the large scale. Even with the highest quality equipment, staff, and theoretical underpinnings and the good intentions of all participants, we have learned that it is the particularities of individual contexts-the orientations and activities of the different teachers, students, schools, and families in the community-that make the difference between educational gains and no effects whatsoever from the introduction of technological innovations.

Whatever else is "effective," it is not educational technologies per se. The social contexts are all important. They include not only the technology but its content, the teaching strategies used both "in" the software and "around it" in the classroom, and the classroom environment itself. It is a recurrent finding that the effects of the best software can be neutralized through improper use, and that even poorly designed software can be creatively extended to serve important learning goals.

In this light, consider that the United States has a highly decentralized K-12 school system, with close to three million teachers and fifty million students. There is no national curriculum, but rather state and local control through school districts. Each school system must negotiate state and federal mandates along with the expectations and values of its local community. An effort to set national goals for education in order to prepare American students to compete in the global economy - a program called *Goals 2000* - was recently decimated by Congress. Each school system, each school, and each classroom struggles with its own unique blend of challenges and strengths.

These facts about American education not only create a fundamental tension in efforts for national improvement throughout a decentralized system but must also be faced when implementing improvement efforts that incorporate educational technologies. What educational technology initiatives could have a national impact in the face of such diversity?

Home Improvement and Educational Reform

The success of any educational reform initiative using technologies depends on embracing and utilizing the diversity of American schools and communities. I propose that we address this problem by looking at the services provided by the builder-supply and home-renovator store called "Home Depot." My wife and I owned a fixer-upper in Northern California and became quite dependent upon the store. After four years in Chicago, where there are no Home Depots, we moved back to Palo Alto for a sabbatical. The first time we went to the local Home Depot for supplies, we realized how much we had missed this place.

Home Depot is a vast superstore with virtually every possible component and tool for any home or garden project. But beyond that, there are knowledgeable workers in the aisles: roaming carpenters, contractors, plumbers, electricians, and other home fixer-uppers. We go into Home Depot with a rough sense of what we want to do, a good description of the context of the project, and a sense for a budget, and their job is to help tailor a solution that will meet our needs. Walk in with a problem (our most recent was to build a nine-foot-wide safety gate between two buildings over a brick walkway leading to a pool), and in thirty minutes all of the parts will be in your basket, and step-by-step instructions for building it will be in hand. In addition to support for individual projects, Home Depot holds free seminars on special topics, and their long store hours ensure that there is always support available-even over the telephone-for projects in process.

Home Depot *empowers* us as home builders, not by leaving us to shop alone, or by *taking over* as experts, or by ignoring the local knowledge we have about our home, but by guiding and supporting our creativity and initiative as we seek to improve that home. We emerge not only with a vision for a solution and strategies and tactics to solve our problem, but with a deeper systemic understanding of how the whole house and garden thing "works." This experience provides general expertise that we can utilize the next time a related problem arises, and that we can share with neighbors and friends when their plumbing blows up.

As you can tell, I love Home Depot. It helps us solve our problems and feel great at the same time. I trust Home Depot to make sure I succeed every time. Can you imagine nearly three million schoolteachers saying such things about a program in support of improving their teaching with technologies? Now consider the outlines of a program, following this analogy, that I will call "School Depot."'

2 This chapter is not the place to provide detailed considerations of which aspects of such a program should be provided by the federal government, the states, local school districts, or business and industry. I would argue that such issues as equity of access, coordination across states, telecommunications subsidies, and laws protecting children would be strong candidates for a federal role.

Research experience with "design experiments" involving educational technologies to reorganize processes of education has found that teachers do not like it when technology know-it-alls come into their classrooms with fix-it attitudes that do not utilize their own teaching expertise. Teachers need recognition for their knowledge of local communities, instructional goals, students, curriculum resources, and assessment. Moreover, given the time pressures and classroom stresses faced by teachers, educational technologies, no matter how well crafted or supported, can be a huge burden rather than an opportunity. Without care, approaching educational improvement with technologies risks alienating teachers or yielding minimal outcomes.

The 1995 Congressional Office of Technology Assessment (OTA) report, *Teachers and Technology: Making the Connection,* observes that: "Helping teachers use technologies effectively may be the most important step to assuring that current and future investments in technology are realized" (p. 2). In the past, the focus and funding in schools has largely been devoted to selecting technologies. In the future, teachers should be offered access to successful models and asked what they want to do with educational technologies to improve instruction. Promoting best practice and effective pedagogy is the primary issue. A productive approach will provide adequate training and continuing support to enable teachers to fulfill their objectives with these new tools, as well as guide them to discover new and more demanding objectives, and alternative practices. Teachers need far more support and training than they receive today. They wish for experience with models of the ways that technology can be integrated with curriculum and enhance their teaching. They must have time and administrative support for using these innovations. While on average, school districts devote only 15 percent of their technology budgets to teacher training, the consensus from many states that have experienced implementation efforts (e.g., Florida, Texas, Washington) is that 30 percent would be a more adequate figure (OTA, 1995).

The OTA report notes that support can include *resources,* such as a personal computer with modem and phone line in each teacher's classroom, *release time* for planning and creating applications of computer-based tools (such as databases for history or science explorations, multimedia lessons in English and fine arts, or spreadsheet applications in mathematics), or *professional* *opportunities* - for identifying cross-curricular applications, team-teaching with their colleagues, or networking with peers from other schools to share experiences and best practices.

In short, educational reforms with technologies must continually help teachers *do their work*, even as they help researchers and policymakers understand what works and what does not. And that is what "School Depot" would do. The aim should be to open up partnerships in which new synergies may grow between the local knowledge of teachers and the knowledge developed by researchers and technology experts outside schools. We can no longer afford technology use just "at the margins" of education (Cohen, 1988), such as in Advanced Placement courses and special education, when it should be fundamental to the entire educational enterprise.

What would need to be done to create "School Depot"?

1. *Give every teacher a computer with a direct connection to the Internet.* Start by getting every teacher and every school wired to the Internet. From any technology platform, a diversity of resources is now accessible through telecommunications, allowing for downloading of information and programs from hundreds of thousands of computers around the globe, as well as electronic mail and teleconferencing interactions with others. In our current studies on network-enhanced science education (see footnote 1), we have found that a level of telecommunications service provision called "basicrate ISDN" (i.e., connectivity at the rate of 56 kbs) is a minimal standard. Slower dial-up connections through a modem tend to be inadequate. A 56 kbs or faster service is needed for reasonable access to multimedia resources and for real-time communication and collaboration.
2. *Establish a national registry of software technologies useful for education.* Create a national clearinghouse of educational software technologies where everything available is registered and in which reviews are provided by experts as well as by educational users. With the web server technologies available today, this is less difficult than it may sound. Companies and suppliers would be responsible for maintaining up-todate product information, and simple web-based "forms" could be used over the network by educators and other professionals to submit reviews from the field.

3. *Create a multimedia database of educational technology case studies.* Design a database that allows teachers to create and to access case studies like those used by business schools. These case studies would provide ideas and cautions concerning the realities of inventing, integrating, and maintaining effective use of a technology for particular learning purposes. Peabody College at Vanderbilt University has pioneered such an approach in teacher professional development (OTA, 1995). A variety of organizational schemes could point teachers to cases that most closely match their own situations. These cases could offer the educator visionary a "pull" into reform-oriented activities with technologies rather than a technology-based "push" from either federal or state top-down reforms. And they could help school districts forge their technology plans-an effort beginning with goals and integrally involving teachers.
4. *Establish design forums.* The Internet may be used to replicate the social network of information and expertise present in the aisles of each Home Depot, but for improving teaching and learning. Just as Home Depot holds seminars on such topics as how to install automatic garden watering systems, School Depot would hold Internet forums on topics such as what software is available for teaching introductory physics, how to assess students' multimedia research projects, how to develop facility in the use of electronic library resources, how to identify and train a computer coordinator for your school. Networked design discussion forums could be established and populated by teachers and moderated by teachers, curriculum experts, technology experts, and researchers. These forums would be crucial mediators of broad reform-oriented appropriations of educational technologies for the people who understand local opportunities and obstacles to technology innovations for learning and teaching are the educators who live them every day.

In these design forums, participants would help one another to craft innovative local uses of the learning and teaching technologies they find in the national registry, and identify appropriate assessment techniques for the learning targeted by such activities. Kids and parents could also link into these forums to share what they find useful, compelling, or problematic. The role of an initiative such as School

Depot should be to facilitate teachers' creativity in curriculum integration of technology - on an ongoing basis - not just to "train" teachers in brief workshops on the mechanics of computer operations, which is the typical in-service "support" that teachers receive today. Some states, such as Texas, have pioneered the use of regional technology resource centers and on-line forums for teachers' continuing professional development.

5. *Provide "just-in-time" support to teachers in effective uses of technologies. Go* to the schools when teachers need help. One thing Home Depot does not do is come to your house to see how your project is going. In business, such guidance in reform-oriented activities is called "change management." Most schools do not have an on-site person devoted to facilitating uses of technology. While this function is probably best handled at the state and local levels, it would be nice if federal support of a School Depot could provide standards for a coordinated framework of support and analysis across states. "Virtual visits" to the classroom can use the telecommunications technology itself to provide just-in-time support to the teacher seeking to effectively integrate new technologies.
6. *Establish educational telecommunications subsidies.* Unpredictable usage fees on a business model have proven to be a deterrent to many schools considering Internet access. As specified in the Telecommunications Act of *1996,* the federal government has the power to support School Depot by providing telecommunications hookup and connection time subsidies to schools. And state governments, such as in Texas, have successfully negotiated very advantageous telecommunications installation and access rates for their schools.
7. *Provide links to teacher preparation.* Use School Depot to make sure that teacher education is tuned to the realities of educational technologies in actual schools. Unfortunately, preservice teacher education today rarely provides experiences in either coursework or internship placement with computer or communications technologies (OTA, *1995).* Yet as a resource for teaching, technologies may help teachers do their work in more effective and satisfying ways, enable them to establish different arrangements of learning environments, or provide access to critical information for improving their teaching practices.

Conclusion

As I have noted, use of computer technologies in society and in schools often leads to redefining what learners need to know, and to changing the nature of instruction and assessment. We know that educational computing has demonstrable benefits. But the studies commonly illustrating these benefits rest on a CAI model of technology use that is no longer adequate to guide design and implementation of educational computing. The CAI model commonly emphasizes teaching the same things more rapidly, and ignores higher educational goals, new learning objectives, and new instructional strategies for teachers to use that were impossible (or cumbersome) without the technology. Such a CAI model is not consonant with emphases on active learning, authentic and challenging learning tasks, and performance-based assessment in educational reform-oriented uses of computers. CAI studies usually restricted their outcome measures to multiple-choice tests that do not tap the communication skills, teamwork, and whole-task reasoning that higher standards for K-12 education demand. Such CAI studies have also insufficiently recognized the diverse social contexts of technology use in classrooms.

A new generation of empirical studies of innovations in educational technology use is underway (e.g., Hawkins and Collins, forthcoming). These action-oriented "design experiments" taking place throughout educational computing research are embedded in the complexities of real educational settings rather than in controlled laboratory studies. They are likely to have greater utility for improving educational processes and outcomes than did CAI research. The primary reasons are that the design experiment approach embraces the qualitative transformations that technology makes possible in what students need to know, and in how their activities can be structured for learning with such technologies (e.g., in distributed collaborative groups). Education needs many more such design experiments. Design experiments involve ongoing partnerships of design, intervention, and evaluation that engage researchers with school systems in realistic conditions over time as technology-based educational innovations are brought into the classroom and researchers seek to establish patterns for the effective use of these innovations. A primary aim of such work has been to provide guidance regarding what works and does not, at a sufficient level of detail so that other schools can "scale" up the model provided in the design experiment.

But educators who take an overly cautious approach to educational technology planning and implementation by awaiting "definitive research" will miss crucial opportunities to learn how to improve the educational experiences in their schools through ongoing testing, monitoring, and refinement at their school sites. It is noteworthy that double standards are often placed on research on learning with educational computing: We insist on research results to warrant investments that are rarely insisted upon for other teaching and learning resources.

In this chapter, I have provided a high-level characterization of an imagined support service for education, which I called "School Depot." It would have the aim of guiding educators' appropriation of educational technologies for improving teaching and learning. This focus has emerged from extensive research on the social context of information technology use, particularly the classroom context, as providing major determinants of the effectiveness of such educational tools. Comprehensive resources, including information, technologies, and ongoing involvement with human expertise, are needed by educators, as well as learners, to achieve effective results with such tools. An initiative like School Depot is needed to coordinate and motivate the creative use of these resources for improving education. It should link teachers, parents, students, developers, and researchers in substantive and sustainable ways. It is realistic: There are already many commercial and free software products that begin to provide the necessary technical functionality. Furthermore, since much of the content is provided by participants, simply "starting it up" would begin the process of providing valuable content and facilitating synergistic partnerships.

Since in their uses of computer tools teachers and students continue the process of design by virtue of inventing and ignoring aspects of their intended designs, it is unproductive to consider these folks to be "problems" for the breakthrough possibilities of educational computing. Instead, their perspectives must be acknowledged, respected, and nurtured. During the post-Sputnik curriculum reforms, "teacher proofing" of instructional materials was a mistaken objective. It still is. Teachers must be partners in design in order for new technologies to work in education. New design methods recognizing the contributions of teachers and students to educational computing should be developed, assessed, and broadly disseminated through such a mechanism as School Depot if the promises of computers for learning and teaching are to be broadly fulfilled.

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