Summary and Policy Options 1

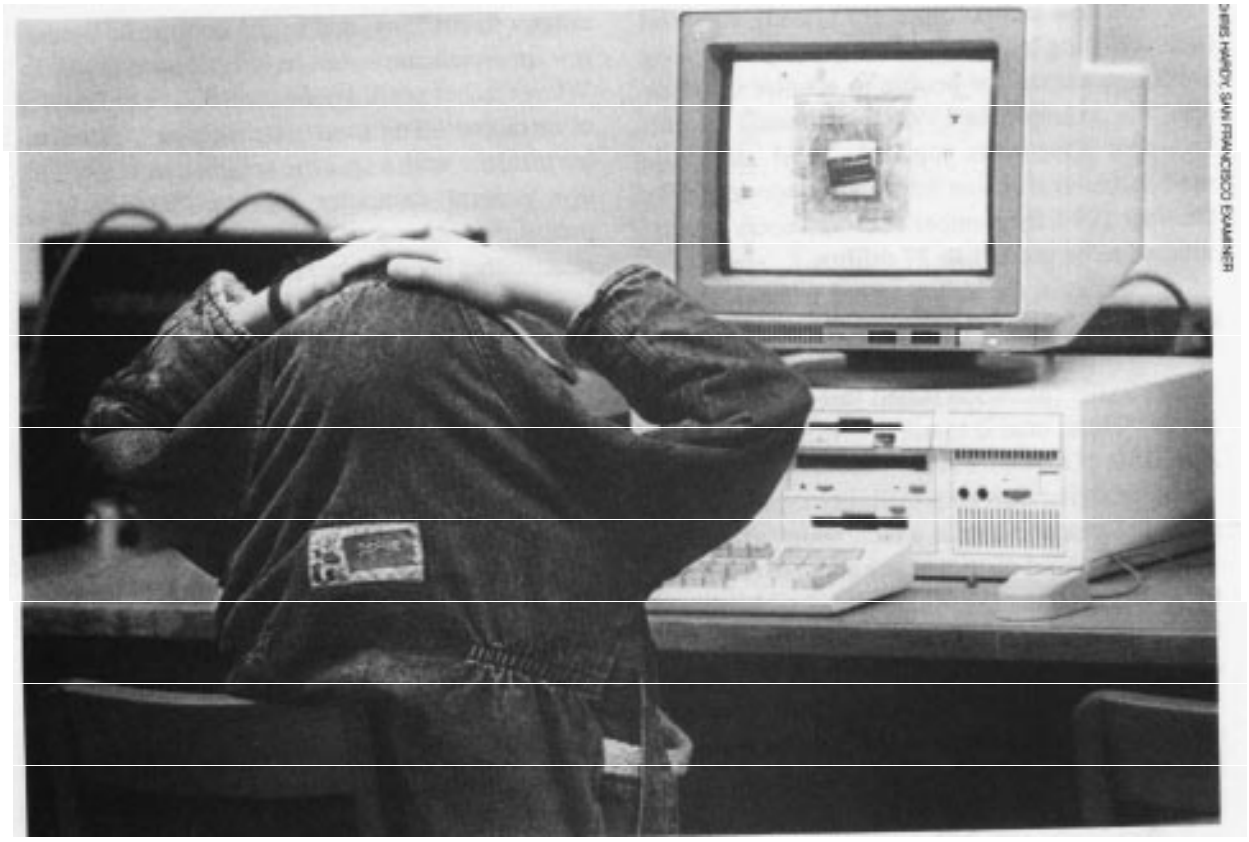
SUMMARY OF KEY FINDINGS

- Projections suggest that by spring 1995, schools in the United States will have 5.8 million computers for use in instruction—about one for every nine students. Almost every school in the country has at least one television and videocassette recorder, and 41 percent of teachers have a TV in their classrooms. Only one teacher in eight has a telephone in class and less than 1 percent have access to voice mail. Classroom access to newer technologies like CD-ROM and networking capabilities are also limited. While 75 percent of public schools have access to some kind of computer network, and 35 percent of public schools have access to the Internet, only 3 percent of instructional rooms (classrooms, labs, and media centers) are connected to the Internet.
- Despite technologies available in schools, a substantial number of teachers report little or no use of computers for instruction. Their use of other technologies also varies considerably.
- While technology is not a panacea for all educational ills, today's technologies are essential tools of the teaching trade. To use these tools well, teachers need visions of the technologies' potential, opportunities to apply them, training and just-in-time support, and time to experiment. Only then can teachers be informed and fearless in their use of new technologies.
- Using technology can change the way teachers teach. Some teachers use technology in traditional "teacher-centered" ways, such as drill and practice for mastery of basic skills, or to supplement teacher-controlled activities. On the other hand, some teachers use technology to support more student-centered approaches to instruction, so that students can conduct

Helping teachers become "fearless"with technology could be the best way to assure that they use these tools effectively in their classrooms.

their own scientific inquiries and engage in collaborative activities while the teacher assumes the role of facilitator or coach. Teachers who fall into the latter group are among the most enthusiastic technology users, because technology is particularly suited to support this kind of instruction.

- Increased communications is one of the biggest changes technology offers classroom teachers. Telecommunications, from simple telephones to advanced networks, can transcend the walls of isolation that shape the teaching profession and allow teachers to converse and share experiences with colleagues, school administrators, parents, and experts in the field.
- Helping teachers use technology effectively may be the most important step to assuring that current and future investments in technology are realized.
- Most teachers have not had adequate training to prepare them to use technology effectively in teaching. Currently, most funds for technology are spent on hardware and software, but experienced technology-using sites advocate larger allocations for training and support. On average, districts devote no more than 15 percent of technology budgets to teacher training. Some states have suggested this figure should be more like 30 percent.
- A majority of teachers report feeling inadequately trained to use technology resources, particularly computer-based technologies. Although many teachers see the value of *students* learning about computers and other technologies, some are not aware of the resources technology can offer them as professionals in carrying out the many aspects of their jobs.
- Although schools have made significant progress in helping teachers to use basic technological tools such as word processing and databases, they still struggle with integrating technology into the curriculum. Curriculum integration is central if technology is to become a truly effective educational resource, yet integration is a difficult, time-consuming, and resource-intensive endeavor.
- Technology can be a valuable resource for improving teacher education overall. It can bring models of the best teaching live from the classroom into the colleges of education, or provide video case studies of teaching styles and approaches. It can forge stronger connections among student teachers, mentor teachers in the field, and university faculty.
- Despite the importance of technology in teacher education, it is not central to the teacher preparation experience in most colleges of education in the United States today. Most new teachers graduate from teacher preparation institutions with limited knowledge of the ways technology can be used in their professional practice.
- The federal government has played a limited role in technology-related teacher development compared with states, universities, and school districts. Even so, past federal programs have piloted innovative educational applications of technology for teachers by providing significant support for professional development, specifically among mathematics, science, and special education teachers, and by providing funding for technology-related professional



Technology is a fact of life in today's society and students will need to be facile with these powerful tools. This young student makes sure his thinking cap is on as he ponders a computer screen in the classroom.

development in school districts that could not have supported it on their own.

- The federal government has tended to focus more on inservice than preservice education, channeling more support to K-12 schools than to colleges of education—an approach that may address current needs but does not greatly influence teacher preparation or quality over the long term.
- The federal government has a unique opportunity to encourage greater links between technology and professional development, through recent legislation such as Goals 2000 and the Improving American's Schools Act. The way the laws are currently written, however, funding for technology and teacher training, and support for effective use, may not be high priorities. National leadership for educational technology can create enthusiasm and support for state and local technology initiatives. Focusing attention, as well as funding, on how technologies can support professional development, and on how teachers are essential to the implementation of technologies, can send important signals to schools around the country.

INTRODUCTION

"A teacher affects eternity; he can never tell where his influence stops."

Henry Adams, from The Education of *HenryAdams*

Technology is a fact of American life. Computers, video, television, telephones, radio, and telecommunications networks exert an incalculable influence on how we live, work, and play—an influence likely to expand as hardware and software become more powerful, affordable, and per-

vasive.[1] New technologies are already essential tools for doing business and are quickly becoming a primary means for people to acquire information. For example, in 1993 an estimated 12 million-plus Americans regularly used electronic mail and related online information services.[2] By October 1994, the number of e-mail users was estimated to be more than 27 million.[3]

For students, the ability to use technology has come to be recognized as an indispensable skill. The Secretary's Commission on Achieving Necessary Skills (SCANS) stated this in the starkest terms, "Those unable to use . . . [technology] face a lifetime of menial work."[4]

Recognizing their responsibility to prepare students to work and live in a technological society, states and school districts have adopted standards for teaching students with and about technology.[5] For example, in a 1994 survey conducted for the Office of Technology Assessment (OTA), all but seven states reported that they require or recommend integrating computers or information technology into the curriculum, and 19 states require seniors to demonstrate computer competency before graduating.[6] The question now is, how can schools use technology more effectively?

Most policy discussions and technology initiatives have tended to focus on hardware and software acquisition, and student access to technology. However, in the enthusiasm to get technology to students, and in the context of limited resources, teacher issues have been shortchanged. When teacher needs are discussed, the emphasis is often on providing short-term training to familiarize teachers with a specific application or encourage general computer literacy. Seldom have policy discussions or initiatives centered on the relationship between technology and the teacher's role. Seldom have they articulated a vision of how technology can empower teachers to carry out all parts of their jobs.

In response to these concerns, noted as issues in earlier OTA reports,[7] OTA was asked to do this study by congressional committees and members of Congress with interests in the application of emerging technologies to education (see box 1-1).

In addition to the usual OTA process of convening an advisory panel, conducting extensive staff work, and obtaining broad peer review of drafts, OTA used a variety of methods to conduct this assessment (see box 1-2). The technologies OTA focused on and their current availability in the nation's elementary and secondary schools are described in box 1-3.

OTA finds the lack of attention to teachers and technologies ironic, for at the center of effective use of instructional technologies are those who oversee the daily activities of the classroom—the teachers. **To use new technologies well, teachers**

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[1] See, e.g., U.S. Congress, Office of Technology Assessment, *Electronic Enterprises: Looking to the Future*, OTA-TCT-600 (Washington, DC: U.S. Government Printing Office, May 1994).

[2] J. Eckhouse, "Internet: Millions of Users Plug in to Hug Computer Network," *San Francisco Chronicle*, June 1, 1993, pp. C-1, C-7.

[3] Matrix Information and Directory Services, Austin, TX, October 1994.

[4] *What Work Requires of Schools: A SCANS Report for America 2000*, Secretary's Commission on Achieving Necessary Skills (Washington DC: U.S. Department of Labor, June 1991), p. 15.

[5] For this study, when the term *technology* is used, it refers to all forms of computers and their peripherals including hard disk drives, printers, CD-ROM, projection devices, and networks offering telecommunications linkages. It also refers to a range of other new or more traditional technologies: telephones, video cameras, televisions and VCRs, fax machines, videodiscs, cable and other one- or two-way links, small devices like electronic calculators, personal digital assistants or other hand-held devices, or combinations of these and other new technologies.

[6] Ronald E. Anderson, "State Technology Activities Related to Teachers," contractor report prepared for the Office of Technology Assessment, U.S. Congress, Washington, DC, Nov. 15, 1994.

[7] U.S. Congress, Office of Technology Assessment, *Power On! New Tools for Teaching and Learning*, OTA-SET-379 (Washington, DC: U.S. Government Printing Office, September 1988); and *Linking for Learning: A New Course for Education*, OTA-SET-430 (Washington, DC: U.S. Government Printing Office, November 1989).

BOX 1-1: Why This Study?

In 1986, Congress asked the Office of Technology Assessment to study the use of computers in schools, In 1988, OTA reported its findings in *Power On! New Tools for Teaching and Learning,* [1] which described the promise of and barriers to using technology in K-12 education. At that time, there were about two million personal computers in American schools, a ratio of roughly one computer for every 30 students. Most educational software was limited to drill-and-practice applications. A handful of small, special-purpose educational software publishers were scrambling to create a market for their products. Schools were focusing attention on teaching students "computer literacy" skills. Teacher training consisted of general computer awareness courses, and a few adventurous souls were learning to program in BASIC or LOGO, so they could design their own software applications. At that time, most teachers did not use computers as a significant part of their teaching-only half the K-12 teaching force reported using computers in instruction. Few teachers had computers of their own at school or at home. Not surprisingly, many teachers were less than impressed with this new wave of educational euphoria.

Similarly, in 1989 when OTA released *Linking for Learning: A New Course for Education,* [3] a followup report assessing how schools were using distance-learning technologies to link students and teachers with resources, activity was limited. At that time, states were beginning to invest in broadcast, microwave, satellite, cable, and computer-based systems, and the federal Star School Project had just funded its first round of projects. In subsequent work assessing technologies for testing [4] and adult literacy, [5] OTA reported on emerging opportunities presented by technology.

In each of these reports to Congress OTA noted the critical role of teachers. To learn more about how schools and teachers use computers and other technologies and what this means for future policies, in the summer of 1993 Congress requested OTA to revisit the issue of teachers and technology in K-12 schools in depth.

Requesters, and their affiliations during the 103d Congress are as follows:

U.S. Senate

Committee on Labor and Human Resources
Edward M. Kennedy, Chairman [6]
Committee on Appropriations
Thad Cochran, Member

U.S. House of Representatives

Committee on Education and Labor [7]
Williarn D. Ford, Chairman [8]
William F. Goodling, Ranking Minority Member [9]
Subcommittee on Elementary, Secondary, and Vocational Education [10]
Dale E. Kildee, Chairman [11]

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[1] U.S. Congress, Office of Technology Assessment, *Power On! New Tools for Teaching and Learning,* OTA-SET-379 (Washington, DC: U.S. Government Printing Office, September 1988).

[2] The main focus of that report was the personal computer, whether as a stand-alone unit, connected to a local area network or as part of a more comprehensive integrated learning system.

[3] *Linking for Learning: A New Course for Education,* OTA-SET-430 Washington, DC: U.S. Government printing Off Ice, November 1989).

[4] *Testing in American Schools Asking the Right Questions,* OTA-SET-519 (Washington, DC: U.S. Government Printing Office, February 1992),

[5] *Adult Literature and New Technologies: Tools for A Lifetime* OTA-SET-550 (Washington, DC: U.S. Government Printing Office, July 1 993),

[6] Now Ranking Minority Member.

[7] Now the House Committee on Economic and Educational Opportunities.

[8] Now retired,

[9] Now Chairman, House Committee on Economic and Educational Opportunities.

[10] Now the House Subcommittee on Early Childhood, Youth, and Farnilies.

[11] Now Ranking Minority Member.

(continued)

BOX 1-1 (cont'd.): Why This Study?

The requesters asked OTA to look at several issues, Do teachers use technology in their teaching? Why? What happens when they do? Why don't more teachers use technology? How do teachers learn about technology? Are prospective teachers being prepared to use technology before entering the classroom? Which factors influence implementation of technology across schools and districts? What roles do schools, districts, states, and the federal government play in helping teachers adjust to the challenges and opportunities presented by new technologies? This report describes the results of OTA's research into all of these questions.

The issue of teachers and technology is of continuing relevance to the 104th Congress. Two major pieces of legislation passed in the 103d Congress have provided authorization for a number of initiatives related to technology. The decisions made by the 104th Congress will shape the direction of these initiatives. The Goals 2000: Educate America Act encourages states to undertake ambitious school reform efforts and funds statewide plans for using technology to achieve these reforms. The Improving America's Schools Act, in a revised Title III of the Elementary and Secondary Education Act (ESEA), contains the most comprehensive legislation for educational technology ever passed by Congress and places a greater emphasis on teacher professional development in several other federal programs. These two laws have the potential to bring more coherent and consistent leadership to the federal role in technology and teacher development, but whether this occurs will depend on how the programs are funded and implemented. This report contains discussion of issues and policy options relevant to implementation.

In addition to funding decisions about current education programs, the 104th Congress faces other issues affecting education technology, most notably legislation to update the Communications Act of 1934. The availability and affordability of telecommunications technologies for schools are two of the most important issues affecting the future of educational technology.

not only need access to them, but they also need opportunities to discover what the technologies can do, learn how to operate them, and experiment with ways to apply them For teachers to make informed choices and wise uses of technology, they must be literate and comfortable with a range of educational technologies.

However, the use of technology in teaching, like any other change to the status quo, should be considered in light of the unique characteristics of the teaching profession. Indeed, teaching has been called many things: an art, a science, a calling, a way of life. Throughout history, teachers have taken up the tools at hand to help them teach—whether marking on clay with a stylus, or writing on a blackboard with chalk. As new technologies have emerged—photography, filmstrips, radio, television—teachers have used them to extend the range of what they could teach, illustrate ideas in different ways, bring new materials to students, and motivate learners.

The process of adopting new technologies has never been quick or effortless, however. Like all professionals, teachers have instructional methods, teaching styles, and working procedures that have served well in the past and that often reflect how they themselves were prepared. And like other large institutions, schools have organizational characteristics that make change difficult. Moreover, the unique culture of schools and changing public expectations for them create conditions substantially different from those of other workplaces.

Although teachers want to enlist all available tools to help their students learn, as new technologies have become more sophisticated, the transition has become even harder, requiring more training before teachers can use them effectively. Teachers, like many in society, can find themselves bewildered by the changing landscape of computer, video, and telecommunications technologies. Many are made skeptical by predictions

BOX 1-2: How This Study Was Cond

Although considerable research has been conducted since 1988 on student uses of technology, far less has been done on teacher uses, and consequently data on teacher issues are limited. As a starting point for this study, OTA reviewed research on teachers and technology, including national surveys and studies, evaluations of federal technology-related programs, and research on state, district, and school technology efforts.

During the course of this study, OTA staff made site visits to schools of all grade levels across the country (see appendix E), and had hundreds of conversations with teachers, researchers, and administrators—in classrooms, at meetings and conferences, and over the telephone and electronic mail. OTA also convened two focus groups of teachers and held a workshop about lessons from research projects on technology in schools.

OTA also drew upon a range of other sources. Much of the background information for the study came from research contracted by OTA (see appendix F), including a series of in-depth interviews with average teachers regarding their experiences with technology,[1] a survey of faculty and recent graduates of colleges of education regarding technology use in preservice teacher education,[2] a research review of telecommunications networks,[3] and a review of past and current federal programs and support for teacher development and technology.[4] A series of OTA-contracted case studies looked at exemplary approaches to training teachers about technology use at the preservice and inservice level.[5] OTA contracted for two other research reviews: an analysis of trend data from several surveys about school acquisition and use of new technologies,[6] and a review of state policies related to technology in K-12 education.[7]

Some of these research strategies yielded statistical data. Others produced information that was mostly descriptive or anecdotal on such issues as teachers' perceptions of the role of technology in their teaching and the factors that encourage or inhibit their technology use. By combining quantitative and qualitative information, OTA has tried to present a multifaceted picture of teacher experiences with technology.

As with all OTA reports, the project was guided by an advisory panel made up of experts and stakeholders in the field: teachers, principals, and district, state, and school board personnel; college of education faculty; representatives of teacher unions and professional organizations; hardware, software, and business representatives; and telecommunications and media experts. The advisory panel met twice, at the beginning of and near the end of the research phase of the project, and helped define the research questions and interpret the information. In addition, dozens of individuals reviewed drafts of and contributed to this study (see appendix D). Although every panel member and reviewer may not agree with all the findings or policy options in this report, the panel's and other reviewers' guidance and direction were critical in shaping its final form.

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[1] Melinda Griffith, "Technology in Schools: Hearing from the Teachers, " Office of Technology Assessment, contractor report, October 1993.

[2] Jery Willis et al., "lnformation Technologies in Teacher Education Survey of the Current Status, " Office of Technology Assessment, contractor report, March 1994.

[3] TERC, "Review of Research on Teachers and Telecommunications, " Office of Technology Assessment, contractor report, May 1994,

[4] Nancy Kober, "Teachers and Technology: The Federal Role, " Office of Technology Assessment, contractor report, May 25,1994.

[5] John R. Mergendoller et al., "Case Studies of Exemplary Approaches to Training Teachers to use Technology, " Office Of Technology Assessment, contractor report, May 1994.

[6] Henry J. Becker, "Analysis and Trends of School Use of New Technologies," Office of Technology Assessment, contractor report, March 1994

[7] Ronald E. Anderson, "State Technology Activities Related to Teachers, " Office of Technology Assessment, contractor report, Nov. 15, 1994.

promising that new technologies will reform education and change schools as we know them.

Making the connection between technology and teachers—helping the 2.8 million teachers in public and private kindergarten-through-twelfth-grade (K-12) schools 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. It is central to the ultimate goal fostered by these investments: not just helping students become competent users of technology, but helping them become more accomplished learners overall.

This report seeks to underscore the connection between teachers and effective implementation of technology in schools.

TEACHING AND TECHNOLOGY: THE POTENTIAL

"You wouldn't want a doctor to remove your gall bladder without the latest technology and the skill to use that technology, would you? It's the same with teaching. [Teachers need tools, skills]. . .it's a profession."

Rusty Sweeny, algebra teacher, Piscataquis Community High School, Guilford, ME

OTA has seen the promise of technology come to light in school districts throughout the country, where many teachers are using technology to teach their students. Some have found it to be a catalyst to support school reform, stimulate new teaching methods, and even redefine the role of teachers. But it is not only in the realm of direct student contact that technology has benefited these teachers. Many other aspects of a teacher's job—preparing materials, developing lessons, assessing student progress, enlisting parent participation, keeping up with advances in pedagogy and content, and participating in the professional community—can be accomplished with technology, often more easily and efficiently. When teachers discover ways that technology can strengthen their teaching, help them carry out administrative tasks, and enrich their professional growth, technology starts to make sense to them. It can be a resource for improving the preparation of new teachers as well. However, there are also many teachers who have not seen this potential, teachers whose use of technology is marginal, limited, and unenthusiastic. The stories and experiences of both these groups suggest lessons for policymakers. Table 1-1 summarizes the potential that technology offers to schools and teachers.

Improving Teaching with Technology

OTA has found many examples throughout the nation of how technology can help teachers with all parts of their jobs. First and foremost, teachers want to ensure that their students are learning. If technology can be a resource to enhance student achievement and interest in learning, teachers are more likely to invest the time and energy to learn to use it in their teaching. However, the relationship between technology and student learning is too often framed as a seemingly simple question: is teaching with computers and other technologies better than teaching without them? Clearly, computers "cannot change leaden instruction into gold,"[8] and there remain numerous questions about how, when, and how well alternative technologies contribute to student learning and achievement. Issues related to measuring the impact of various approaches to teaching, including the use of new technologies on student learning are complicated and beyond the scope of this study (see box 1-4). This report's analysis of the potential of technologies for improving teaching and learning focuses on two aspects of the teaching-learning continuum: teachers' perceptions of how new technologies help them improve their instruction and how they see their classrooms changing as a result.

Many technology-using teachers find that technology can help them improve student learn-

[8] James Bosco, Western Michigan University, personal communication, August 1993.

BOX 1-3: Technologies in U.S. Schools: Definitions and Availability

What are the technologies available in U.S. schools today and how are they used? Following is a brief outline of some technologies found in schools and the potential impact of those technologies on teachers and students.

Computers

A computer is a programmable, electronic machine that can store, retrieve, and process data. Desktop computers are sometimes called microcomputers because they have a single integrated circuit known as a microprocessor.

During the last three years, the total number of computers in schools has risen by about 18 percent annually and, based on those projections, there will be an estimated 5.8 million computers in U.S. schools by spring 1995. That translates to approximately one computer for every nine students. There is enormous variability in student-computer ratios *(computer density)* from school to school and across states. The greatest disparities are found between small schools (enrollments of 300 or less) and large schools (enrollments of 1,000 or more); schools with fewer students tend to have more computers per student.

Still, sheer numbers of computers do not indicate real access or use. For example, although 35 percent of all U.S. public schools have access to the Internet, only 3 percent of instructional rooms (classrooms, labs, and media centers) are connected. Many factors dictate technology use, but the age and power of the technology seems to be a prevalent influence in K-12 schools. As of 1992, one-half of the computers used for K-1 2 instruction in the United States were older, less-powerful Apple II models, yet most software and applications currently being developed today cannot run on these machines.

Two-Way Communications

Two-way communications that allow teachers and students to share and receive ideas with others outside their immediate classroom are an important aspect of telecommunications networking. For basic two-way communications, telephones and *modems* are staple equipment. Currently, though, only one teacher in eight has a telephone in the classroom that can be used for outside calls. In addition, less than 1 percent of teachers with telephones have access to voice mail, which is a useful tool to leave or retrieve messages when parents, administrators, or other teachers are hard to reach during the school day.

A *modem* is a device that allows computers to communicate electronically across telephone lines by converting digital computer signals into analog format for transmission. In recent years, schools have begun installing more modems for teacher use: in 1989 one-fourth of U.S. schools had a modem that could be used by teachers or students, and by 1992 the figure had grown to 38 percent of all schools, although more high schools (60 percent) had modems than middle schools (35 percent) or elementary schools (33 percent).

Telecommunications Networking

Telecommunications networking includes the Internet and other means of accessing shared communications systems that support digital communications among connected computers.

Local area networks (LAN) link computers and peripherals (e.g. printers) within a limited area, often a classroom or building. Wide *area networks (WANS)* connect computers over greater distances, such as building to building, city to city, and so on. Overall, 75 percent of public schools have computers with some networking capabilities-either LAN or WAN access—and of those schools, 40 percent report that machines with these capabilities are located in classrooms;[1] 71 percent say they are located in administra-

1 Many schools responding to the survey reported access in more than one location. U.S. Department of Education, *Advanced Telecommunications in U.S. Public Schools,* K-12 (Washington, DC, U S Department of Education, OERI, February 1995), NCES 95-731,

(continued)

BOX 1-3 (cont'd.): Technologies in U.S. Schools: Definitions and Availability

tive offices; 62 percent, in library/media centers; and only 15 percent in teacher workrooms. Electronic mail (e-mail) is the most common use of telecommunications reported by teachers who are accomplished telecommunications users.[2]

The Internet

The Internet is an international collection of interconnected electronic networks and a set of protocols for communication between computers on these networks. The protocols also include a large and growing list of services that can be provided or accessed over the Internet.

Of the schools reporting networking capabilities, 49 percent have WANS; 35 percent of those have access to the Internet, and 14 percent have access to other types of wide area networks, such as America Online, CompuServe, or Prodigy. Of those with Internet access, on average, only 3 percent of schools have access in instructional rooms (classrooms, library/media centers, computer labs). This means students and teachers typically do not have access to Internet services.

Television/Video

Nearly every school in the country has at least one television set for instructional use. Video is the most common technology used for instruction in schools, from sources such as direct broadcast and cable television and satellite (distance learning). As of 1991, the typical school had seven television sets and six videocassette recorders, which teachers typically use to record and show students commercially broadcast educational programs. While the use of more interactive video resources, such as camcorders, videodiscs, and CD-ROM is growing, these are not used with as much frequency in schools.

Broadcast television (national networks, such as NBC, CBS, ABC) is received by 70 percent of all public schools (61 percent of schools receive PBS). Eighty-three percent of those schools report that broadcast access is available in classrooms, and 84 percent report access in the library/media center.

Cable television (subscription television, such as CNN, the Discovery Channel, The Learning Channel) is available in 74 percent of all public schools, and 70 percent of those schools say access is available in classrooms, while 85 percent report access in library/media centers.

Closed-circuit television (neither broadcast nor cable, but in-house transmission on noncommercial lines) is only available in 25 percent of schools, but 94 percent of those schools say classrooms have access, and 89 percent report access to closed circuit TV in library/media centers.

[2]Margaret Honey and Andres Henriquez, *Telecommunications and K-12 Educators, Findings From A National Survey (New 'fork:* Center for Technology in Education, Bank Street College of Education, 1993).

SOURCE: Office of Technology Assessment, 1995, based on Henry J. Becker, "Analysis and Trends in School Use of New Technologies, " Office of Technology contractor report, March 1994; *also, Advanced Telecommunications in U.S. Public Schools, K-72,* National Center for Education Statistics NCES95-731 (Washington, DC: U.S. Department of Education, OERI, February 1995), see also chapter 3 of this report.

ing and motivation, address students with different learning styles or special needs, expose students to a wider world of information and experts, and implement new teaching techniques. There are many examples of how technology has enhanced teaching:

- Students engaged in a group problem-solving project based on a software or video simulation are learning to work as a team, develop expertise in specific areas, become more confident learners, and weigh the merits of several possible solutions.

- Teachers involved in an international telecommunications project find their students acquiring a new interest in geography, and bonding with students across the globe or in the different world that exists even on the other side of town.
- With graphing software, students appear to develop a deeper understanding of mathematical concepts for which they had learned the formulas but had not applied consistently.
- Special education students, mainstreamed into regular classrooms, work on a more equal basis with their classmates when a computer speaks for them, gives them big print, or adjusts to their difficulties.
- Students who were on the verge of dropping out take anew interest in school when, as part of a class project, they interview other students with camcorders and create daily news shows.
- Using CD-ROM, students research a multimedia term paper, evaluating resources from print, video, and audio media.

After the teacher downloads satellite pictures of daily weather patterns, students use a network to compare their weather data with weather data reported by students around the country, analyzing trends and predicting likely conditions.

A scientist working on cancer research can come online and advise a student setting up a science project on molecular biology.

These kinds of experiences, while far from the norm in schools today, can and do occur in classrooms with access to technology and a teacher who can skillfully guide its use. In most of the above examples, teachers find that their students are doing more than learning generic technology skills or subject-specific technology applications. Rather, they see them developing the kinds of skills and competencies that numerous reform panels have encouraged as essential for all high school graduates-problem-solving skills; broader scientific literacy and mathematical understanding; strong communication skills; personal responsibility, integrity, and initiative; and skills and competencies for the workplace. These workplace competencies include working with resources, acquiring and evaluating information, working with others in groups or teams, understanding complex relationships and systems, and using a range of changing technologies.[9] Although these skills can be developed without technology, technological tools can help teachers structure, organize, or enhance the activities that facilitate the development of these skills.

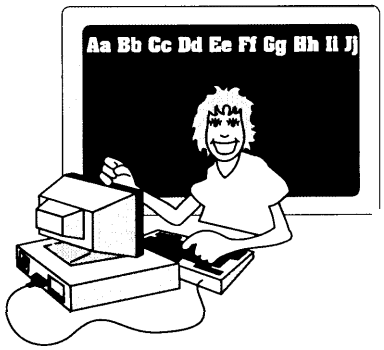
Teachers find that using technology can encourage students to take more responsibility for their learning, to learn to work cooperatively, and gain experience in acquiring, evaluating, and using information in various forms.

Accomplished technology-using teachers indicate that using computers has changed their teach-

[9] See, e.g. Secretary's Commission on Achieving Necessary Skills, op. cit. footnote 4; Anthony Patrick Carnevale, *America and the New Economy* (Washington, DC: American Society for Training and Development, 1991); and William B. Johnston and Arnold H. Packer, *Workforce 2000* (Indianapolis, IN: Hudson Institute, June 1987).

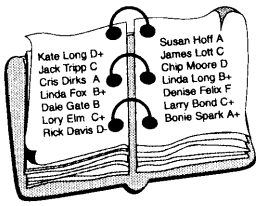
TABLE 1-1: Teaching and Technology: The Potential

Changing teaching and learning



- *Resources for teaching* abstract concepts, complex systems, problem solving—and basic skills
- *Resources for group work and collaborative inquiry*
- *Adaptable* to various student learning styles and special needs
- *Teachers report they:*
  - —Expect more of students
  - —Are more comfortable with students working independently
  - —Present more complex materials
  - —Tailor instruction more to individual needs
  - —Adopt new roles, more ‘(guide on the side” than “sage on the stage”
  - —Spend less time lecturing, so classrooms are more student-centered

Assisting with daily tasks



- *Preparing lesson plans*
  Online databases, CD-ROMs, videodiscs, and other electronic sources help teachers create, customize, and update lessons.
- *Tracking student progress*
  Gradebook programs and databases to update student profiles and maintain records.
- *Communicating*
  Telephone, voice mail, e-mail to contact parents, other teachers, or administrators to plan meetings, discuss student and administrative concerns.

Enhancing professional development

- *“Just-in-time” training and support*
  Satellite, video, cable, or computer access to new ideas, master teachers, and other experts for training and followup.
- *Formal courses and advanced degrees*
  Distance learning technologies for courses not available locally.
- *Informal educational opportunities*
  Online contact with teacher colleagues and other experts.

Preparing new teachers

- *Models of effective teaching*
  Video can take prospective teachers into classrooms to watch effective teachers in action.
- *Computer and video simulations and case studies*
  Give prospective teachers practice solving teaching challenges in a non-threatening environment.
- *Electronic networks*
  Minimize violation during field experiences, provide support and interaction with college faculty or mentors.

SOURCE: Office of Technology Assessment, 1995

ing.[10] Among the changes teachers reported were that they expected more of students, became more comfortable with students working independently, presented more complex material, tailored instruction more to individual needs, and spent less time lecturing and more time overseeing small groups or working one-on-one with students (see chapter 2, box 2-1). Some teachers suggest that using technology has meant they are transforming the educational process—their curriculum and classroom organization. These teachers report that, ultimately, they see a change in their roles as they become more like coaches, encouraging, guiding, and facilitating student learning, and students assume more initiative and responsibility for their own learning. While not all teachers want to make this transition from "sage on the stage to guide on the side," many find it exhilarating.

Assisting with Daily Tasks of Teaching

Teachers perform a wide variety of duties in addition to being instructional leaders, including preparing lesson plans and instructional materials, keeping and transmitting records of student progress, attending school meetings, meeting with parents, and staying abreast of the profession. Yet schools rarely consider the role of technology in assisting teachers with the many parts of the job that go on when the students are not present. And few schools have contemplated how teachers could use their time differently or how teaching personnel could be assigned more flexibly (e.g., teachers working with small groups of students for some parts of the day, large groups at other points) if teachers were freed from mundane tasks that technology could handle.[11]

Technology can assist teachers with daily activities in many ways:

- With electronic gradebook software, teachers can keep and more easily update running grading histories and profiles for every student and counsel them about problems as soon as they occur.
- Teachers can videotape student presentations to evaluate and maintain records of student performance as a part of assessment activities.
- By accessing an electronic database, a teacher can quickly locate a host of current materials relevant to next week's science lesson.
- A teacher can retrieve a voice mail message, at a convenient time, about a change in the time of a parent conference.
- Teachers can plan meetings with other teachers online and save time in coordinating multiple schedules.

OTA has observed that, as teachers develop expertise in these administrative applications, confidence grows, encouraging them to try additional applications to meet instructional and professional development goals.

Enhancing Professional Development for Today's Teachers

Teachers are learners too. They take courses, workshops, and other forms of training to fulfill recertification requirements, learn new instructional methods, or keep up with changes in their specialties. However, the current approach—typically a short inservice course on a specific topic in which a large group of teachers are gathered in one place for an "injection" of training—is limited and often disliked by teachers, administrators, and parents alike. For example, a school district may gather elementary school teachers from across the district to spend a morning learning about a new strategy for teaching reading. This "one-size-fits-all" model of training is rarely used in other pro-

[10] Karen Sheingold and Martha Hadley, *Accomplished Teachers: Integrating Computers into Classroom Practice* (New York, NY: Center for Technology in Education, Bank Street College of Education, September 1990).

[11] See, e.g., Margaret Riel, "The Future of Teaching," contractor report prepared for the Office of Technology Assessment, U.S. Congress, Washington, DC, Jan. 12, 1994.

BOX 1-4: What Difference Does Educational Technology Make?

When a technology is introduced in education, many people want to compare its effectiveness with that of existing methods of instruction. In the 1960s and 1970s, a number of studies compared learning via radio and television with learning via classroom lectures or textbooks. More recently, many studies have been conducted comparing computer-assisted instruction with more traditional methods of instruction. These studies have consistently demonstrated that computer-assisted instruction technologies are either equivalent or superior to conventional instruction.[1] Meta-analyses, which examine the results of many studies and aggregate their combined effects, show effects that range from .26 to .66 standard deviations, which represent a sizable improvement on many achievement measures as well as positive attitudinal effects.[2] Small, but growing, numbers of studies have begun to examine effects of newer technologies such as videodisc or telecommunications networks.

Several factors belie simplistic approaches to the important but complex question of effectiveness. These issues include:

- *Conceptual* factors—are researchers, parents, teachers, and policymakers asking the right questions and interpreting available research correctly?
- *Methodological factors*— is the research designed well enough to answer questions of effectiveness? and
- *Timeliness factors*— with rapid advances in technology, including rapid obsolescence of yesterday's "new" technologies, do the research results tell interested parties what they need to know today to plan tomorrow's classroom uses of technologies?

Conceptual Issues. In general, many available studies of the effectiveness of educational technologies can be thought of as "horse race" studies because, when interpreted too simplistically, they are expected to provide evidence that one technology can "beat" another by showing that students "learn more" when it is used.[3] This approach can be misleading.[4] Whenever a new educational treatment is tried its effects are not just attributable to the technology (e.g., computer, video, books) but also to the particular content (e.g., subject matter, targeted skills) and pedagogical approach (e.g., software, teaching materials, teachers, and classroom environment). The type of learner (e.g., age, previous achievement, special needs) also influences the effects of these other variables on learning. In other words, it is not the effects of the technology by itself that are analyzed in these studies, but the aggregated effects of *how the technology is being used in the classroom context.* Available and future research should be interpreted with an eye to these factors, which can attenuate or enhance the effects of particular technologies.

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[1] See, e g., C. Kulik and J.A. Kulik, "Effectiveness of Computer-Based Instruction' An Updated Analysis, " *Computers in Human Behavior, vol.* 7, pp. 75-94; John Pisapia and Stephen M. Perlman, "Learning Technologies in the Classroom A Study of Results" (Richmond, VA: Metropolitan Educational Research Consortium, Dec. 1992); Alice Ryan, "Meta-analysis of Achievement Effects of Microcomputer Applications in Elementary Schools," *Educational Administration Quarterly,* vol. 27, No. 2, May 1991, pp. 161 -184; Interactive Educational Systems Design, Inc., *Report on the Effectiveness of Technology in Schools,* 1990-1994 (Washington, DC: Software Publishers Association, n.d.).

[2] Mark W. Lipsey and David B. Wilson, "The Efficacy of Psychological, Educational, and Behavioral Treatment. Confirmation from Meta-analysis,'' *American Psychologist,* December 1993; Effect size (ES) is a measure of the difference between a control group that did not use the technology and the treatment group that did. ES is expressed in standard deviation units. "An ES of 17 is quite small and unimportant, whereas an ES of 33 is modest but important To interpret the numbers more easily, they can be converted to percentiles. For example, an effect size of .33 means that the treatment group would be at the 63rd percentile compared with the control group at the 50th percentile." (J. Johnston, *Electronic Learning, 1987,* p 50)

[3] Barbara Means et al , *Using Technology to Support Education Reform* (Washington, DC: U.S. Government Printing Office, September 1993), p. 73.

[4] Means et al., op. cit., footnote 3, Ann□. Thompson, Michael R Simonson, and Constance P. Hargrave,*Educational Technology: A Review of the Research* (Washington, DC. Association for Educational Communications and Technology, 1992).

BOX 1-4 (cont'd.): What Difference Does Educational Technology Make?

Methodological Issues. It is important to note that there are several basic factors frustrating researchers, teachers, and policy makers looking for simple yes or no answers about technology's effectiveness. One is the overall context of real world educational research. As one researcher noted, "Schools are messy and noisy environments for research, far from the pristine, controlled setting available in the research laboratory, the model on which most quantitative evaluation studies are based. "[5] Comparable comparison groups are scarce; interventions with technology are usually a part of broader interventions that also influence outcomes; and different treatments for experimental and control groups run counter to a teacher's impulse to treat all students equitably.

A second major flaw in the existing research is the lack of good outcome measures for assessing the impact of technology-based innovations. Most of the research to date relies on existing measures of student achievement (e.g., standardized achievement tests). Although there are many promising efforts to broaden the kinds of indicators that can be used to assess student achievement, these are not yet in widespread use.[6] New achievement measures would assess areas that many believe can be particularly affected by using new technologies (e.g., higher-order thinking). Also key, however, is the need to include outcomes that go beyond student achievement, because student achievement may be affected by students' attitudes about themselves, school, and learning, and by the types of interactions that go on in schools. For example, some research has documented the positive effects of computer-assisted instruction on students attitudes about school and learning.[7] Also promising is recent research that suggests that technology-based innovations can affect student self-concept as well as interactions between students and teachers in the classroom environment.[8] Technological changes are likely to be nonlinear, and technological changes may show their impacts not only on student learning, but also on the curricula, the nature of instruction,[9] the culture of schools, and the fundamental ways teachers do their jobs.

Timeliness. The rapid pace and the potentially high cost of some technological changes[10] create a dilemma for the typically slower pace of careful research. Policymakers—and taxpayers-faced with deciding whether to invest millions of dollars in an information infrastructure typically want to know whether their investment will be worth the increased financial burden (assuming technology does not replace existing methods). For example, they will want to know whether what is on the '(information superhighway" will really help their children achieve, whether putting a telephone on every teacher's desk will really improve parent-teacher communication, or whether investing in new personnel to provide "just-in-time" support for technology-using teachers will enhance the instructional capabilities of existing technology investments. Equally reasonable seem the frustrations of those who have experienced the promise of particular educational technologies in small experimental programs (e.g., downloading real-time information on weather data from satellites for science lessons). By the time the external evidence has been compiled, "proving" that technology integration works and districts are ready to commit to purchases of the appropriate hardware and software, the technology that has been researched may be obsolete and a golden opportunity to use it for current students will have been lost.

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[5] Joan O. Herman, "Evaluating the Effects of Technology In School Reform, " *Technology and Education Reform The Reality Behind the Promise,* Barbara Means (cd.) (San Francisco, CA. Jossey-Bass Publishers, 1994), p. 145

[6] See *Testing in American Schools: Asking the Right Questions,* OTA-SET-51 9 (Washington DC: U.S. Government Printing Off Ice, February 1992),

[7] Thompson et al., op. cit., footnote 4.

[8] J. Sivin-Kachala and Ellen R. Bialo, *Report on the Effectiveness of Technology in Schools:1990-1994* (Washington, DC, Software Publishers Association, n.d.).

[9] Jerome Johnston, *Electronic Learning: From Audiotape to Videodisc* (Hillsdale, NJ: Lawrence Erlbaum, 1987).

[10] The costs of educational technologies are not known with certainty. What is known is that they will vary considerably depending on an array of factors. See section on "Costs" later in this chapter

(continued)

BOX 1-4 (cont'd.): What Difference Does Educational Technology Make?

Directions for the Future. Although there are some promising studies, more research on the broad variety of educational effects of technology is needed. A more fruitful research approach than merely asking whether a particular technology works is to ask about the "value added" to instruction when technology is present in schools; in other words, when, why, and how do technologies improve teaching, professional development, and, ultimately, learning for children? Increasingly, researchers are concentrating their efforts on this type of more contextualized research—studying how complex-technology-based innovations "work" in real classroom settings over time. Such research can help to determine how technology environments can best be designed to support student learning and what approaches to instruction work best in conjunction with various types of technologies for what kinds of subject matter. The role of the teacher in implementing and facilitating student learning in such environments is an important focus of such studies. ' [11] Additional research models are needed to deepen understanding about which instructional uses of technology are most effective and under what circumstances, and how teacher interactions with technology play into this effectiveness. By taking a more contextualized approach, research can help schools, parents, teachers, and policymakers understand the necessary steps to diffusing and continuously refining educational technologies in the schools.

[11] For examples of this kind of research see A.L. Brown, "Design Experiments Theoretical and Methodological Challenges in Creating Complex Interventions m Classroom Settings, " *Journal of the Learning Sciences,* vol. 2, No. 2, pp. 141-178, Cognition and Technology Group at Vanderbilt, "The Jasper Experiment An Exploration of Issues in Learning and Instructional Design, "Educational *Technology Research and Development, Vol.* 40, pp. 65-80, 1992.

SOURCE: Office of Technology Assessment, 1995.

fessions, and, although it may be efficient for school districts, many suggest it is not the most effective way to encourage teachers to learn new skills or teaching approaches. It appears to be a particularly ill-chosen method for encouraging teachers to use technology, where hands-on training with the hardware and software, curriculum-specific applications, and followup support are all necessary.

OTA has found examples of how technology can provide teachers with "just-in-time training and support" when and where they need assistance in many curricular areas. It can transcend the walls of isolation that separate teachers and extend formal and informal learning opportunities. The following are some examples:

- Without leaving their school buildings, teachers from across the 90 school districts in sprawling Los Angeles County can participate in a satellite staff development course on topics such as how to apply the California history and social science framework in lessons in their classrooms.
- School counselors from across Wyoming meet regularly over a compressed video network to discuss student truancy and behavior problems.
- A special education professor at the University of Northern Iowa offers courses to teachers throughout the state over the Iowa Communication Network. With this fiberoptic network, teachers at each site can see and hear each other as they develop skills for adding the certification credits that will enable them to teach students with moderate, severe, and profound mental disabilities.
- Mathematics teachers use a computer network to discuss the mathematics teaching techniques they have observed through video presentations in the Mathline project sponsored by the Public Broadcasting System.

- Using cable television, teachers from remote locations around the country can take courses leading to a masters in educational technology degree from George Washington University in Washington, DC.

In examples like these, technology can be the vehicle for providing teachers access to new ideas, master teachers and other professionals beyond their school setting, in both formal and informal courses and enrichment activities. It can also provide the support teachers need after a course ends, as they apply and refine in the classroom the lessons and techniques they have learned.

■ Preparing New Teachers with Technology

In colleges of education where technology is an integral part of the teacher education preservice program, technology has been used not just to train prospective teachers about technology, but also as a resource to enhance the overall teacher preparation experience. For example, live broadcasts, tapes, video networks, CD-ROMs or videodiscs can provide teacher education students with case studies or models of effective teaching. Furthermore, technology-whether computer or video networks-can create closer connections among student teachers, college of education faculty, and mentor teachers in K-12 classrooms, whether in lab schools or professional development schools closely allied with colleges of education, or in more traditional student placement activities. Electronic networks can provide a safety net for communication, sharing knowledge, and experience for student teachers in the field, as well as for new teachers launching their careers. The loneliness and anxiety common to teachers' first teaching experiences can be mitigated through contact with professors and peers via electronic networks. The following are examples of ways technologies have enriched preservice teacher education:

- Teacher education students at the University of South Carolina appreciate what students with language learning disabilities might experience when dealing with text by working with a software simulation called "The Language Mangler." Another simulation serves as a surrogate field observation, enabling prospective teachers to observe, critique, and discuss ways teachers handle students with special needs in a variety of settings.
- At the Peabody College of Education at Vanderbilt University, teacher education students review CD-ROM discs that contain video cases of mathematics teachers working with students. Teacher education students can each have copies of the inexpensive CD-ROM discs, play them on computers supplied with CD-ROM drives in dorms and on campus, and review teaching techniques individually or in a group. They add notes and observations on accompanying software that serves as an electronic notebook, which instructors then collect electronically for grading and return.
- All the schools in which the University of Virginia's Curry School of Education preservice students spend their internships are linked to Virginia's Public Education Network, permitting the teaching intern, the supervising teach-

The use of technology in teacher preparation programs is limited, but it can enhance the overall preservice experience.

er, and the faculty at the Curry School to confer via the electronic network throughout the teaching internship.
- At the Price Lab School at the University of Northern Iowa, a fiberoptic network linking the college and the lab school enables teachers in any of the 48 classrooms at the lab school to ship video to teaching methods classes. Teacher education students see lessons related to topics they are discussing in their courses and, with two-way video and audio, talk to the teacher after they see the lesson and hear the teacher's on-the-spot analysis of what worked and what was problematic in that lesson. Since most lab school faculty use technology in their classes, the teacher education students can see effective modeling of technology use via technology.
- University of Wyoming students conducting student teaching meet via a compressed video system with their supervising faculty member, collaborating teacher, and clinical supervisor as often as necessary to discuss problems and questions arising out of student teaching experiences.

TEACHERS AND TECHNOLOGY: THE BARRIERS

While promising, the above examples of what technology can do are far from the reality in many schools, in colleges of education, or in the daily teaching experience or professional development of the typical teacher. There are a number of common barriers to more widespread use of technology by teachers (see table 1-2):

- First, there is the question of access to appropriate technologies. The question of access is also tied to problems of costs.
- Although most teachers see the value of students learning about computers and other technologies, many teachers lack a clear understanding about what resources technology can offer *them* as they try to meet their instructional goals.
- As do most users of emerging technologies, many teachers encounter technical and logistical problems they cannot solve themselves and often lack the training and support necessary to resolve the problems.
- Many feel the need for more knowledge—not just about how to run the machines—but about what software to use, how to integrate it into the curriculum, and how to organize classroom activities using technology.
- The current assessment system, if it relies heavily on standardized achievement tests, can also be a barrier to experimentation with new technologies because teachers are not sure whether the results they are seeking will be reflected in improved student test scores.
- In addition, issues created by technology itself are also factors to be dealt with, including those related to copyright and intellectual property rights, privacy of student records, and control of student access to objectionable materials.

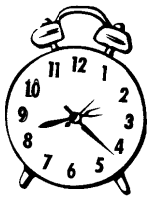
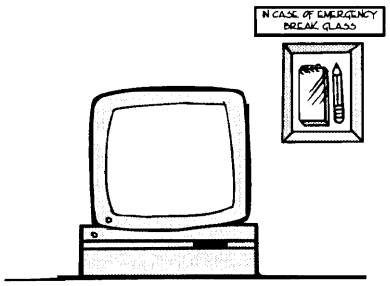
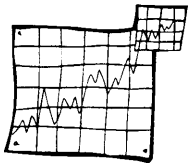
Access Issues

Equipment

One basic prerequisite for effective teacher use of technology is access. Schools have made substantial investments in hardware and software over the past several years, increasing their technology inventories (see box 1-3). OTA finds that, despite past investments in technology, many schools still lack the basic technology infrastructure to support the most promising applications of educational technology. About half the computers in U.S. schools are older, 8-bit machines that cannot support CD-ROM-sized databases or network integrated systems or run complex software. This aging inventory limits the ability of many teachers to use some of the most exciting applications of computers—information gathering from networked databases or CD-ROM encyclopedias, desktop publishing, mathematics instruction using analytic graphing and calculating software, and collaborating in joint projects over networks.

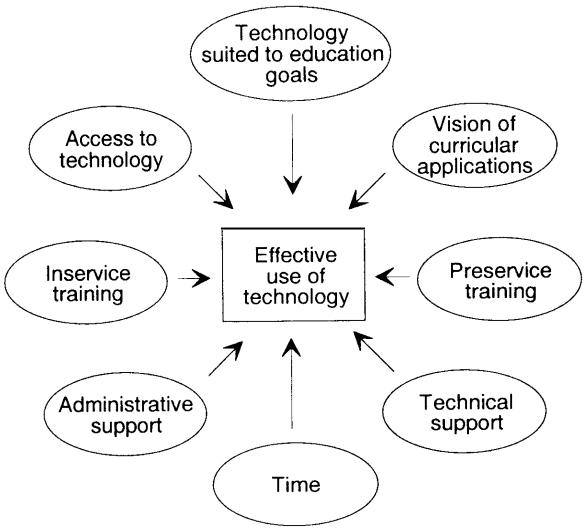
Some schools do not always make the most of the equipment they already have, and some do not

TABLE 1-2: Teaching and Technology: Current Barriers

Teacher time		*Teachers need time to:* ▪ Experiment with new technologies. ▪ Share experiences with other teachers. ▪ Plan and debug lessons using new methods that incorporate technologies. ▪ Attend workshops or training sessions.
Access **and costs**		*In addition to limited hardware and software, other factors affect access:* • Costs are high for purchasing, connecting, and training to use technologies. ▪ Technologies may not be located in or near the classroom. ▪ Hardware in schools today is old (50 percent of computers in schools are 8-bit machines) and cannot handle many newer applications. ▪ New or additional wiring or phone lines are necessary for telecommunications networks.
Vision or rationale for technology use		▪ Schools must have plans, and teachers a clear understanding of curricular uses of technology. ▪ It is difficult to keep up with the rapid rate of technology development and changing messages of best use. ▪ Teachers lack models showing the value of technology for their own professional use.
Training and support		▪ Overall, districts spend less than 15 percent of their technology budgets on training, but they spend 55 percent of the budget on hardware and 30 percent on software. ▪ Technology training today focuses primarily on the mechanics of operating equipment, not on integrating technology into the curriculum or selecting appropriate software. ▪ Only 6 percent of elementary and 3 percent of secondary schools have a full-time, school-level computer coordinator for technical support.
Current assessment practices		▪ Existing standardized measurements of student achievement may not reflect what has been learned with technology. ▪ Teachers are held immediately accountable for changes that take time to show results.

SOURCE: Office of Technology Assessment, 1995.

FIGURE 1-1: Requirements for Effective Use of Technology



SOURCE. Office of Technology Assessment, adapted from Jane L. David, "Realizing the Promise of Technology Policy Perspective" in Barbara Means (ed), *Technology and Education Reform* (San Francisco. Jossey-Bass Publishers, Inc., 1994), pp. 169-189

always locate technology in the most accessible places. Most computers are still in labs rather than in classrooms, and modems may be located on a central computer in the principal's office, making it hard for teachers to use them during the course of a day. Thus, it is not surprising that computers are not used very often (about two hours per student per week, according to coordinators; less, according to the students). They are not used regularly in the teaching of academic subjects—only 9 percent of secondary school students reported using computers for English class, 6 to 7 percent for a math class, and 3 percent for a social studies class. The most common uses of computers are for basic skill practice at the elementary level and word processing and other computer-specific skills in middle and high schools. Other uses, such as desktop publishing, developing math or science reasoning with computer simulations, gathering information from databases, or communicating by electronic mail (e-mail) are much rarer. And, despite the growing interest in connecting schools with information resources like the Internet, most school districts with local area networks do not always configure them or use them for the most up-to-date applications.

Furthermore, a majority of schools are ill--equipped to take advantage of the potential presented by telecommunications networks. Fewer than one teacher in eight has a telephone in the classroom that can be used for outside calls. Moreover, most schools lack the connectivity, administrative and organizational support, and technical expertise needed to integrate networks into teaching and learning.

OTA finds that it is necessary to consider a new definition of what constitutes "access" to technology by teachers and students. Counts of equipment, student-computer ratios, dollars spent and requirements, while important, alone are not sufficient to define meaningful access to technologies. It is appropriate rather to consider infrastructure in a broader sense: type of technology (including older but overlooked resources such as the telephone), age, capacity, connectivity, software, and services. Organizational arrangements —the placement and flexibility of technology— also affect the ease of use by teachers and students. For example, a cart of laptop computers that can be moved anywhere in a school may be used much more often than a computer lab far from the classroom. An additional component of a new definition of access includes the kinds of support teachers need to use the infrastructure effectively: exposure to innovative uses, flexible "just-in-time" training, and ongoing technical support and expert advice.

If access to technology is an equity concern, then the definition should be expanded to encompass access to necessary information. Telecommunications and networking technologies, in particular, may create incomparable opportunities for teachers and students to gain immediate access to information. Combined with hardware like CD-ROM players, the excitement and power of video can be combined with the information transmission power of the computer and communication

capabilities of high speed networks. Connectivity is likely to become the major technology issue of the next several years. Major investments of time and other resources will be required to prepare ‘schools to effectively access the information and electronic communities telecommunications can provide.

costs

As new technologies, new opportunities for increased levels of connectivity, and educational applications emerge, those concerned with expanding the use of technology in schools and by teachers have turned their attention to the issue of cost.[12] The cost of any new initiative is always an issue for elementary and secondary education, which is funded almost exclusively by a combination of state and local taxpayers. Some have suggested, however, that there be greater roles for the federal government, private businesses, or some combination to ensure that schools obtain new technologies. These suggestions have stimulated the Congress to direct the U.S. Department of Education (ED) to estimate costs on a national basis.[13] The ED estimate, to be developed by the Rand Corporation under contract to ED, was not available at the time this report was prepared. Previous attempts at rough estimates, at the state and national levels, can be informative in illustrating the range of costs-and the range of uncertainty—involved.

States vary greatly in their installed base of technology, their technology plans and goals, and the numbers of students served (see chapter 3, figure 3-5). Consequently, states will require varying levels of funding to meet these goals. For all states, however, substantial commitments will be required.

The costs of technology are a major hurdle for many schools.

Table 1-3 estimates installation and operating costs of selected telecommunications technologies. The table is based on rough estimates by OTA of the costs of installing telephone lines in all U.S. classrooms, and by projections made by two economists[14] based on various configurations for connecting schools, school districts, and/or classrooms. Analysis of the estimates suggests that at ***the national level*** and ***depending on a variety of factors:***

- estimated one-time installation costs (including training) ***may range*** from $0.08 billion (for one personal computer plus modem per school, connected to the Internet through a school-district-based file server) to $145 billion (to have one personal computer per student desktop, with full, ubiquitous connection to the Internet for a complete suite of text, audio, graphical and video applications); plus
- estimated annual operating costs for the configurations described above (including annual

[12] See, e.g., Russell I. Rothstein, "Connecting K-12 Schools to the NII: A Preliminary Assessment of Technology Models and Their Associated Costs," a working paper (Washington, DC: U.S. Department of Education, Aug. 4, 1994); Robert Cohen, "The Cost of NII Access to K-12 Schools: preliminary Assessments," paper provided by Robert Blau, director, Policy Analysis, Bell South, Washington, DC, 1994.

[13] See, **e.g., Public** Law 103-382, Title III.

[14] Rothstein and Cohen, op. cit., footnote 12.

TABLE 1-3: Estimated Installation and Operating Costs of Selected Telecommunications Technologies

Examples of technology, training, support, and infrastructure configurations	Source of estimate	Range of estimated one-time installation and training costs	Range of estimated annual operating costs	Limits on capability
Telephone in each public school classroom.	OTA[a]	$123.00 mil.[b] (low) - $220.00 roil. (high)[c]	$310.00 mil. (low)[d] - $333.00 mil. (high)[e]	Phone line could be used to connect to modem.
One personal computer (PC) plus modem per school, connected to a school-district-based file server, connected to the Internet, with minimal initial teacher training, and $2-$10K per year for teacher support and $1-$5K per year for teacher training.	Rothstein, 1994	$80.00 roil. (low) - $390.00 roil. (high)	$160.00 mil. (low) - $560.00 mil. (high)	Limited access by teachers and students; allows text-based applications only (e.g., e-mail, telnet, gopher).
An average of 60-100 PCs, modems, and a local area network (LAN) using copper wire per school; district-based file server to remote locations, **IAN,** router to the Internet; initial teacher training of 5 to 20 staff per school, and annual teacher support and training.	Rothstein, 1994	$2.59 bil. (low)- $7.75 bil. (high)	$1.37 bil. (low)- $3.38 bil. (high)	Supports only a few users at a time because it is limited by the number of phone lines going out of the school.
One PC per classroom with additional dialup lines. Districts support file server to remote locations, LAN, and router to the Internet; with initial teacher training of 10-20 staff per school and annual teacher support and training of 1-2 support staff per district, and $10-20K for training. Includes major retrofitting costs.	Rothstein, 1994; Cohen, 1994	$5.38 bil. (low)- $13.26 bil. (high)	$1.30 bil. (low)- $3.84 bil. (high)	No real-time access to video or graphics.

60 PCs per school plus LAN, file server with high-speed links, and router. District offices have IAN, file server to remote locations, and router; with initial teacher training for 40-50 staff per school and annual teacher support and training of 3 support staff per district, plus annual training costs of $15-$35K.	Rothstein, 1994	$11.75 bil. (low) - $27.53 bil. (high)	$1.85 bil. (low) - $4.94 bil. (high)	Base needed for connecting each public school to the Internet, allowing use of "limited" video, graphical and text-based network applications.
1 PC per desktop, plus school-based IAN, a larger file-server, and router to district office; each district has a file server to remote locations, LAN, a high-speed line to school; and a larger dialup system than in previous model; with initial teacher training for all teachers in all schools, and annual teacher support and training consisting of 4-5 support staff per district; plus annual training costs of $16.5-$38.5K. Includes significant retrofitting costs.	Rothstein, 1994	$65.80 bil. (low) - $145.62 bil. (high)	$4.46 bil. - $11.28 bil.	Full connection to the Internet, supports full suite of text, audio, graphic and video applications. Would not support full-motion video.
4 schools per district have PCs, LAN, file server/ router; each district has a file server LAN, a data line to wide area networks, and dialup lines; assumes initial training costs of $100K and annual support and training costs of$133K total. Includes costs of retrofitting school buildings.	Cohen, 1994	$35.76 bil.	$5,49 bil.	None: individual schools linked directly to a national information infrastructure; circuit can accommodate very wide array of services including full motion video.

[a] Figures do not reflect the fact that one-eighth of classrooms now have phones; thus, these estimates may be too high

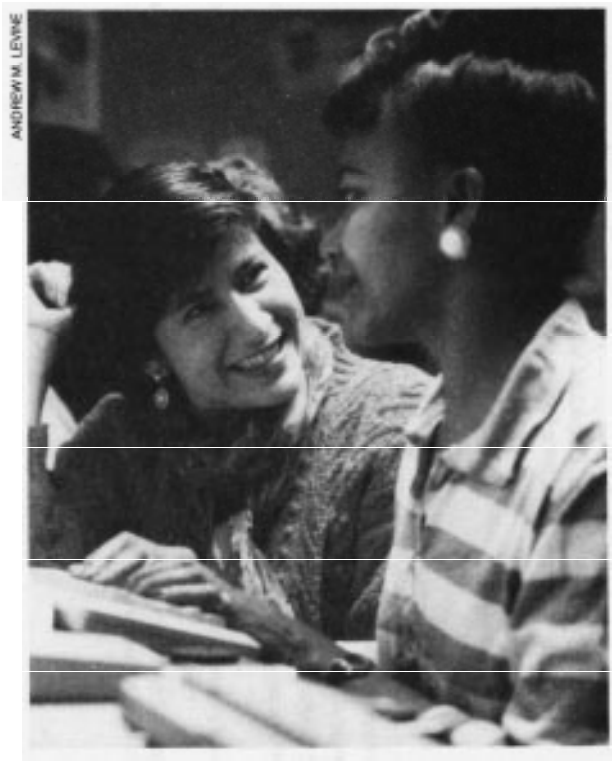
[b] Based on an estimate of 83,389 public schools (Software Publishers Association, 1994), with an average of *20* classrooms per school (Rothstein, 1994).

[c] Includes additional charges for labor and installation (optional) of $42 upfront charge, plus $16 for 15 minutes (per classroom), for an additional cost of $96,731,240,

[d] Calculated for regular (non-centrex) service as follows: $16.77 per line monthly charge + $1.45 per month message unit charge [@20 message units per month] - $18.22 X 10 months in school year X 1,668,000 classrooms = $303,909,600 Figures may not total exactly due to rounding.

[e] Calculated for centrex service as follows: $18.22 per line monthly charge + $1.45 per month message unit charge [@ 20 message units per month] = $1995 X 10 months in school year X 1,668,000 classrooms = $332,766,000= $291,170,250 Figures may not total due to rounding

SOURCE" Off Ice of Technology Assessment, 1995, based on Russell I. Rothstein, "Connecting K-12 Schools to the NII: A Preliminary Assessment of Technology Models and Their Associated Costs, " a working paper (Washington, DC U S Department of Education, Aug. 4, 1994); Robert Cohen, "The Cost of Nll Access to K-12 Schools" Preliminary Assessments, " paper provided by Robert Blau, director, Policy Analysis, Bell South, Washington, DC, 1994



Teachers working together can create a shared vision for technology use.

training and support for teachers) may *range* from $0.16 billion to $11.28 billion.

The range in the estimates in table 1-3 is striking, and the estimates could easily be far from the mark. Furthermore, these estimates have not considered costs of using additional technological configurations that offer potential, such as cellular telephones and wireless modems.[15]

Key factors that appear to account for current differences in available estimates include:

- the configuration of technologies envisioned for the estimate (from a simple telephone line, to technologies that are on the cutting edge);
- the number of desktops, classrooms, school buildings, and school districts that are assumed to obtain access to the system'
- the amount of retrofitting required of school buildings (e.g., to install new wiring for telephone and cable lines or to provide additional electrical power, to deal with asbestos during required construction); and
- the amount of support and training required for the human resources-the teachers-to make best use of the new technologies.

Clearly, different assumptions about these factors-and development of new, perhaps less expensive, technologies in the future-could greatly affect cost projections. In addition, at the local level, prices for individual technologies may vary considerably, meaning that any one school, school district, or state could experience a considerably different level of costs than any other.[16]

A Vision of Goals and Rationale for Technology Use

There is also a gap between having technology and using it effectively. As described above, equipment is often placed in locations where it is inconvenient for regular classroom use. Furthermore, schools and teacher share received conflicting advice over the years about the best ways to use their technology. As the technology has evolved, so has the prevailing wisdom on how teachers should use technologies in schools-from teaching programming, to encouraging individualized drill and practice, to building computer literacy, to participating in electronic communities. Conventional thinking also has shifted about how to organize technology resources, from self-contained labs, to one computer per classroom for teacher demonstrations or single student tutorials, to a few computers per classroom on which stu-

15 See U.S. Congress, Office of Technology Assessment study on wireless telecommunications, forthcoming.

16The policy issues and options section of this chapter provides examples of different state policies (e.g., with respect to group puchasing, with respect to subsidies for telecommunications charges) can affect the costs actually incurred at the local level.

dents can work in small groups, to one computer per student and on the teacher's desktop. It is small wonder that teachers have become confused, and administrators frustrated, with many educators unclear where they should be headed in directing technology use.

Support and Training

Other barriers in many schools hamper more effective use of technology by teachers. These include lack of time, inconvenient scheduling, attitudinal barriers, and barriers of school organization, curriculum, testing, and other policies.

In general, teachers have little in the way of technology support or training available at their schools, although many teachers seek training on their own. Currently schools spend much more on hardware (55 percent) and software (30 percent) than they do on training (15 percent). Less than half of American schools report that an introductory computer course is available for teachers through the district or a local college.

Furthermore, the kind of training, not just availability, is important. Much of today's educational technology training tends to focus on the mechanics of operating new machinery, with little about integrating technology into specific subjects, how to choose software, and how to organize classes, e.g., to use four computer workstations or a single computer with a modem.

Regular, onsite support for technology use is an even more daunting problem. Only 6 percent of elementary and 3 percent of secondary schools have full-time school-level computer coordinators; in nearly three-fifths of schools, no one had any portion of their workweek officially allocated to coordinating computer activities. Even in schools where someone is designated to spend at least half of his or her time as computer coordinator, very little of this time goes directly to training or helping teachers use computers.

Probably the greatest barrier to technology use, however, is simply lack of teacher time—time to attend training or workshops, to experiment with machines and explore software, to talk to others teachers about what works and what doesn't, and to plan lessons using new materials or methods. The diverse jobs teachers are asked to do and roles they are asked to play also affect their ability to take on another challenge. Teachers are given very little compensated staff development time and there are multiple competing demands for this time. Unless there are significant changes to the rhythm of the school day or changed incentives for giving teachers more time to learn and experiment with new technologies, this barrier to technology use will remain immense.

Other Emerging Issues

As the possibilities for widespread information networks—and their use by schools, teachers, and students—emerge, other issues are coming to light that may affect the ability of teachers to use technologies for administrative, instructional, and professional development purposes. These issues include copyright and intellectual property issues, privacy of student records, and censorship of objectionable materials versus protecting students' access to potentially valuable information.

Copyright and Intellectual Property Issues

Currently, one of the most widespread and promising uses of telecommunications technology by teachers is the retrieval of information from remote sources, including networked information, collections of books, journals, music, images, databases, software, and multimedia works—so-called digital libraries.[17] As students and teachers develop multimedia materials or projects, share them with colleagues, and store them in portfolios for student and teacher evaluation, use of copyrighted works in the classroom could grow dra-

[17] Margaret Honey and Andrés Henriquéz, *Telecommunication and K-12 Educators: Findings from a National Survey* (New York, NY: Center for Technology in Education, Bank Street College of Education, 1993).

matically. Some examples of student use of such materials might include:[18]

- creating a Quicktime clip from a segment of a videodisc of a popular movie,
- digitizing a video clip from a "60 Minutes" segment,
- scanning a copyrighted photograph to use in a Hyperstudio program,
- using music from a compact disc for background, and
- scanning a copyrighted picture of "Goofy" to use in a project.

Teachers' use of new media and curriculum development activities using copyright materials might include such activities as:

- keeping student developed multimedia projects using materials cited above as examples to show others,
- showing multimedia projects at professional conferences,
- sharing multimedia projects over the school district's cable channel,
- using an object from a copyrighted authoring program in another courseware authoring program for teaching purposes, and
- sharing projects on a listserv on the Internet.

These applications all raise issues related to fair use of copyright material and copyright protection.

The nature of digital works also changes how people read or use the works,[19] which presents new challenges to educators for the proper use of intellectual property. In earlier work,[20] OTA has found that the application of intellectual property law to protect works maintained in digital libraries continues to be uncertain; concepts such as "fair use" are not clearly defined as they apply to these works, and the means to monitor compliance with copyright law and to distribute royalties are not yet resolved. Resolution of these issues will provide teachers with clearer guidance for using digital information; meanwhile, school systems must struggle to remain in compliance with the existing law.

Privacy of Student Records

Use of computers by teachers may raise new issues of privacy for teachers and their students. One area of particular concern is computerization of student records. Increasingly, educators and policymakers will use data gathered and maintained in computers to monitor progress toward educational achievement standards, determine how well curricular content areas are covered, track performance of all students, and analyze information about special groups, such as disadvantaged and language-minority children.[21] In some states, lawsuits have challenged the right of state educational agencies to create computerized records by

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[18] Rosemary Taub, College of Education, Kansas State University, personal communication, August 1994.

[19] Digital information differs from information maintained in more traditional forms (e.g., analog) in several ways: 1) digital works are easily copied, with no loss of quality; 2) they can be transmitted easily to other users or be accessed by multiple users; 3) they can be manipulated and modified easily and changed beyond recognition; 4) they render text, video, and music to an essentially equivalent series of bits and store them in the same medium; 5) they are inaccessible to the user without hardware and software tools for retrieval, decoding, and navigation; and 6) with appropriate software, they create opportunities to experience works in new ways, for example, interactive media.

[20] U.S. Congress, Office of Technology Assessment, *Finding A Balance: Computer Software, Intellectual Property, and the Challenge of Technological Change*, OTA-TCT-527 (Washington, DC: U.S. Government Printing Office, May 1992).

[21] National Education Longitudinal Study of 1988, Student Questionnaire, prepared for the U.S. Department of Education, National Center for Education Statistics.

collecting individually identifiable data. Typically the legality of such data collections is upheld, but not always.[22]

The Family Education Rights and Privacy Act of 1974 (FERPA), commonly called the "Buckley Amendment" after former New York Senator James Buckley, was enacted in part to safeguard parents' rights and to correct some improprieties in the collection and maintenance of public records. The legislation establishes the right of parents to inspect school records, limits access to school records (including test scores) to those who have legitimate educational needs for the information, and requires written parental consent for the release of identifiable data.

The growing use of computers to collect and store potentially sensitive information also requires heightened awareness from computer users about their responsibility to respect confidentiality when accessing data. It is already evident to users of electronic information technologies that functions such as e-mail make the anonymity and ease of manipulating data within electronic communities far more likely.

Censorship and Protecting Student Access to Information

A particularly challenging issue for K-12 education is finding the appropriate balance between encouraging students' rights of access to information and protecting students from objectionable materials and potentially harmful contacts over wide area networks. Bringing the world into the classroom is a laudable concept, but it can also have a downside. Educators and parents are concerned that children will be able to gain access to pornographic, dangerous, salacious, or otherwise undesirable material over networks, material that might never be allowed in textbooks, school libraries, or at home. The same information superhighway that makes it possible for students to talk to the Archbishop of Canterbury or the state governor online could also link them to criminals, pedophiles, or psychopaths.[23] As one news article recently noted:

> The cyberspace battles may prove especially contentious, because the Internet contains a great many works not found on the shelves of most schools. "The School Stopper's Textbook," for instance, tells how to short-circuit electrical wiring, set off explosives in school plumbing and "break into your school at night and burn it down." . . .Schools can keep a pornographic book off the library shelf by not buying it, but they can't keep it from entering the building through cyberspace.[24]

Some educators fear that, without proper safeguards, concerns like this could block the educational potential of telecommunications in schools. Schools are also worried about the potential for litigation, since some states prohibit "exposing minors to dangerous material or information."[25] Some schools have addressed this issue by educating teachers about the potential "risks" on the Internet; others have developed network use policies that students and parents must sign. For example, a school district in Colorado sends home a notice warning parents that potentially "defamatory, inaccurate, abusive, obscene, profane, sexually oriented, threatening, racially offensive, or illegal material" exists online. [26]

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[22] Aaron M. Pallas, "Statewide Student Record Systems: Current Status and Future Trends," National Education Goals Panel, Mar. 26, 1992. Some teachers have also voiced concern that states will use the data for accountability purposes that teachers believe are inappropriate, thereby jeopardizing local autonomy. While most states do not use their statewide student record systems for accountability purposes, local districts and state education departments may disagree about the propriety of these purposes.

[23] Paul Evan Peters, "In Your Face in Cyberspace," *Educom Review,* September/October 1994, pp. 70-73.

[24] Stephen Bates, "The Next Front in the Book Wars," *The New York Times,* Educational Life Section, Nov. 6, 1994, p. 22.

[25] Ibid.

[26] Ibid.

Other schools have given accounts and passwords to teachers only, not allowing students access to telecommunications. However, many educators consider this educationally shortsighted, especially since the possibilities of exploration and freedom of inquiry are what many find so promising about the Internet.[27] Increasingly, schools have put some of the responsibility on the students, setting up rules for permissible "surfing" (browsing through discussion groups or information sources) and taking away student passwords or accounts if they engage in "hacking" (destroying files or other materials on a computer system) or "flaming" (using abusive or offensive language on e-mail). Still others seek technological solutions that block access to certain areas of the Internet: development is underway on "reverse firewalls" that keep users from going beyond prescribed areas on the Internet. Until such prototypes are in place, schools and teachers face a substantial challenge.

PROMISING APPROACHES TO TECHNOLOGY IMPLEMENTATION

> The challenge of integrating technology into schools and classrooms is much more human than it is technological. What's more, it is not fundamentally about helping people to operate machines. Rather, it is about helping people, primarily teachers, integrate these technologies into their teaching as tools of a profession that is being redefined through the . . . . process.[28]

Some schools and colleges of education are developing approaches to technology implementation from which others can benefit. The approaches differ, depending upon the existing resources (human and technological) at a site, the visions the sites have developed for how technologies are to be used and what problems they can address, and the leadership and support marshaled to meet those goals. These approaches include the following:

- developing technology-rich classrooms, schools, or districts, in which local expertise in various applications of technology can be developed and shared;
- training master teachers, who then serve as resources for their colleagues;
- providing expert resource people from other staff, such as librarians, computer coordinators, or volunteers from business, parent, and student groups;
- giving every teacher a computer, training, and time to develop personal confidence and expertise;
- training administrators so they can serve as technology supporters and guide efforts within their schools or jurisdiction; and
- establishing teacher or technology resource centers, ideally with ease of teacher access through online services.

Most schools combine several of these approaches, and there is no clear evidence that any one model is more successful than others. OTA found a number of promising practices, including the following examples:

- At Webster Elementary School in St. Augustine, Florida, all staff received broad training in technology use, but those interested were given more time, more training, and the opportunity to attend conferences. They became the "local experts" that other teachers could draw on for assistance or advice.
- To ease the burden of setting up alternative arrangements for substitutes, the Monterey California Model Technology Schools developed the concept of "SuperSubs," in which teachers on early retirement, armed with technology lessons and resources, substitute

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[27] "Lifelong Learning and the NII," unpublished proceedings, Westfields Conference Center, Chantilly, VA., Nov. 18-20, 1994.

[28] Barbara Means et al., *Using Technology to Support Education Reform*, OR-93-3231 (Washington, DC: U.S. Department of Education, Office of Research, September 1993), pp. 83-84.

for other teachers who are then free to observe still other teachers' technology lessons and approaches.

- In Indiana, four schools were given grants allowing every teacher to receive a computer and printer for use at home or in school, to improve their personal productivity and, ultimately, instructional efforts. Training, involvement of support staff and administrators as well as teachers, and broad public commitment helped to meet the goals of the program.
- In the Apple Classroom of Tomorrow Teacher Development Center Project, principals are encouraged to attend training with teacher teams and commit to providing extra time and resource for teachers to work together, reflect on what they are learning and doing, and assist their colleagues in technology activities.
- Texas supports 20 regional education service centers, with extra funding to support technology initiatives, including such areas as technology preview centers, training first-year teachers and preservice teachers in technology use, and training personnel on the use of TENET, the statewide computer network for teachers, with connections to the Internet.

These examples suggest a number of important lessons for implementation (see box 1-5).

CURRENT FEDERAL SUPPORT FOR TEACHER TRAINING AND TECHNOLOGY

As in the past (see box 1-6), multiple categorical programs for different needs and niches continue to comprise the world of federal teacher training programs.[29] Of the 58 programs OTA has identified that support preparation of teachers to use educational technology of some sort, most are small (under $10 million). **What is striking about most of these programs is the optional nature of support for technology-related training.** Not one program is devoted exclusively to **technology-related** teacher training, although federal agencies sometimes choose, in the case of discretionary grant programs, to make technology-related teacher training an absolute priority for one funding cycle.[30] The programs that provide the most consistent funding for technology-related professional development usually combine technology with science and mathematics training or include technology-related activities for both teachers and students, as in the Star Schools program.

In myriad programs, it is up to state, local, or university grantees to decide whether technology-related training is provided at all and in what form. This is the case with large formula grant programs, such as the Title I Chapter 1 (usually referred to as) program for disadvantaged children and the Vocational Education Basic Grant program, as well as smaller demonstration programs, such as the National Science Foundation (NSF) Teacher Enhancement program. Even programs with a primary focus on teacher development seldom mandate or recommend that grantees consider technology as either a topic for training or a mode for delivery. And with few exceptions, the federal government does not collect data from grantees in the format or detail necessary to discern which projects are actually providing technology-related teacher development, or how much they are spending for it, or what the impact has been.

FEDERAL POLICY ISSUES AND OPTIONS

The appropriate federal role in education has always been debated. The extent to which there should be a federal role in assisting teachers to make the connection with technology is and will continue to be part of this debate.

There seems to be little question of whether technologies should be used in the nation's schools for purposes of instruction, administra-

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[29] The General Accounting Office counted 86 programs supported by the federal government in support of teacher training of all kinds. "Multiple Teacher Training Programs" (Washington, DC: U.S. General Accounting Office, February 1995).

[30] An *absolute priority* means that only projects that address the priority will be funded in a given year. Priorities change from year to year.

BOX 1-5: Some Lessons About Technology Implementation

A number of schools, districts, and states have made the adoption of technology a priority. Important lessons from these sites include:

- **Educational rationale should guide technology decisions.** Developing a technology plan—thinking through the goals for technology use at the local site and involving teachers in the planning process—is key to successful implementation.
- **Those wishing to invest in technology should plan to invest substantially in human resources.** Training, maintenance, technical support and time to learn to use the technology have proven to be constant and continuing, yet key expenditures. Recently, several states (e.g., Texas and Florida) have recommended that at least 30 percent of technology funds be spent on training.
- **Teachers cannot use technology without systemic support.** The roles of principals, other administrators, and the community are critical in fostering sustained use of technologies. Other staff, such as media specialists, can provide technical and motivational support for teachers in their building if time is allocated for them to do so.
- **When it comes to learning to use technology, "hands-on" training is more than a gimmick or motivator.** It is a necessity. Teachers must have the chance to make the computer (or camera or whatever) work, and gain confidence in their own competence, before they try the same thing with their own class.
- Access **to equipment is essential.** It is extremely frustrating for teachers to learn to use technology in a workshop, then return to a classroom where the technology is not readily available. Many programs are increasing teacher access to technology by letting them take the equipment home (e.g., laptops, summer loaner programs, etc.) since most teachers put in many hours at home grading, planning, and preparing. Putting technology in the hands of teachers—allowing them to see and explore how technology can help them do their jobs—can be an effective way of motivating teachers to learn about technology.
- **Although there are a number of models for training teachers and implementing technology, there is no one best way of using technology or of training teachers to use technology.** Districts are most successful when they have multiple and complementary training and support strategies.
- **Followup support and coaching is as essential to effective staff development as is the initial learning experience.** Teachers don't "learn it all" at a training session—even if it extends over several weeks. When they return to the classroom the unexpected inevitably happens. At this point, teachers need to be able to reach out for technical assistance and support.
- **Many technology-rich sites continue to struggle with how to integrate technology into the curriculum.** Curriculum integration is central if technology is to become a truly effective educational resource, yet true integration is a difficult, time-consuming, and resource-intensive endeavor.
- **When conditions are right—resources, time, and support are high-exciting things happen in technology-rich environments.** Today we are faced with the broader issues of how to move these lessons to the second stage of dissemination. How can these lessons be translated when resources aren't as rich? When teachers aren't as enthusiastic or energetic? Issues for policy consideration include the need to consider the development of products based on research and experience of experimental sites, seeding of more "real world" projects, and better dissemination of lessons learned.

SOURCE: Office of Technology Assessment, 1995

tive efficiency, and teacher professional development, *as appropriate*. The policy options in this report focus on the question of teachers' roles in accomplishing this goal, and on the advantages and disadvantages of selected legislative actions related to teachers and technology.

The array of technology for education is diverse, changing, and flexible, and these characteristics enable development of hardware, software, and learning environments that can suit special needs, allow new approaches to teaching and learning, strengthen teaching, and create excitement in the classroom. The broad and expanding range of educational technologies complements the diversity of the American education system. In the past, federal policy has often floundered on the enormous scale and differences that characterize American schools, compounded by the strong tradition of state and local control. In thinking about policy for technology, decisions can be made to allow for variation, change, experimentation and differing outcomes, and so strength can build upon strength.

Federal policy over the past decade has too often focused solely on generating funds for capital investment in hardware. Other policy initiatives have been diffuse and, until recently, there has been little focus on technology by the leadership of the U.S. Department of Education. Insufficient attention has been given to teacher preparation, development and support of learning tools and techniques, issues of connectivity, and the constantly growing demands on teachers' time. While costs of hardware will remain an issue, it is important to remember that technology capacity continues to increase at an astounding rate and that hardware costs often drop relevant to the power one purchases. While direct funding or other financial incentives are, of course, effective ways to demonstrate leadership and commitment, OTA concludes that, if the federal government wants to support the expansion and appropriate use of technologies in K-12 schools and colleges of education, federal policy must go beyond funding. Leadership; a commitment to research, development, and dissemination; an increased focus on teachers; and attention focused on issues related to the challenge of school access to the emerging electronic telecommunications infrastructure are equally critical.

OTA has identified a number of necessary components for taking advantage of learning technology and optimizing use of technology by teachers. These components are summarized in box 1-7 and discussed below.

Federal Leadership: Legitimizing, Funding, and Targeting Technology

If it wants to promote the appropriate uses of technology in elementary and secondary schools and colleges of education, the federal government can **move to fully legitimize the role of technology to enhance instruction, increase teacher productivity, create new teaching and learning communities, and support educational change.** Federal signals that technology is not only welcomed but needed in schools will strongly influence state and local decisions over the next five years. Until very recently, with little focus on the use of technology within the Department of Education, technology was an acceptable expenditure in many programs but was not held up as a tool for improvement. An important exception to this was the Star Schools Program, initiated by Congress in 1988, which has addressed a number of educational needs for students and, to a lesser degree, teachers, through emerging applications of technology.

The Goals 2000: Educate America Act (P.L. 103-277) called for creation of an Office of Educational Technology within the Department of Education. The need for high-level coordination of technology issues had already been recognized by the Secretary of Education in the appointment of a Director of Educational Technology in 1993. An office like this can **provide the much needed spotlight on technology, coordinate programs, and lead in evaluating and disseminating research result**s. Continuing to support this office, and seeing that adequate resources and authority are provided, will be critical.

A valuable related step is to **make the most of the national long-range technology plan to be**

BOX 1-6: Past Federal Efforts To Support Teacher Development

Although it is in the national interest to have a high-quality teaching force, the federal role in teacher preparation and professional development has been limited. There are exceptions: spheres where the federal contribution has been larger and more influential, such as teacher training in mathematics and science, and personnel preparation for special education, In general, however, the federal government has shown caution about becoming too deeply involved in an area traditionally considered a state responsibility, and until very recently has avoided even the suggestion of minimum federal standards for teacher education, It is the states that have exercised primary authority for teacher preparation, licensing, and certification, and more recently, competency testing. Substantial responsibility for preservice education also rested with universities and for inservice education, with local school districts.

In keeping with this limited role, **federal contributions for teacher training have been modest compared with overall federal spending for education.**

Purposes of Federal Involvement in the Past

The federal government became involved in teacher training for a variety of reasons. Often the impetus was a perceived crisis, such as threats to American competitiveness or widespread teacher shortages, In other cases involvement was an outgrowth of other federal commitments. The enactment of federal programs to improve education for the handicapped, for example, created new demands for specially trained teachers to staff these programs. Similarly, effective implementation of federal drug education programs required new training for teachers. Other motives for federal action stem from dissatisfaction with the quality of teacher education or with other aspects of K-12 education.

This diversity of motives resulted in programs that had various purposes, took various forms, and employed various strategies.

Impacts of Past Programs

Past federal programs had many positive effects on teacher preparation and professional development. It might be said that the federal government helped give credence to the concept of inservice education and professional renewal, through such programs as the National Science Foundation teacher institutes and the National Defense Education Act institutes and Teacher Centers,

developed by the Secretary of Education in accordance with Goals 2000. This plan could provide along-overdue strategy for the federal role in educational technology, not only in ED but across the government. It is crucial that the Secretary take maximum advantage of the directive in the law to join forces with other agencies to produce coherence and vision at the national level. Using all national agencies and programs wisely to expand, evaluate, and build upon knowledge in educational technology is a policy model that can also apply to federal programs affecting teacher preparation and the professional development of the current teacher force.

The executive branch is involving professional associations and citizen groups, as well as federal agencies and researchers, to develop a plan with foresight and credibility. An important caution, however, is that the plan must respect and build upon the extraordinary level of change occurring in technology capacity and the multitude of developing applications. The plan should be a framework for an environment of experimentation and learning, evaluation, and sharing of results. A plan of this nature could call forth rich results, opportunities to learn from problems as well as successes, and build respect for state and local expertise and decisionmaking.

Goals 2000 contains other provisions that could set the direction for educational reform for the next several years and could be used to leverage improved technology policy. A key provision

BOX 1-6 (cont'd.): Past Federal Efforts To Support Teacher Development

Although federal training programs never reached more than a small percentage of the total teaching force, this should not obscure the fact that many millions of teachers benefited from federally supported training. In some subject areas and specialties enough teachers were trained through federal programs to have a significant effect on instructional quality or teacher supply. Mathematics and science is a case in point. Even if the National Science Foundation institutes reached somewhat fewer teachers than the agency's estimate of half the math and science teachers in the nation, there were still enough trained to constitute a potent force for improvement within their discipline.

The federal government was also a major force in the growth of certain teaching subspecialties, such as special education, bilingual education, and instructional media. In a sense there was a chicken-and-egg relationship between federal funding and the need for specially trained teachers. On one hand, it was the power of federal mandates that created a demand for some subspecialties in the first place. On the other hand, federal intervention filled a void because the special needs of some children were not being met through traditional instruction or teacher preparation.

Federal aid also changed the composition of the teaching force. Scholarships, fellowships, and training opportunities broadened access to the teaching profession for students from blue-collar or low-income families and for minority individuals. Federal programs such as Teacher Corps attracted talented and energetic persons into teaching who might have pursued other careers.

Participation in federal training programs produced substantial improvements in the knowledge, attitudes, behavior, and career advancement of many teachers. At the school district level, federal funding sometimes provided the external stimulus needed to promote change. Federally supported training familiarized many teachers with instructional approaches that were once considered innovative, such as individualized instruction, interdisciplinary approaches, team teaching, and multicultural education. And, most significantly for this study, the integration of various technologies into the classroom—including audiovisual materials, educational television, and computer technologies—was hastened and encouraged by federally supported training.

SOURCE: Office of Technology Assessment, 1995, based on Nancy Kober, "Teachers and Technology. The Federal Role, " Office of Technology Assessment contractor report, May 25, 1994.

authorizes federal grants to states that develop "a systemic state-wide plan to increase the use of state-of-the-art technologies that enhance elementary and secondary student learning and staff development."[31]

In addition, states that submit an approved application will receive funds under Goals 2000 to establish state content and performance standards for student learning. Whether these standards will instigate the massive reforms desired by advocates will depend on what the standards contain and how seriously they are taken. **The *inclusion* of technology issues in these standards, however, could signal that technology is an appropriate tool for all core subjects, while the *omission* of technology could prove a genuine setback.** Although the federal government does not have the authority to dictate the substance of these national and state standards, the law established a National Education Standards and Improvement Council (NESIC) to review and "certify" the standards. If NESIC or some variant

[31] Public Law, 103-227, 20 USC 5897.

BOX 1-7: Areas for Federal Policy

1. Federal and state Leadership that articulates the value of integrated, technology-based teaching and legitimizes technology as a path to achieve educational goals. This leadership will be meaningful to the extent that it is supported by commitments to fund and encourage technology use, and is linked to continuing research, development, and dissemination. It can also focus attention on the potential of technology for providing resources to improve the preparation of new teachers and as a valuable tool for the "just-in-time training and support" for professional development,

2. **Increased focus on teachers, both in training and in the field, including: time and money to allow teachers to learn to use technology, support for their professional growth, respect for the complex nature of learning and the many demands facing teachers today, and research on how technology affects teaching and school change.** Congress has taken some steps to promote increased technology use in schools, and greater support for teachers who use technologies. Technology planners in K-12 schools and in colleges of education can take advantage of such support to further their goals.

3. **Provisions to ensure that access to data and information, through services such as the Internet, are available to all teachers and students.** The special needs of education are likely to be overlooked or neglected unless they are built into federal, state, local, and private sector decisions on telecommunications regulation and funding over the next few years, Access to high-quality information and necessary resources may be today's measure of equity in education.

4. **Commitment to research, development, and dissemination that will advance technology use by and for teachers.** The development of powerful curriculum products, tools, and telecommunication resources is often beyond the capability of individual states, districts, or schools. The private sector may be able to play a greater role in developing new educational technology products than they have in the past, but some observers note that education may not be a promising enough market unless incentives are found to aggregate it.[1] Federal support may be needed to infuse the appropriate funding, expertise, and attention to standardization, evaluation, and dissemination that can facilitate school use of promising technologies and their applications. Furthermore, research is needed on teachers and technology use if these applications are to be used most effectively.

[1] The Software Publishers Association reports that the average elementary school spent $12,500 and the average high school spent $10,400 on software in the 1993-94 school year Software Publishers Association, *SPA K-72 Education Market Report* (Washington, DC: July 1994), Overall, the annual expenditures made by K-12 schools has been estimated to be approximately $1 billion, and software purchased by K-12 schools has been growing at the rate of about 20 percent per year Ronald E. Anderson, "The Technology Infrastructure of U S Schools," *Communications of the ACM, vol. 36, No 5,* May 1993, p 72,

SOURCE Off Ice of Technology Assessment, 1995

is supported, its criteria for certifying standards could include a review of whether technology needs and methods have been considered.[32]

Another very critical step that the federal government can take to provide both leadership and dollars is to **make the most of the opportunities available to support and encourage technology-related professional development in current programs, and the Improving America's Schools Act (P.L. 103-382), with its amendments to the Elementary and Secondary Education Act of 1965.** The Office of Education-

[32] Legislation has been introduced that would eliminate funding for NESIC (H.R. 977, H.R. 1045, S. 323, and S. 469, all in the 104th Congress).

al Technology will be well suited to lead a review of existing and proposed programs to ensure that they give fair consideration to technology-related expenditures and to determine whether there are program regulations, guidelines, and accounting procedures that either discourage expenditures for technology and professional development or have untapped potential to encourage them.

P.L. 103-382 also included a major **new Technology for Education Act** that could be the centerpiece of a stronger federal role in providing technology-related teacher development, ensuring greater access and equity in the area of technology, and demonstrating and disseminating several promising educational applications.

The federal government could **take several steps to achieve better use of programs and funding authorized under current laws. Federal regulatory actions could include establishing priorities or bonus points related to technology in competitive grant programs, issuing policy statements highlighting acceptable expenditures for technology and professional development where the law permits, and eliminating unnecessary nonstatutory restrictions on the use of funds for technology or training purposes**. A message from federal leaders can send a strong signal of reassurance to state and local educators that they can acquire and upgrade technology and, most important, train teachers in its use with no regulatory constraints.

Particular attention should be focused on the revised **Eisenhower Professional Development Program**, given greater emphasis in P.L. 103-382, which calls for a larger federal teacher professional development effort in several critical subjects. The Secretary of Education could encourage states, universities, and school districts to consider integrating technology into the various professional development activities supported under this program.

Other federal programs that should be examined include the programs for students with special needs that are a cornerstone of the federal role in education, particularly **Title I of ESEA for disadvantaged children (referred to commonly as Chapter 1), the Part B state grant program under the Individuals with Disabilities Education Act (IDEA) (20 U.S.C. 1400 et. seq.), and the Bilingual Education Act (20 U.S.C. 7401 et. seq.).** Together these programs channel almost $10 billion to states and school districts. Educational technology has become an important tool for delivering instruction to the children served by these and other special needs programs, yet teacher professional development has not kept pace.

In Chapter 1, for example, technology continues to be used primarily for drill and practice of basic skills rather than for the more promising and integrated kinds of teaching described in this report. Amendments to Chapter 1 in P.L. 103-382, and discussions about future policy directions in IDEA, are stressing improved program quality and professional development in these programs. For example, as justification for changes in Chapter 1, P.L. 103-382 states that, "Since 1988. . .[the nation has learned that] insufficient attention and resources are directed toward the effective use of technology in schools and the role technology can play in professional development and improved teaching and learning."[33]

Similarly, the 1994 Bilingual Education Act authorized $215 million in grants for activities intended to educate limited-English-proficient children and youth so that they would be able to "meet

[33] Public Law 103-382, Title I, 108, Stat. 3520, sec. 1001 (c)(6).

TABLE 1-4: Major Federal Policy Levers for Enhancing Teachers' Use of Technology and Teachers' Professional Development

Legislation or Program Level	Program	Goal	Funding[a]
Improving America's Schools Act (P.L. 103-382) (amending and revising the Elementary and Secondary Education Act (ESEA) of 1965 and several other federal education statutes)	ESEA Title I: Helping Disadvantaged Children Meet High Standards	Major activities supported grants to states for funding local improvement programs, family literacy, education of migratory children, others	$7,2 billion
	ESEA Title II: Dwight D. Eisenhower Professional Development Program	Supports professional development in core academic subjects	*$359* million
	ESEA Title III: Technology for Education Act	Expanding access to and use of educational technologies, strengthening the technology infrastructure, supporting technical assistance and professional development	*$40* million
	■ Star Schools	Improve instruction through grants to telecommunications partnerships for programming and facilities	$30 million
	■ Challenge Grants	Innovative projects, can include teacher training	*$27* million
	■ National Activities	Regional technical assistance and teacher training consortia and other implementation activities	$13 million
	■ Product Development	Develop, produce and distribute technology enhanced instructional resources and programming for instruction or professional development	unfunded

	ESEA Title VI: Innovative Education Program Strategies	In the past, districts have spent funds on hardware and software purchases and professional development	*$347* million
	ESEA Title Vll: Bilingual Education, Language Enhancement, and Language Acquisition	To educate limited-English-proficient children and youth to meet the same rigorous standards for academic performance expected of all children and youth	*$350* million
	ESEA Title XII: Education Infrastructure Act of 1994	Ensure the health and safety of students through repair, renovation and construction of schools	$100 million
Individuals with Disabilities Education Act (20 U. SC. 1400) * Eligible for reauthorization in 104th Congress		Educating children with disabilities	$3.3 billion
Goals *2000:* Educate America Act (P.L. 103-227)	Part C Leadership in Educational Technology, Office of Educational Technology	Encourage technology as a resource for providing instruction and professional development, and teacher training as part of technology investments	NA
	Part B National Education Standards and Improvement Council, Assessment, Development, and Evaluation Grants	Grants to states for plans, part of broader state improvement plans, to increase use of educational technologies for learning and staff development	$5 million (fiscal year 1994)
Revisions to Communications Act of 1934	Revisions will be important to pricing of telecommunications services	To be determined	NA

(continued)

TABLE 1-4 (cont'd.): Major Federal Policy Levers for Enhancing Teachers' Use of Technology and Teachers' Professional Development

Legislation or Program Level	Program	Goal	Funding[a]
Other Selected Areas and Activities			
Department of Commerce	Advanced Technologies Program - education activities		
	Public Telecommunications Facilities Program	Develop telecommunications facilities to serve local communities (distance-learning projects have been supported in the past)	$29 million
	Telecommunications and Information Infrastructure Assistance Program	Planning activities and demonstration projects for telecommunications networks	$64 million
National Science Foundation	Teacher Enhancement Program	Funds teacher training programs in math, science and technology	$101 million
	Teacher Preparation	Supports projects to improve undergraduate teacher preparation in math and science and technology	$18 million
	National Education Infrastructure for Networking	Demonstrates innovative applications of networking for education	$15 million
	Applications of Advanced Technologies	Funds research and demonstration in revolutionary technologies for education	$10 million
Public Broadcasting Act of 1967 (P.L. 90-1 29)	Corporation for Public Broadcasting	Support for development and activities in support of education and professional development	$285 million (estimated)

a FY 1995 appropriation unless otherwise indicated
SOURCE Office of Technology Assessment, 1995.

the same rigorous standards for academic performance expected of all children and youth."[34] Federal grants were authorized for projects using educational technologies, "if appropriate," among a range of other permitted activities. Furthermore a subpart of the Bilingual Education Act was devoted to professional development and, among the evaluation components required of recipients of bilingual education capacity and demonstration grants was a demonstration of "appropriateness of the program's staff professional development."

The recognition of technology and professional development in these legislative authorizations represents an opportunity to encourage states and school districts to use a portion of their program funds for additional professional development in forming the effective uses of technology for special needs children. However, without specific requirements in legislative language, it will be up to grant applicants or the Department of Education (in regulations or grantee requirements) to ensure that professional development and/or technology are foci.

Other programs, such as Star Schools, have as their primary purpose the use of technology to meet educational needs. These programs can continue to be leaders in experimentation, helping to add to the store of knowledge on how technology is effectively used.

OTA also finds that while great interest centers on advanced educational technology such as integrated curricula products and multimedia tools, **"small" technology is also needed to bring schools along the learning curve.** Telephones, voice mail, fax machines, calculators, television sets and VCRs, camcorders and editing tools all have a place in today's classrooms, but are often denied to teachers. In fact, providing a classroom telephone that puts a teacher in direct contact with a parent can facilitate the parent-teacher communication and parent involvement that many believe is essential to improving student achievement. Yet tools as basic as telephones are denied for a complex set of reasons, and cost is normally one of the smaller issues. Traditional methods of conducting school business, reluctance by principals to allow teachers more control over their professional lives, and general fear that teachers will somehow "misuse" telephones are frequently cited to researchers as reasons that telephones and other technology should not enter classrooms. **Congress may not be able to change such attitudes, but it or the executive branch could set the tone by taking steps to encourage the installation of telephones in classrooms.** As discussed earlier in this chapter, costs are likely to be a factor inhibiting the installation of technologies, whether small or large.

Research, Development, and Dissemination

Support for educational research, development, and the dissemination of research results has traditionally been viewed as an area of national concern, supported by federal funds. This is also true of such activities as they are related to educational technologies.

First, more and better information is needed on the effectiveness of various technology tools, and applications, including whether and how technologies work for teachers. Are some types of training or support more effective than others? Are they more effective for some type of teachers (by field) or by level (elementary versus secondary)? Some literature suggests that educational technology "takes off" when there is a critical mass of teachers committed to using it. Can this be substantiated? Experience has shown that teachers must be given time to learn and prepare, adequate technical and content support, and a supportive attitude from the principal's office, but surely there is more to be learned about teachers and effectiveness. Although some recent studies are beginning to investigate how the teacher's work life is changed by technologies, there has been little research on teachers as members of work groups, or

[34] Title VII of the Amendments in Title I of Public Law 103-382.

Research to date has looked at student achievement, comparing results of instruction with technology versus other methods. However, there are other important factors that make simple comparisons misleading.

on the breadth of activities teachers undertake. All these are fertile areas for federal research.

Alternatively, the federal government, states, school districts, and schools could leave the topic of effectiveness research to private sector product developers or form research partnerships with local university-based, research-oriented colleges of education. One disadvantage of a private sector approach is that product developers may use research as an opportunity for marketing. Publicly funded research may be more likely to point out both the positives and negatives of a new technology. Clearly, the education community needs additional exploration of research strategies that will lead to providing both accurate and timely results for use by adopters of new educational technologies.

Development of advanced integrated curriculum materials, projects and tools could be appropriate investments for the federal government, continuing along tradition of research and quality applications. Because the upfront investments are high, and state and local funds for development are limited, federal support has been important in the past. Many of the innovative technology applications reported on in this study have been supported by federal research funds, particularly the National Science Foundation.[35]

The work of the Department of Education, the Department of Energy, the National Technical Information Administration, the Department of Defense and its research agencies, and others has also been invaluable in creating new methods, new technologies, new materials, and new approaches with educational technology. Projects of this type can also enhance the link between teachers and the research community. Comparatively small amounts of money in the federal budget have had substantial impacts on technology use in schools.

Much of the focus and experimentation to date has been in the areas of math and science; work is needed in other subject areas. If Congress wishes to encourage the development of powerful, flexible learning tools and applications, federal support for continuing research and development will be necessary. **The development of the next generation of integrated curriculum projects can work hand-in-hand with proposed educational standards in all curricular areas, and could be undertaken as a national research priority.**

Congressional concern about timely development of new educational technology software was reflected in the 1994 Technology for Education Act's provisions on product development. Grant applications were encouraged that "promote the acquisition of higher-order thinking skills. .., convert technology resources developed with support from the Department of Defense and other

[35] For example, the National Science Foundation's Applications of Advanced Technology program.

federal agencies for effective use in the classroom; . . .[and] show promise of reducing the costs of providing high-quality instruction." No funds were appropriated for this program in FY 1995.

The federal government's seed money for product development can be said to have resulted in a sequential form of public-private partnership. A good example is the Kid Net project initially funded by NSF, further developed by TERC (a not-for-profit organization), and eventually turned into a marketable product that schools can purchase from National Geographic, which sells Kid Net as part of their profit-making company.

Alternatively, Congress could leave development of new education technologies entirely to the private sector. It is unclear, however, that K-12 schools, with their persistent constraints on resources, represent enough of a market for educational technology product developers. For example, the Software Publishers Association (SPA) estimates that K-12 schools spent an average of about $11,000 each on software in the 1993-94 school year.[36] In half the school districts surveyed by SPA, funds for software purchases came primarily from discretionary funds held by principals and teachers, from donations or business partnerships, or from school fundraising efforts. Possible tradeoffs between public and private sector approaches to new product development would be a good subject for further analysis.

Federal action can improve dissemination of research results. Experimentation with new technologies is only the beginning; teachers need to know what works and why. Dissemination of research results has not been adequately emphasized in the past, but it too can be enhanced and extended through technological means.

Educating New Teachers, Professional Development and Teacher Support

People preparing for teaching and teachers in the field face a vast and constantly growing set of demands for their time and attention. Mastering technology use may be only one goal placed before them. Yet using technology with facility is a daunting challenge for most people; teachers are no exception. One of the clearest findings of the OTA case studies and other research is that even very highly motivated teachers require substantial amounts of time—often over a three to five year period—before they feel fully versatile with a complicated new technology and are able to expand technology tools to fit their particular teaching goals. And finding time in the teaching day and year for training, collaboration, and "messing around with" technology is a bane of the profession.

A goal for states and localities that want their schools to function more effectively is to find ways to give teachers time for lesson preparation and learning, and support for continuing work. Exposure to new materials and resources, training in use of actual technologies, and development of new classroom patterns take time. They also require strong organizational support from principals, administrators, and colleagues. There is little point in acquiring hardware but making no provision for teacher development and support. Fortunately, technology itself offers some inherent solutions, if teachers can have equipment to use when they have time, and can be rewarded for learning. The use of telecommunications linkages to provide resources and opportunities for training is one of the most promising aspects of technology, but it cannot be a substitute for adequate time. As mentioned earlier, states with a strong commitment to effective technology use are beginning to allot as much as 30 percent of technology expenditures for teacher training and support. This includes the cost of substitute teachers as well as training resources.

The demographics of the teacher pool and the school population indicate a substantial increase in the number of teachers required just after the turn of the century. Teacher preparation has al-

[36] Software Publishers Association, *SPA K-12 Education Market Report* (Washington, DC: Author, July 1994).

ways been the province of states, colleges and universities. The federal government has played a limited role in the general area of teacher professional development, despite the fact that a large number of federal programs have been aimed at this issue and some have made an impact in specific subjects such as math and science (see box 1-6).

Prior federal efforts to improve teaching or increase the teacher pool reflect a scattershot approach. Preservice programs have included fellowships, scholarships, loans, support for certification efforts, and some direct training programs aimed at specific kinds of teachers or curricular materials. Current teachers have been exposed to summer and academic-year institutes, seminars, workshops, and one-time training sessions. Federal funds have provided institutional support to local school districts and schools of education to build their capacity. Strategies to magnify the effect of federal dollars have included targeting key teachers who are expected to train their peers or promote school change, training teams of teachers and administrators from one school, developing model training programs and, to a more limited degree, encouraging collaboration between school districts and universities.

A review of many other federal programs (see chapter 6) makes clear that in some instances, technology has been introduced to schools, but funding has been limited to the cost of hardware or software only, with no allocation for the preparation and support of teachers and other personnel. This strategy is a bad investment.

Congress could more definitively express its wishes to see adequate budgets for teacher support and training in future legislation or report language.

OTA concludes that an effective policy mechanism would be to **require that all applications for federal financial help that include technology show adequate budgets for high-quality support and preparation of staff**. This approach would remind anyone preparing an application how important planning is to assure technology will be well used; it will help to assure that teachers will be given support over the long term, not just when the technology is brought in the door.

States that are leading technology users have already adopted this approach. The Texas Education Agency recently recommended that districts allocate 30 percent of their technology funds for hardware, 30 percent for software, 30 percent to staff development, and 10 percent to maintenance. For the 1993-94 school year, the Florida legislature allocated $55 million for technology and $8.65 million for software, and required that schools seeking these funds set aside at least 30 percent for teacher training.

The importance of teachers for the effective use of technology, the need for expanding the population of teachers in the next decade, and the inclusion of teacher professional development in the national education goals suggest that **the time is ripe to consider whether the nation wishes to make a more direct and coordinated commitment of federal attention and resources for teacher preparation and professional growth.** Goal 4 of the National Education Goals specifies that by the year 2000, "the Nation's teaching force will have access to programs for the continued improvement of their professional skills and the opportunity to acquire the knowledge and skills needed to instruct and prepare all American students for the next century." Meeting this goal must surely mean competence in working with technology. **Policy decisions to meet this challenge could be carried out through the revised Eisenhower program, through other innovation programs such as the Fund for the Improvement of Post-Secondary Education, through broad initiatives such as the National Teacher Corps, or even through a national-level teacher certification.** A first step toward making this policy decision would be a review and evaluation of existing programs as recommended above, and consultation with professional societies, educators, parents, and others to identify appropriate federal actions.

Colleges of education remain generally low on the totem pole when value is assigned to undergraduate and graduate training. One force working to improve teacher preparation is a movement to raise standards for accreditation of teacher colleges; state and federal policy decisions that em-

phasize accreditation (or other outcome measures) are likely to encourage improvement. Awards and honors bestowed by professional education groups also contribute to higher status. **The federal government can play a role through its grantmaking activities, by encouraging and supporting technology applications when considering funding requests from schools and colleges of education**. In particular, education research centers and major graduate educational sites could be strongly encouraged to adopt teaching with technology, so that new teachers learn by example. In teaching, as in most other professions, the techniques modeled for new entrants by their own teachers are extremely powerful. If new teachers have not experienced the power of learning through technology-based tools, they will have less motivation to make the effort to master these tools themselves.

In addition to relying on the public sector for support, states, school districts, and schools that accept offers of hardware or installation from private sector companies (e.g., computers, wiring schools or providing other hookups to electronic information sources) could request or require that the companies also provide meaningful levels of initial training and continuing support for teachers. Some companies have provided such support on a short term basis (see chapter 4). Companies might be persuaded to agree with requests for more intensive support for technology-using teachers because technology-friendly teachers are likely to make more and better use of the technologies provided, and expand companies' markets. Schools may be reluctant to make such demands in the belief that the companies will be less likely to offer any assistance in the future, but the strategy might be worth trying and monitoring, as a means of providing more effective private sector support to schools.

While it is clear that diffuse, shifting federal teacher training programs that reach only a tiny fraction of teachers cannot change the profession, it is also clear that if a decision were made to intensify the emphasis on use of technology as a resource for preservice and inservice teacher development, efficiencies and improvements could be made in the overall ways these activities are conducted.

Access to the Emerging Information Infrastructure

In the early days of "computer education," great attention was given to the distribution of machines per capita. It is becoming clear that actual equity for technology today goes well beyond machine counts; in fact, machines are a necessary but not sufficient component of teaching and learning. Students in some classes may have access to machines, but nothing available from or through the hardware of any real value. Likewise, teachers need to be able to locate and retrieve information, collaborate with others electronically, and develop and share materials at their own pace and for their own needs. In the information age, access to necessary information may be the true measure of equity. Over the next decade, many individual, local, state, federal and business decisions will determine whether this resource is broadly available or greatly restricted.

At the present time, computer networks, electronic communities, software for searches and retrieval, and myriad other elements of an emerging information infrastructure are coming into use on a highly idiosyncratic basis. This takes advantage of technology capacity and caters to individual needs. It means, however, that teachers, schools, and students can easily miss the boat.

An intense debate is now under way about the role of education with respect to the emerging national and global information infrastructure. The policies that result from this debate may be the most difficult and important decisions of all. All sectors of the economy are struggling to come to grips with the new opportunities, products, and choices offered through these developing technologies and policies. The constantly shifting definition of the system, changing technologies, entry of new public and private participants, and the simple newness of the system mean that it is very hard to articulate policy choices for the near future, much less for a decade. Some conclusions seem clear, however:

- Having ready electronic access to information is likely to be necessary for schools.

  The costs of these services cannot be fully determined but will include hardware, software, connectivity, use of guides and helpers to effectively navigate the system, and fees for line access and use. How the nation's schools might afford ready electronic access to information, especially in a time of restricted or even reduced funding for education, is a major policy concern. School districts are facing huge costs just to bring their aging, dilapidated school buildings to where they meet basic standards. The General Accounting Office reports that $112 billion is required for the repairs, renovations, and modernization required to restore the nation's 80,000 public schools to good condition and to comply with federal mandates related to accessibility and safety regulations, for major building features such as plumbing and environmental conditions such as ventilation, heating, lighting, or physical security.[37]
- Intellectual property and privacy issues are important for schools, as they are for other groups.
- The K-12 education community, and the college-of-education communities are not well positioned to negotiate effectively in the open market or in the regulatory arena for rights and access, and are unlikely to have the funding, legal support, and bargaining power to protect themselves, unless there is intervention or guidance from state and national policymakers or the private sector.

Congress is considering a number of approaches for education and the emerging telecommunications complex. Some reflect the desire to apply the concept of "universal service," contained in the current legal framework for the broadcasting system, to schools. There have been suggestions to set aside portions of the information infrastructure for school and other public uses, and suggestions to provide special sources of funding for school connections to these system.[38] The education market could possibly be aggregated into a purchaser that generates substantial market clout. This model reflects the success of some states in centralizing purchasing of hardware, specifying arrangement for network connections, and specifying software from competitive vendors. For example, some states have regulated tariffs and established targeted subsidies for schools. Georgia, for example, through its state department of telecommunications, procures telecommunications services for schools at the same prearranged rate that state agencies pay.[39]

In California, the Industry Council for Technology and Learning worked with the Public Utility Commission (PUC) in developing a PUC Educational Telecommunications Plan for the state. When the commissioner, who originally did not know that the schools were not connected, met with the state's education agency, together they developed recommendations that overcharges to customers be channeled to education. This amounted to an estimated $40 million for telecommunications in the schools per year. As a part of this partnership, Pacific Bell pledged to connect every school in the state.[40] Currently, 18

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[37] U.S. Congress, General Accounting Office, *School Facilities: Condition of America's Schools* (Washington DC: February 1995).

[38] See, e.g., National Association of Secondary School Principals, Council of Chief State School Officers, National School Boards Association, American Library Association, and National Education Association, press release, Nov. 15, 1994.

[39] James Bailey Matthews, vice chancellor, Information Technology for the University System of Georgia, Atlanta, GA, personal communication, Mar. 13, 1995.

[40] John Cradler, Far West Education Lab, presentation to National Coordinating Council-Technology in Education and Training, meeting, Washington, DC, December 1994.

BOX 1-8: Organization of the Report

This first chapter highlights some of the main findings of the study and lays out several policy options for Congress. It also analyzes several issues related to educational access to the global information infrastructure, including rough estimates of cost of and possible financing strategies for developing a telecommunications infrastructure with various levels of school access. It addresses other issues relevant to emerging electronic information sources and teachers, such as intellectual property rights, confidentiality and privacy of records, and limits on student access to potentially obscene or harmful materials.

Each of the next five chapters begins with a summary of key findings from that chapter.

Chapter 2 discusses the potential of technology to support, enhance, and, in some cases, redefine the job of teacher. Based on the actual experiences of teachers as reported in interviews, site visits, case studies, and published research, the chapter examines why some teachers are using technology and how it is changing their classrooms and teaching methods. The chapter also describes how technology can help teachers carry out many of the administrative, productivity, and communications tasks associated with their jobs. Finally, the chapter considers how technology can be a resource for teachers' professional growth, whether through formal professional development courses or informal exchanges with colleagues and outside experts.

Chapter 3 provides a statistical picture of the presence and use of technology in schools today. The chapter examines the extent to which schools and teachers have access to various kinds of technologies, including computers, video resources, telephones, and networking technologies. It also looks at how schools actually use these technologies: how often, in which kinds of classes, and for which kinds of activities. Finally, the chapter examines state policies for technology access and use.

Chapter 4 analyzes the factors that influence how effectively teachers implement technology. The chapter examines multiple barriers limiting teachers use of technology and describes the resources currently available to support teacher use of technology. Building on case studies of promising practices, the chapter outlines some approaches that schools and districts are currently using to help teachers learn more about technology and draws some lessons about technology implementation from these pioneer sites.

Chapter 5 addresses the role of technology in the preparation of new teachers. It examines the treatment of technology issues in teacher certification requirements and teacher education reform proposals. The chapter analyzes the kinds of technology preparation currently provided to teacher candidates. Drawing on case studies of institutions that have made technology a priority, the chapter also describes some promising approaches for integrating technology into teacher preparation and highlights ways in which technology can improve the teacher preparation experience.

Chapter 6 summarizes the federal role in technology-related teacher preparation and professional development. It outlines current sources of federal support for these activities, the nature and extent of federal commitment, and new opportunities for federal leadership created by recent legislation. The chapter also examines past federal efforts to improve teacher training and promote technology, analyzing their impact and their lessons for future federal action.

states are using preferential telecommunications rates as sources for expanding the use of technology.[41] Legislation proposed (and in effect) at 'he state level speaks only to telecommunications access rates for intrastate service; any special rates for interstate service would fall within the authority of the Communications Act of 1934.

Congress may be left in a quandary as it considers how much it should do with respect to expanding the technological capabilities of elementary

41 Ibid.

Our children face a future in which technology will touch every aspect of their lives. Teachers want them to be ready

and secondary schools and colleges of education. Clearly, federal support for an *extensive* expansion of educational technologies, even if it were ideologically desirable, could be costly.[42] Because technologies are advancing so rapidly, there may never be an adequate, up-to-the-minute answer to the question of whether such investments are worth their cost.[43] Some states and local school districts may be able to take on the burden of investing in new educational technologies, even without a definitive answer as to the long-term payoff, but others will not have the resources. Given the federal budget deficit, and the tax burdens felt by American citizens in all localities, an extensive federal investment at this time may not be possible. The analysis in this report suggests strongly, however, that whatever investments in hardware and software are made, and at whatever level, with whatever sources of funds, the investments be made thoughtfully. In this case thoughtful investment will require that infusions of resources be accompanied by concomitant investments in the teachers who will be working with the students and the technologies.

The Department of Education is struggling to keep attention focused on educational access, as it works to define what products the education market needs and how schools can best participate in the emerging telecommunications system. Given the large federal role in interstate telecommunications issues, if schools are not to be left behind, Congress will need to pay close attention to this issue as it debates regulatory and subsidy measures.

Regardless of decisions made about funding, if unintended consequences of new technologies are not to hinder teachers' access to technology and telecommunications, policymakers must be vigilant regarding three additional areas pertinent to education and new information systems. These areas, discussed earlier in this chapter, are privacy, particularly with respect to the records of students, copyright law, and the tradeoffs between protecting children from inappropriate materials and untoward censorship of emerging networks. Protection of intellectual property products also requires effective education of the public about intellectual property rights. This education could begin in school as students, teachers and administrators are connected to online information systems.

CONCLUSION

Bringing about change in the diversified U.S. school system is a formidable task. With over 2.8 million teachers in the United States, and 3.3 mil-

42As discussed earlier, the costs of connecting schools, teachers, and studentsto emerging information technologies and sources are highly uncertain. Available rough estimates suggest the costs on a national basis could be minimal (for minimal interconnectivity) or they could be astronomical, relative to current spending by elementary sod secondary schools. In the 1992-93 school year, the National Center for Education Statistics estimates that public and private elementary and secondary schools spent $280 billion (U.S. Department of Education, Office of Educational Research and Improvement, National Center for EducationStatistics, *Digest of Education Statistics, 1993,* table 33, October 1993).

43 True costs will likely vary on both a national and local bases depending on what technology plans are developed, the state of current school infrastructures, technology costs at the time of implementation, and other factors.

lion estimated to be needed by 2003, any attempt to "retool" or provide the entire existing teacher workforce with new skills or knowledge will need to be done on a very large scale. Most teachers have many years of teaching experience (the median is 15 years) and, at a median age of 42, most attended school before computers were used in the classroom.

Teachers are an incredibly diverse group. Some already have experience with technology—computers at home, for example—while others have never even been shown how to "boot one up." And some teachers are eager to experiment with new ideas even at the risk of failure, while others have little interest, energy, or time for experimentation. The great majority of teachers probably lie somewhere in between.

Technology has been viewed by a few as a frill, by some as a distraction, and by others as an intriguing but peripheral component of education. OTA finds, however, that technologies offer the ability to do many traditional things efficiently and quickly, and a way to encourage entirely new educational opportunities that may be of vital importance to the next generation of learners. If these learners are to make the most of the investments made in educational technologies, support must be given to the teachers who guide and encourage its use.

How can policymakers help to realize a vision of schools where teachers effectively and carefully identify, enlist, and use electronic and communications technology to improve learning?

OTA concludes that if the federal government wants to maintain or enlarge its involvement in this area, the linchpin of federal policy could be a set of initiatives that develop and support technology, and help teachers in their teaching and professional activities. When technology is effectively harnessed to goals identified by teachers, schools, states, and national policymakers, it becomes a vehicle for learning that is powerfully attractive.

One of the principal policy challenges for the next decade is to lead by example and by commitment. The experience of effective technology use in classrooms needs to be widely shared, evaluated and used as building blocks. Resources are needed to develop advanced learning products (hardware, software, curriculum materials, and tools focused on educational applications); both resources and farsighted regulation will be needed to make electronic communities affordable and well designed for schools. Effective policy and well-organized private sector involvement could create technology options that assure resources are equally available across the country, for all teachers, for all students, in all schools.