Technology Access and Instructional Use in Schools Today 3

SUMMARY OF KEY FINDINGS

- Research to date has collected only minimal data from teachers about how much technology is available to them and how they use various technologies for instructional or professional use.
- Projections suggest that by spring 1995, U.S. schools will have 5.8 million computers in use for instruction—about one for every nine students. Nevertheless, a substantial number of teachers still report little or no use of computers for instruction.
- Compared with other countries, the United States leads the world in the sheer number of instructional computers in schools. About half the computers in U.S. schools, however, are older, 8-bit machines that cannot support CD-ROM-sized databases or network integrated systems or run complex software. This problem is particularly pronounced in elementary schools. When compared on the availability of the more powerful 16- or 32-bit computers, the United States falls well below other countries. This aging inventory limits the ability of many teachers to use some of the most exciting applications of computers.
- During the past two years, the most rapid growth of technology in schools has been in CD-ROMs, videodiscs, modems, and local area networks (LANs). Available data are weakest in providing information about how much access schools actually have to these newer technologies, much less how they are being used.
- Video is the most common technology used for instruction in schools; sources include direct broadcast, cable, satellite, or videotaped programming. As of 1991, the typical school had seven TVs and six videocassette recorders (VCRs). Most

teachers make some use of video instruction during the school year, but data about kinds of use and effectiveness are lacking.

- The most common uses of technology in schools today are the use of video for presenting information, the use of computers for basic skills practice at the elementary and middle-school levels, and the use of word-processing and other generic programs for developing computer-specific skills in middle and high schools. Other uses of technologies—such as desktop publishing, developing mathematical or scientific reasoning with computer simulations, information gathering from databases on CD-ROM or networks, or communicating by electronic mail—are much rarer in the classroom. Technologies are not used widely in traditional academic subjects in secondary schools.
- Schools do not always locate their technology in the most accessible sites. Most schools still place a majority of their computers in computer labs rather than individual teacher's classrooms. Similarly, modems may be located on a central computer in the principal's office, making it difficult for teachers to integrate computer or telecommunications activities with other learning or professional activities during the course of a day.
- High schools are more likely than elementary schools to have newer or more powerful computers, LANs, hard disk drives, laser printers, videodisc players, and distance-learning capabilities. The greatest disparities in the distribution of computers among schools at the same level (i.e., elementary, middle, secondary) are found between small schools and large schools. Schools with fewer students tend to have many more computers per student. This pattern of more resources per student in smaller schools also holds for video equipment such as VCRs and TVs.
- The majority of K-12 schools are ill-equipped to participate in the opportunities presented by telecommunications networks. While telephones, modems, fax machines, and other telecommunications links with the outside world are present to varying degrees in school buildings, they are not yet generally found in classrooms. Fewer than one teacher in eight has a telephone in the classroom. Furthermore, most schools lack connectivity, administrative and organizational support, and technical expertise to integrate electronic networks into the teaching and learning process. Major investments of time and other resources will be required to prepare schools to effectively use electronic communities.

INTRODUCTION

As demonstrated by many promising examples throughout the United States (see chapter 2), technology can be a rich resource for teachers of all kinds to use in various educational settings. With available technologies, teachers can solve a range of educational problems, meet a variety of learning goals in all curriculum areas, and serve varying age levels or student populations. In addition, technologies offer teachers tools for accomplishing a variety of administrative tasks and for enhancing their own professional development.

Before teachers and students can use technology for these ends, however, they must have access to the hardware and software. How widespread is access to various technologies in classrooms today? How much and what kinds of technologies are available to the typical teacher? How are available technologies being used? This chapter attempts to provide an objective statistical portrait of the presence and use of educational technologies in American schools. The technologies covered include:

- computers of different levels of power and sophistication;
- computer-based equipment such as CD-ROMs, printers, and LANs;
- video resources such as televisions, videocassette recorders, cable, satellite, and videodisc players; and
- telecommunications networks and other technologies for two-way communication of voice, data, and graphics.

Statistical information in this chapter comes principally from three major nationwide surveys of schools, teachers, and students conducted in the United States between 1989 and 1993[1]: the U.S. portion of the 1992 Computers in Education Study of the International Association for the Evaluation of Educational Achievement (IEA),[2] the 1991 National Study of School Uses of Television and Video conducted by the Corporation for Public Broadcasting (CPB),[3] and the 1993 Communications Survey of Member Teachers of the National Education Association (NEA).[4]

Although these are the best, most nationally representative data sources[5] currently available, they still provide only a rough estimate of what schools are doing with technology. In part, this is because the landscape is changing so rapidly—hardware and software available in today's marketplace have grown in technical sophistication and decreased in cost compared with what was available just a few years ago. In addition, much of the available survey data come from principals or technology coordinators who tend to focus more on technology access and use at the building or district level rather than the classroom level. **In general, recent national survey data are weakest in providing information about the classroom context of technology use and teachers' professional use of computers**.

Available data are also lacking regarding access and use of telecommunications networks by teachers and schools—in part, because these applications have been increasing so rapidly in the past several years. Telecommunications networks allow teachers to interact with other professionals and take advantage of resources beyond the limits of their school or community. This chapter will discuss the ways in which schools are obtaining access to these networks and factors that affect their participation.

WHAT TECHNOLOGIES DO SCHOOLS OWN AND HOW ARE THEY USED?

Available survey data provide a picture of which technologies schools own and how much the average school has. In examining these data, however, one must remember that the presence of hardware is only a first step. To use hardware effectively, schools also must acquire the computer software and video programming that give it life and must orchestrate the available equipment to make it accessible to teachers and students. Teachers need to see the value of using technology, have an idea of how to use technologies effectively to accomplish their instructional goals, and must receive the training and continuing support necessary to overcome the inevitable challenges technology poses.

Estimating the amount of hardware available in schools today is relatively easy compared with estimating how frequently it is used and for what purposes. Yet information about the uses of technology is necessary for under-

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[1] Much of this chapter is adapted from Henry J. Becker, "Analysis and Trends of School Use of New Information Technologies," contractor report prepared for the Office of Technology Assessment, March 1994. In this contractor report, results of a number of major national surveys of educational technology were synthesized and analyzed. See appendix B.

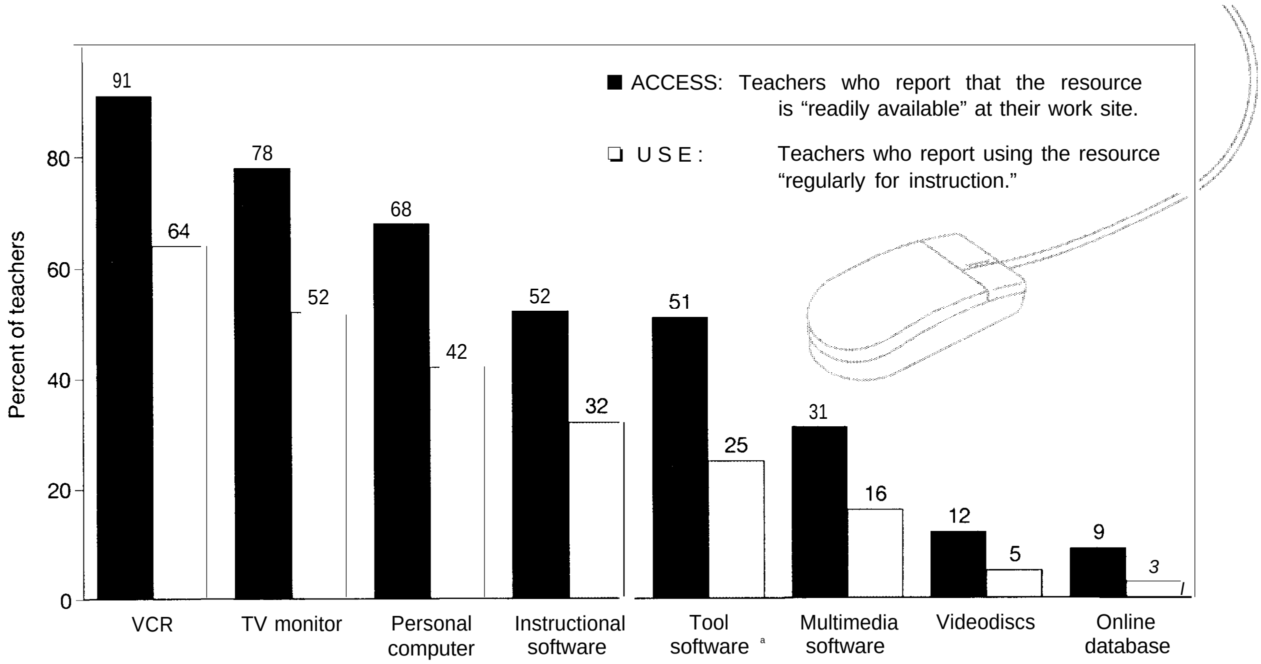
[2] Ronald E. Anderson et al., *Computers in American Schools, 1992: An Overview,* International Association for the Evaluation of Educational Achievement Computers in Education Study (Minneapolis, MN: University of Minnesota, 1993).

[3] Andrew L. Russell and Thomas R. Curtin, *Study of School Uses of Television and Video: 1990-1991 School Year* (Arlington, VA: Corporation for Public Broadcasting, February 1993). Also, see Research Triangle Institute, *Study of the School Uses of Television and Video: Methodology Report* (Research Triangle Park, NC: Research Triangle Institute, Mar. 20, 1992).

[4] Princeton Survey Research, *National Education Association Communications Survey: Report of the Findings* (Princeton, NJ: Princeton Survey Research Associates, June 2, 1993).

[5] This chapter also includes information from reports in progress or published and technical documents related to these three studies. The major features of these three studies and the four other studies used in the analysis are described in appendix B.

FIGURE 3-1: Teacher Reports of Access and Use of Technology Resources, 1991



[a] For example, word processing, database management, spreadsheet

SOURCE: National Education Association, *Status of the American Public School Teacher, 1990-1991* (Washington, DC: 1992)

standing the status of technology in today's schools.

One nationally representative survey of teachers illustrates the gap that often occurs between having access to technology and actually using it.[6] Teachers who reported having various technology resources “readily available” at their worksite were asked if they used that resource “regularly.” About 70 percent of teachers who have access to video resources use them regularly, and about 60 percent with access to personal computers use them regularly (see figure 3-l). Among teachers who have access to multimedia, videodiscs, online databases, and other newer technologies, an even smaller share report using them regularly.

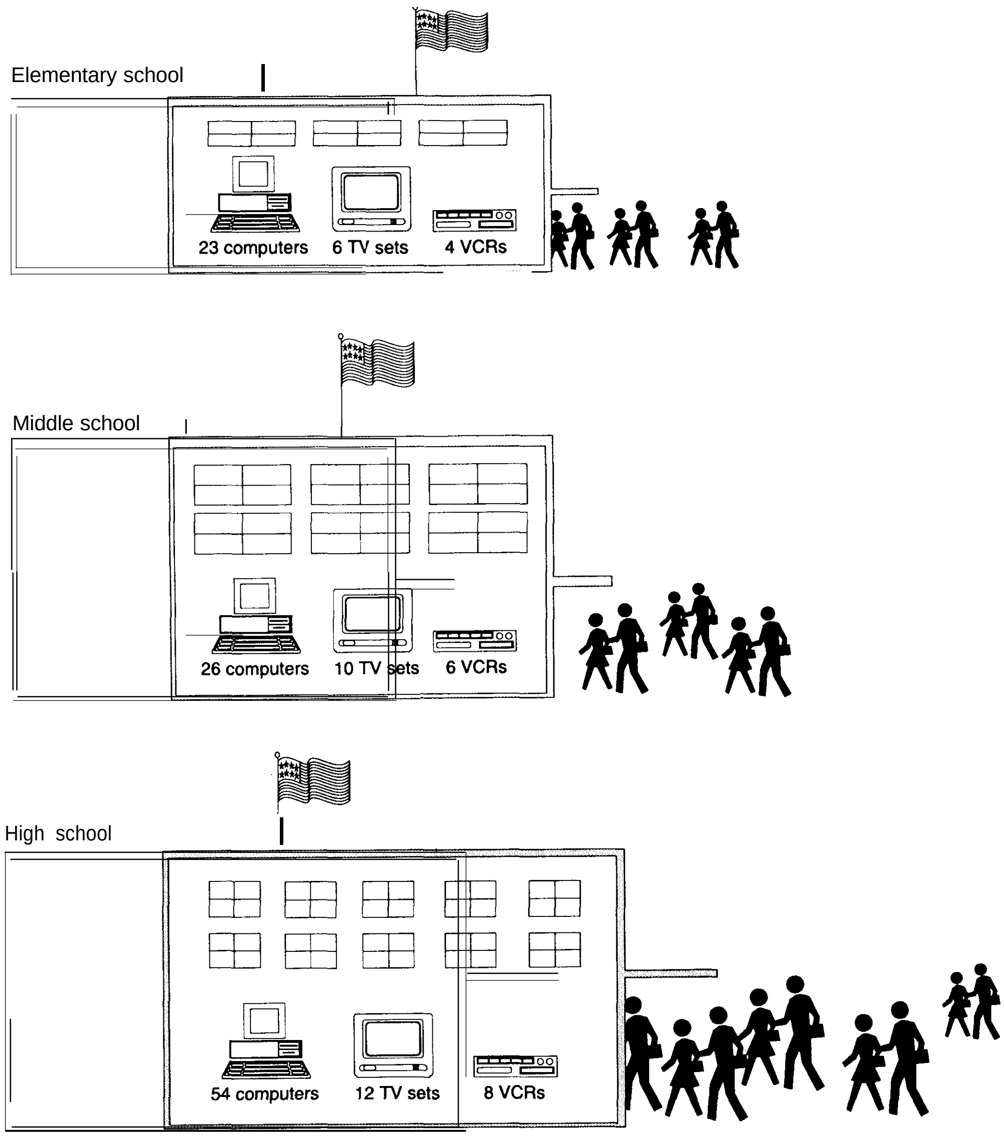
Computers

Of their total expenditures to date for technology (as defined in this report), schools have spent the most on computers. Over the past decade, schools have spent roughly $500 million on new computers. Between 1989 and 1992, for example, schools added 1.1 million computers, increasing their inventory by nearly 50 percent, from 2.4 million to 3.5 million.

The typical high school in 1992 had 54 computers (median), and the typical elementary or middle school had about 25 (see figure 3-2). The United States leads the world in sheer numbers of computers in schools (see box 3-l), although many of

[6] National Education Association, *Status of the American Public School Teacher 1990-91* (Washington, DC: National Education Association, 1992).

FIGURE 3-2: Installed Base of Computer and Video Technologies in Typical Schools, 1991-92



NOTE: Figures given are medians. Computer data from 1992, video from 1991.

SOURCES: R.E. Anderson (ed.), *Computers in American Schools* 7992: *An Overview* (Minneapolis, MN: University of Minnesota, 1993). A.L. Russell and T.R. Curtin (eds.), *Study of School Uses of Televisions and Video: 1990-97 School Year* (Arlington, VA: Corporation for Public Broadcasting, 1993).

BOX 3-1: Results from an International Study of Computers in Education

In 1989, the International Association for the Evaluation of Educational Achievement (IEA) conducted its first Computers in Education study of schools in 23 countries, including Austria, Germany, Japan, the Netherlands, and the United States.[1] Surveys were conducted in each of three types of schools: elementary schools (those with a 5th grade), middle schools (those with an 8th grade), and high schools (those with the last year of secondary education). Within each school sampled, the principal, a computer coordinator, and several teachers completed questionnaires. At that time, nearly 100 percent of schools in the United States had some access to computers. Advanced 16- or 32-bit computers were found to be rare all over the world.

In 1992, the survey was repeated in the aforementioned five countries, and in eight more. In addition, the 1992 study also tested over 69,000 students in grades 5, 8, and 11 in 2,500 schools to assess their practical computer knowledge. Western European students had the highest scores, followed by American students, then Japanese students. The Western European countries in the study have a formalized computer education curriculum, while the United States does not. Japan only recently has introduced computers into its educational program.

Results from the survey indicate that the United States leads the world in raw number of school computers as well as in computer density (the ratio of computers to students). However, because American schools started introducing computers years before most other countries, they now have many more older 8-bit machines. If countries are compared on the median percentage of their school computers that are 16- or 32-bit computers, the United States falls well below the other countries.

[1]Twenty-three countries participated in the 1989 study, and 13 m the 1992 study Currently, published data are available for the 1992 survey of these five countries.

SOURCE: Ronald E Anderson (ed.), Computers *in American Schools 1992: An Overview,* IEA Computers in Education Study (Minneapolis, MN: University of Minnesota, 1993)

those in current inventory are older 8-bit models, as discussed below.

Projections based on these data indicate that as of spring 1994, the number of computers used for instruction in K-12 public and private schools totaled about 4.95 million.[7] During the last three years, the total number of computers in schools has risen by about 18 percent annually-about 700,000 more computers per year---compared with an annual net of about 15 percent during the 1980s.[8] Further projections suggest that by spring 1995, instructional computers in the United States will number about 5.8 million units----or approximately one computer for every nine students.[9]

Age and Power of Computers

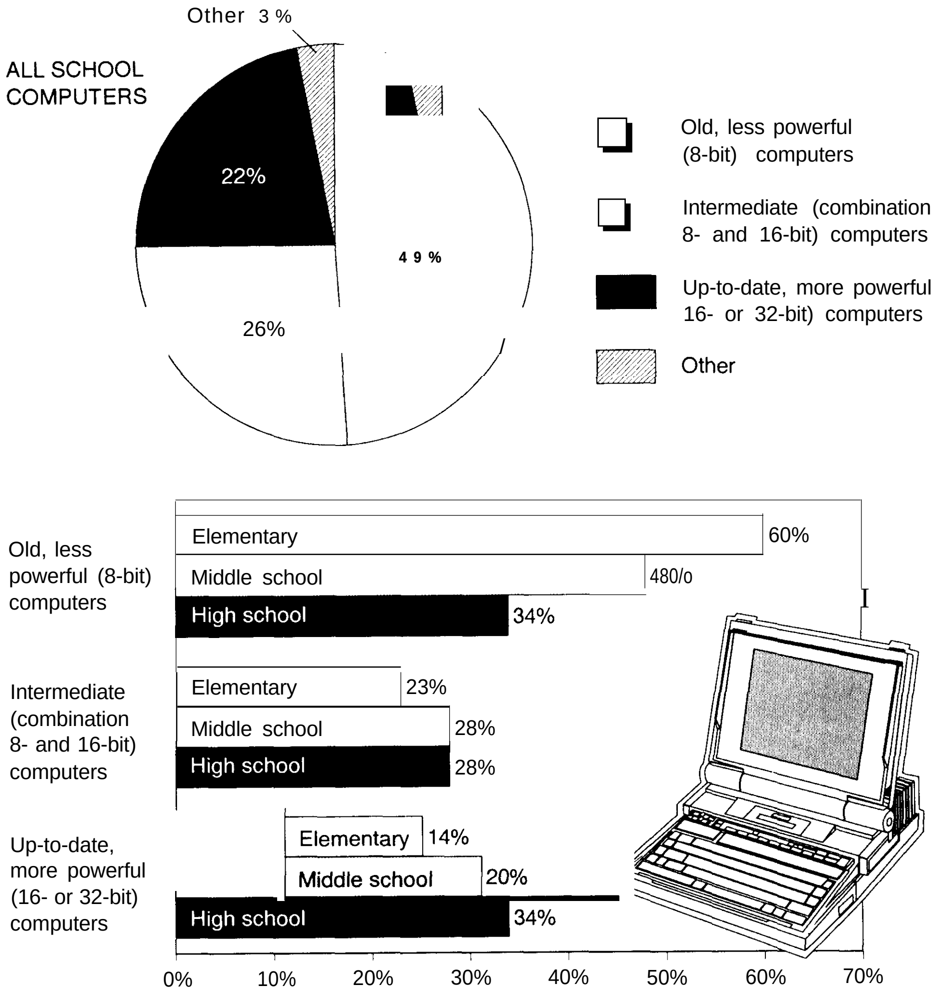
Over the past decade, most schools have acquired computers incrementally, making purchases on different occasions. Consequently schools often

[7]Ronald E. Anderson, "Hardware Projections in K-12 schools," technical memo from the IEA Computers in Education Study, University of Minnesota, Oct. 22, 1994. Projections based on 1992 IEA data, op. cit., footnote 2, and Quality Education Data, *Technology in Public Schools,* 1993-94 (Denver, CO: Quality Education Data, 1994).

8 Although industry sales indicate about 1 million units are sold each year, the instructional inventory only increases by 700,000 because schools discard some and use some mainly for administrative purposes.

[9]Anderson, op. cit., footnote 7.

FIGURE 3-3: Inventory of School Computers by Age/Power of Computers, 1992



[a] Includes primarily Apple II+, IIc, and IIe.

[b] Includes the Apple IIgs and IBM XT8088.

[c] Includes the Mac 6800, Mac 11, Mac LC, AT 80286, 386, and 486

SOURCE: R.E. Anderson (cd.), *Computers in American Schools 1992: An Overview* (Minneapolis, MN: University of Minnesota, 1993),

have machines of varying age and power. The 8-bit Apple II computer, the most popular computer marketed to K-12 schools for use in instruction in the 1980s, still comprises a large portion of school computer inventories even though it is no longer made and cannot run most newer software. As of 1992, one-half of the computers used for instruction in the United States were **8-bit** computers, primarily Apple IIs. An additional 26 percent were somewhat more powerful but still comparatively limited computers with 16-bit processors and 8-bit transmission buses (see figure 3-3). 10 Most new software being designed today cannot run on either of these types of machines.

[10] These machines include the Apple IIgs and the IBM XT 8088.

Outdated inventories are particularly pronounced in elementary schools. The number of newer 16- and 32-bit computers has grown most rapidly at the high school level, where the inventories have been shifting fairly quickly away from Apple II and toward IBM PC-compatibles. (Many school districts moved Apple IIs from high schools into elementary schools.) In 1992, over 40 percent of the elementary schools had no computers newer than Apple IIs.[11]

Why are there still so many Apple II computers in K-12 schools? First, until recently their unit costs remained lower than the more powerful 16-bit models. Second, until only four or five years ago, more software aimed at the school market was available for the older model computer. And third, schools tend to continue to outfit labs and classrooms with more of the same kind of computers they already own, to accommodate all the students in a classroom at the same time or within a reasonable period.

Enhanced Capabilities and Peripherals

In the brief history of personal computers, there have been several technological advances that might be called "order-of-magnitude" improvements—changes involving a 10-fold increase in speed, miniaturization of components, or a 10-fold improvement in capabilities. For example, at the beginning of the 1980s, floppy disks quickly replaced audiocassettes as input-output storage devices because they enabled users to access data at least 10 times as fast. Obvious examples today are the 16- and 32-bit computers whose order-of-magnitude increases in RAM memory and speed accommodate much more complex software than older machines; slowly these newer models are displacing 8-bit computers in schools.

Four other order-of-magnitude improvements in personal computers have the potential to revolutionize computer use in schools: hard disk storage, LANs that connect computers within the school building, CD-ROMs, and laser printers. The first three each promise 10-fold or greater increases in access to programs and data beyond the typical floppy-disk-based computer. Laser printers—especially in conjunction with LANs—promise substantial improvements in both the speed and appearance of printed output. All of these innovations have been widely implemented in business settings. What about in schools?

With hard disks and LANs, teachers and students can store program and data files without worrying about the mechanics of loading programs from diskettes. As of spring 1992, hard disks and LAN-connections were each available on about 20 percent of all K-12 school computers. Based on current purchasing trends, the Office of Technology Assessment estimates that at least 25 percent of school computers have both LANs and hard disks today, and perhaps one-third now have one or the other.

LANs are somewhat less prevalent in elementary schools than in high schools: 16 percent of elementary school computers were part of a LAN compared with 24 percent of high school computers. Similarly, hard disks are found much more often on high school computers. As of 1992, 30 percent of high school computers had hard disks compared with only 12 percent of elementary school computers.[12]

CD-ROM drives allow storage of and easy access to large amounts of data, including text combined with detailed illustrations, animation, sound effects, and spoken language. Schools are at a much earlier stage in acquiring CD-ROM storage than hard disks and LANs, although CD-ROM drives are among the fastest growing computer peripherals. According to one survey conducted during the 1992-93 school year, 44 percent of U.S. public schools had at least one computer equipped with CD-ROM, nearly triple the percentage found two years earlier; as with other computer technologies, high schools were more

[11] Anderson, op. cit., footnote 7.

[12] Hard disks and LAN data from 1992 IEA survey, op. cit., footnote 2.

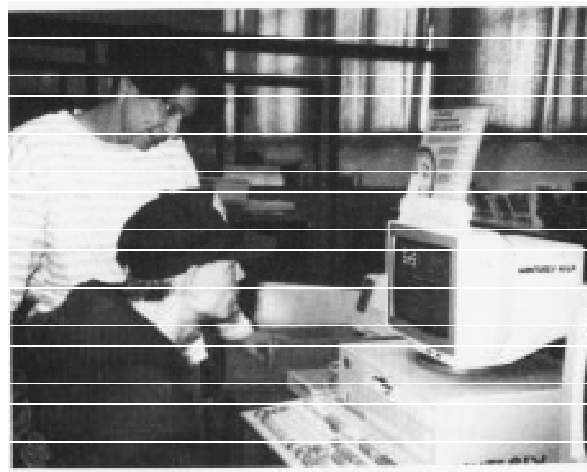
likely to have CD-ROM than elementary schools (see figure 3-4).[13] Unfortunately, surveys have not yet collected data on the number of school computers equipped with CD-ROM, nor on whether computers so equipped reside on a network, what levels of schools have them, or how much they are used. CD-ROM equipped computers tend to be placed in the school library or media center, to make them accessible to a larger number of students and teachers.

Since the mid-1980s, when teachers and students began using computers as word processors, schools have also invested heavily in printers. In 1989, for example, schools had one printer for every three computers, although more than 90 percent of these printers were the slower dot-matrix kind. Four years later, dot-matrix printers still made up nearly 90 percent of the inventory of school computer printers. Between 1989 and 1992, high schools acquired an average of one laser printer, but they also acquired seven more dot-matrix printers per school. Even less change occurred at elementary and middle school levels. In 1992, only one-sixth of elementary schools and one-third of middle schools had a laser printer for teacher or student use, compared with about two-thirds of high schools.[14]

Together these data suggest that some of the more promising uses of computers by teachers and students-desktop publishing, mathematics instruction using analytic graphing and calculating software, information-gathering from CD-ROM encyclopedias or network databases-can only be accomplished in a limited way, if at all, on most of today's school computers.

Location of Computers

As discussed above, the speed, memory, and peripherals available on school computers affect the ways teachers use them in their teaching and pro-



CALIFORNIA MODEL TECHNOLOGY SCHOOLS PROJECT—MONTEREY

About half of all public schools have at least one computer with a CD-ROM drive. They are often placed in central locations like this high school library

fessional activities. Another key factor that affects how teachers use computers is the location of the computers within the school building. Placing several computers in a common location, such as a computer lab, enables teachers to use computers with the whole class simultaneously, but also makes it more difficult for teachers to integrate computer activities with other learning activities throughout the day. When computers are in labs, teachers lack the easy access needed to use them as an everyday tool or resource. About one-half of all computers used for instruction in 1992 were located in centralized computer labs, while about 35 percent were located in teachers' classrooms. The rest were placed in other special instructional rooms, libraries, offices.[15] As schools' inventory of computers continues to grow, more computers will probably be placed in classrooms, although experience from the past decade suggests that this is likely to occur gradually.

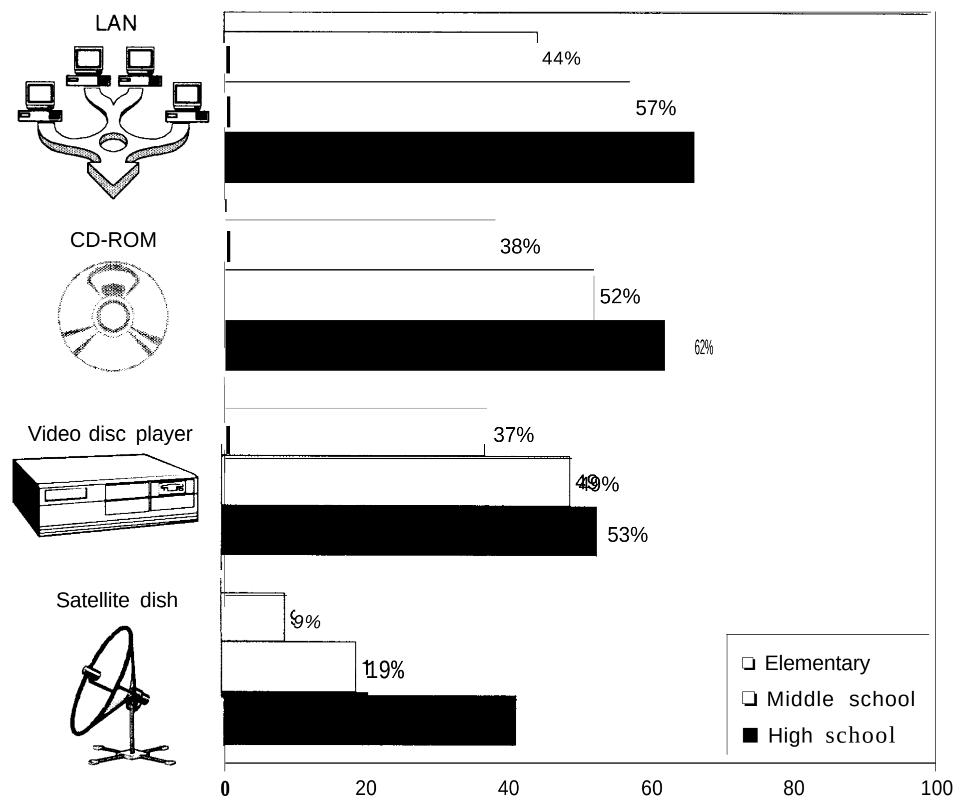
OTA site visits suggest that schools with a substantial inventory of technologies are investing increasingly in laptop computers, which can be moved around the school building and taken home

[13] Market Data Retrieval, *Educational Technology 1993: A Survey of the K-12 Market* (Shelton, CT: Market Data Retrieval, 1993).

[14] IEA data, op. cit., footnote 2.

[15] Ibid.

FIGURE 3-4: Percentage of Public Schools Owning Specific Technologies, 1993



SOURCE: Market Data Retrieval, *Education and Technology, 1993: A Survey of the K-12 Market* (Shelton, CT: 1993)

by teachers and students. Some schools place their laptops on carts that can be wheeled around to make any teacher's classroom into a temporary computer lab.[16] No data are available on the number of laptops currently owned by schools. Similarly, some districts and states are investing in computers for teachers (workstations) equipped with software and tools commonly needed by teachers. Again, no systematic data are currently available on teachers' access to this kind of resource.

Differences in Computer Resources Among Schools[17]

The student-computer ratio[18] gives some indication of how many students have to share a computer. This ratio has declined dramatically over the

[16] See, e.g., John R. Mergendoller et al., "Case Studies: Exemplary Approaches to Training Teachers To Use Technology," contractor report prepared for the Office of Technology Assessment, September 1994.

[17] Unless otherwise indicated, the data in this section are taken from Ronald E. Anderson et al., *Computers in American Schools 1992: An Overview,* International Association for the Evaluation of Educational Achievement Computers in Education Study (Minneapolis, MN: University of Minnesota, 1993).

[18] The number of students enrolled in a school divided by the number of computers available for students to use.

past 10 years; as of 1992, United States schools averaged one computer for every 13 students. Closer examination of available data suggests, however, that there is enormous variability in student-computer ratios from school to school. For example, there are vast differences between schools with the lowest "computer density" (in the 20 percent of schools with the fewest number of computers per capita) and those with high computer density (in the 20 percent of schools with the largest number of computers per capita). For example, elementary schools with high computer density average only seven students sharing a computer, while those with low computer density average 35 students sharing a computer (see table 3-1).

There is also a wide range in student-computer ratios across states-varying from a low of eight students per computer in Wyoming to 22 per computer in New Hampshire (see figure 3-5). This variability may reflect the fact that some schools, districts, and states launched large-scale technology initiatives over the past several years, while others have emphasized different educational reforms, placing less emphasis on computer acquisition.[19]

Another way of looking at whether computers are equitably distributed is to compare the student-computer ratios of schools having different demographic characteristics. Using the most representative national data available, this kind of analysis shows that the most pronounced differences in computer density among schools at the same level (e.g., comparing elementary schools with each other) are between small schools and large schools. **Schools with fewer students tend to have many more computers per capita.** Statistical analysis suggests that these differences are not simply due to differences between urban and rural schools. For example, in middle schools, where the differences are most pronounced, small schools have approximately 14 students per computer, while large schools have 24 (see table 3-l). This pattern of more resources in smaller schools also holds for video equipment such as VCRs and televisions.[20] This finding may reflect the tendencies of many districts to allocate technology funds on a per building basis, rather than a per student basis. It could also reflect commitment to providing every school building with what is viewed as a "critical mass" of technology (e.g., 30 computers for a lab).

Placing computers together in a computer lab is common and supports some forms of instruction. Teachers also need computers and other technologies in the classroom if they are to use them regularly as teaching tools.

The percentage of minority students in a school has a different relationship to student-computer ratios across the three school levels. While there are small differences among elementary schools with different proportions of minority children (see table 3-l), there are no differences among

19 Ronald E. Anderson, "State Technology Activities Related to Teachers" contractor report for the Office of Technology Assessment, Nov. 15, 1994.

20 CPB data, op. cit., footnote 3.

TABLE 3-1: Average Student-Computer Ratios in 1992 by Computer Density, School Control, School Size, and Percent Minorities

	Elementary	Middle	High School
Computer density[a]			
Lowest 20%	34.5	35.5	31.4
Middle 60%	15.8	14.0	10.4
Highest 20%	7.2	5.4	3.7
School control			
Private	20.5	18.2	15.2
Public	17.5	15.1	11.9
School size[b]			
Small	‘15.9	14.4	11.5
Large	22.5	24.3	17.1
Percent minorities			
0-3%	16.7	14.0	12.5
4-24%	18.6	16.2	12.5
25-100%.	18.7	18.3	12,4

[a] Schools were di vided into three groups based on the computers per capita. “Highest 20%” refers to the 20% of schools that have the most computers per capita, “Lowest 20%” refers to the 20% of schools with the fewest number of computers per capita.

[b] The dividing point between small and large schools was at an enrollment of 500 students at the elementary level, 700 students at the middle school level, and 1100 students at the high school level,

SOURCE: R.E. Anderson (cd.), *Computers in American Schools 1992: An Overview,* (Minneapolis, MN: University of Minnesota, 1993), table 2,3, p. 17.

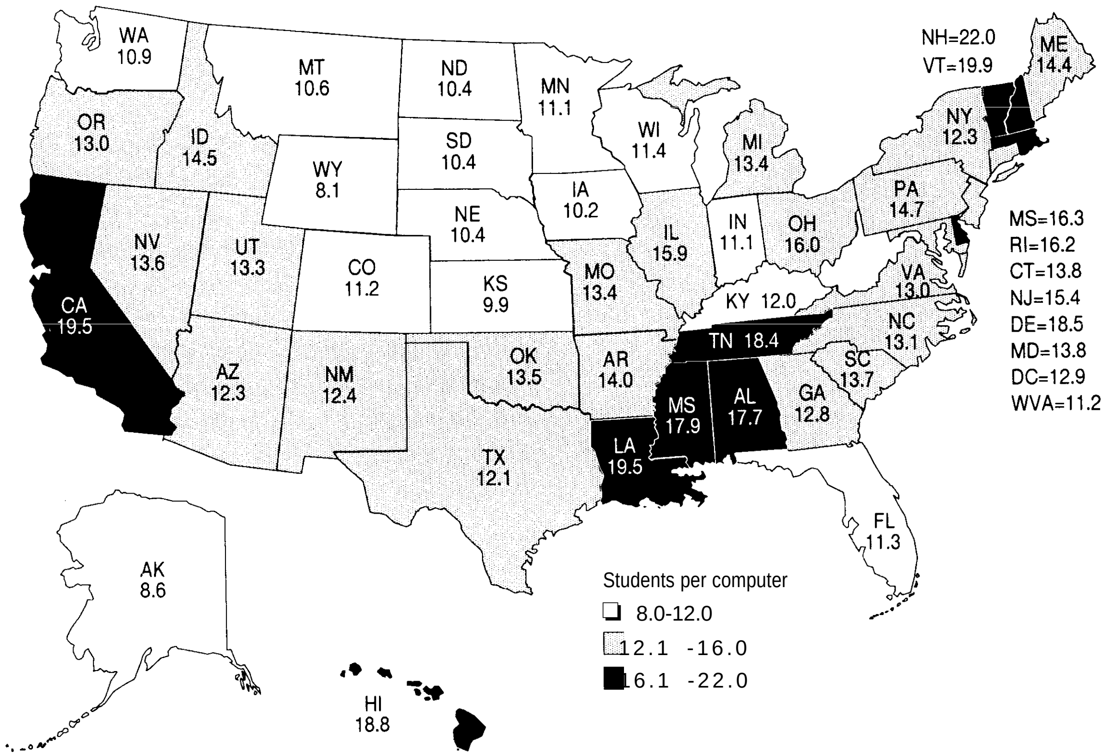
high schools. The largest differences appear in middle schools, where schools with less than 4 percent minority enrollments have an average of 14 students per computer, while schools with more than 24 percent minority enrollments have 18 students per computer.

Ratios of students to computers do not indicate which students within the schools have access to and experience with computers. Research done in the 1980s found that in the early years of computer adoption in schools, poor and minority students had less access to computers both at home and at school. In addition, data showed small gender differences favoring boys over girls in access to computers in school.[21] Some recent data from the IEA study suggest that while girls are still somewhat less likely to report using computers at school or receiving instruction in computers, ethnic minority students are slightly more likely than white students to report having had these opportunities. The authors of this report write:

> The advantage of ethnic minority students over white students will come as a surprise to those who read the statistics from previous studies in the early to mid- 1980s. Further investigation of the forces behind this pattern is needed, but we might speculate that the minority advantage at the 5th- and 8th-grade levels stems from the success of programs like Chapter One which

[21] See Rosemary E. Sutton, “Equity and Computers in the Schools: A Decade of Research,” *Review of Educational Research,* winter 1991, vol. 61, No. 4, pp. 475-503.

FIGURE 3-5: Average Number of Students per Computer by State, 1994



NOTE: Students per computer is a measure of how many students have to share a computer. Smaller numbers (e.g., 8.0) mean that fewer students have to share a computer.

SOURCE: Quality Education Data, *Technology in Public Schools, 1993-94* (Denver, CO: 1994).

fund the purchase of new technology to be used with disadvantaged students.[22]

How Much Do Students Use Computers?

There are few reliable data about how much the 4 million-plus computers in schools are actually being used; the only estimates are rough ones. One problem is that reports of use vary greatly depending on the source. For example, using reports of computer coordinators and making certain assumptions about shared use of computers (i.e., that one-half of the time students share a computer with a peer, and both are profiting from its use simultaneously) yields the following estimates:

- Computers are used about one and three-quarters hours per student per week at elementary schools.
- Computers are used approximately two hours per student per week at middle schools.

[22] Anderson, op. cit., footnote 2, p. 81.

Schools are beginning to invest in laptop computers because of the flexibility they provide. These students use computers like books or notepads, taking them wherever they go.

- Computers are used approximately three hours per student per week at high schools.
- On average, computers are used about two hours per week per student across all school levels.[23]

The students themselves, however, report much less frequent use:[24]

- 24 minutes per week in grade 5,
- 38 minutes per week in grade 8, and
- 61 minutes per week in grade 11.

At most, this is only one-third of the time estimated from the coordinator reports. There are several possible explanations. School computers may be sitting idle much more than the adults reported; students may be underestimating their experiences; some students may be having rather intensive computer experiences while the rest are having more limited, occasional, or exploratory ones. Available data do not provide answers to these questions.[25]

The data from both the coordinators and the students suggest that, in the aggregate, older students who use computers to any significant extent use them two to three more times during a typical week than younger students do. However, universality of use—providing experience with computers to all students-is more likely at younger grade levels. For example, student data suggest that 74 percent of all 5th graders used computers during the year on more than a few occasions, in comparison to 57 percent of llth graders.

How Many Teachers Use Computers?

Data on the number of teachers who use computers vary greatly depending on how one defines a "computer-using teacher." Two different definitions-one quite inclusive, the other much more stringent-yield very different estimates. In addition, these definitions have focused on use of computers for direct instruction with students only; no data are available on other teacher uses such as administrative tasks or professional development.

In the 1992 IEA survey, a "computer-using teacher" was defined liberally as a teacher who "sometimes" used computers with students. Using this broad definition of how much teachers themselves report using computers, 75 percent of 5th-grade teachers, and about half of 8th- and

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[23] Based on the 1992 IEA data, these estimates are, of course, averages and do not indicate whether all students have this same experience with computers or whether some students monopolize their use—either because of their own preferences, the course-taking patterns of different students, or the assignment practices of different teachers.

[24] In the Becker contractor report for the Office of Technology Assessment (see footnote l), the estimate of total computer time for a student was made by adding the number of occasions of computer use the study reported for each of nine subjects. Answers were coded according to grade level. Each occasion was multiplied by the number of minutes estimated for that grade level, and the total number of minutes was divided by 30, representing the roughly 30 weeks that had elapsed during the school year up to the time the questionnaire was completed.

[25] Another possible reason for the apparent inconsistency between teacher and student reports is that many teachers may have *some* (but not all) their students in a class or some (but not all) of their classes use computers, or they allow students to do so at their option without systematically requiring computer use of all students.

11th-grade teachers were found to be "computer-using" teachers.

A more stringent way to define "computer-using" teachers is to include only those teachers who clearly required most or all students to do work on computers.[26] Under that definition, about one-half of 5th-grade teachers, one-third of 8th-grade English teachers, and one-fifth of 11th-grade English teachers qualify—roughly 20 to 30 percentage points fewer than under the other definition. If an even more stringent criterion is employed, one related to frequency of use,[27] the percentage of teachers who identify themselves as "computer using" is even lower—about one-third the size of the original group. **Thus, the percentage of teachers classified as computer-using teachers is quite variable and becomes smaller as definitions of use become more stringent.**

Instructional Uses of Computers by Teachers

Over the past decade, the advice of "experts" in educational technology about what teachers *should* do with computers has been constantly changing—from BASIC programming, to Logo programming, to tutorials provided by integrated learning systems, to generic computer applications such as word processing, to activities integrated with existing curricula, to student-developed multimedia presentations, and now to telecommunications-based learning communities[28] (see box 3-2). **According to survey data, however, when teachers are using technology for instruction they do so in much more traditional ways.**

For example, IEA survey data indicate that the most common activities on computers for elementary students have been drills in basic skills and instructional games. Also popular at all levels are general "computer literacy" activities: use of various instructional programs and generic computer applications such as word processing. School computer coordinators estimate, for example, that students spend the most computer time learning to type on computer keyboards and use word-processing programs. Interestingly, the estimated share of computer time students spend on mathematics declines between elementary school and high school from 18 to 8 percent, suggesting that math teachers are using computers primarily for students to practice arithmetic skills rather than to solve higher-level mathematics problems. Between 1989 and 1992, the one significant change in the allocation of student computer time was a one-third decline in the time spent teaching students computer programming as a part of computer literacy education.

Available data suggest that in secondary schools, computers are used relatively infrequently for teaching and learning in traditional academic subjects, far less than in classes focused on teaching students *about* computers.[29] Although most middle-school and high-school students reported using computers for at least one academic subject, for most subjects, this meant using computers only once or twice over most of the school year. If one examines only those classes for which students had used school computers on at least 10 occasions during that

[26] The criterion used by Becker (see footnote 1) was that at least 90 percent of a teacher's students actually have used computers for their class as reported by the teacher. This presumably counts only those cases where students use computers at the teacher's instruction rather than totally on their own initiative.

[27] For example, when the class is using computers, a typical student will do so at least once during the week; or during the school year an average student will have had six experiences using any one of several types of software such as word processing, "print shop" programs, or desktop publishing.

[28] Henry Jay Becker, "Computer Experience, Patterns of Computer Use, and Effectiveness—An Inevitable Sequence or Divergent National Cultures?" *Studies in Educational Evaluation*, vol. 19, 1993, pp. 127-148.

[29] IEA Student data, op. cit., footnote 2.

BOX 3-2: Timeline of Changes in the Prevailing Wisdom of "Experts" About How Teachers Should Use Computers in Schools

1982

Teachers are told to:	**Teach students to program in BASIC.**
Rationale:	"It's the language that comes with your computer. "

1984

Teachers are told to:	**Teach students to program in LOGO.**
Rationale:	"Teach students to think, not just program. "

1986

Teachers are told to:	**Teach with integrated drill and practice systems.**
Rationale:	"Individualize instruction and increase test scores. "

1988

Teachers are told to:	**Teach word processing.**
Rationale:	"Use computers as tools, like adults do. "

1990

Teachers are told to:	**Teach with curriculum-specific tools (e.g., history databases, science simulators, data probes).**
Rationale:	"Integrate the computers with the existing curriculum. "

1992

Teachers are told to:	**Teach multimedia hypertext programming.**
Rationale:	"Change the curriculum—students learn best by creating products for an audience. "

1994

Teachers are told to:	**Teach with Internet telecommunications.**
Rationale:	"Let students be part of the real world."

SOURCE: H.J. Becker, "Analysis and Trends of School Use of New Information Technologies, " Off Ice of Technology Assessment contractor report, March 1994.

school year (i.e., once every three weeks since the survey 'was completed 30 weeks into the school year), more than one-third of secondary school students reported using computers this often in a computer class, but for other subjects the percentages were much lower: 9 percent for an English class, 6 to 7 percent for a math class, and only 2 to 3 percent for a social studies or science class. Since word processing is a major activity in secondary school computer education classes as well as in business education classes, it seems clear that high school is still primarily a place to learn how to use word processing, rather than a place where teachers have students do word processing in order to achieve other academic goals. This is even more likely for other applications, such as spreadsheets and database programs, which have been less integrated by teachers into subject-matter instructional practices than word processing.

At the elementary school level, the survey data suggest that students use computers overwhelmingly in an exercise mode-doing drills and playing various kinds of games with instructional content—rather than in a productivity mode, using computers as a tool to

solve problems or create products. For example, 53 percent of 5th graders said that they used school computers to play games on 10 or more occasions during that school year, while 13 percent said they did word processing. Similarly, about 65 percent of 5th-grade teachers report that computers in their classes are mainly used for language arts skills practice and games, while 18 percent say they are used primarily for writing and word processing; about 17 percent report both categories of use.

Video Technologies

The past several years have witnessed a growing interest in teaching that uses video as a resource. This is due, at least in part, to the expansion of cable programming with educational content, the widespread availability and familiarity with videocassette recorders, developments in computer-based video, and an increase in the supply of videodiscs for schools.

For the next several years, the basic projection mechanism for video will likely remain the television set or the composite (computer) monitor. Nearly every school in the country has at least one TV set for use in the instructional program. According to a 1991 survey of public schools, the mean number of sets per school was 12; the median per school was seven sets.[30]

Unlike the case for computers, the availability of television sets is nearly the same among elementary, middle/junior highs, and high schools. In 1991, there were slightly more than four television sets for every 10 full-time teachers at each of those levels. In a 1993 survey, 41 percent of teachers reported having a television set in their own classrooms.[31]

Almost every school in the United States has at least one VCR. As of 1991, the mean number per public school was 6.3, or one for every 1.9 televisions. As with televisions, elementary, middle, and high schools have about the same number of VCRs per capita. The typical school has one for every five teachers.

Teachers use VCRs for showing commercially produced videos and for recording programs from cable or broadcast television and showing them later. Most schools maintain a library of prerecorded cassettes. Based on Corporation for Public Broadcasting (CPB) data, 67 percent of teachers reported that they record shows at home for school use, and many others said that they ask other school personnel to make recordings for them.

It is interesting to note that, unlike most surveys on computers in schools, data on video and television are given at the classroom level, or per teacher, rather than per student. This may reflect the fact that, unlike computers, video technologies are seen more as technologies to be controlled by the teacher, who presents information to groups of students or the entire class, rather than technologies operated by individual students.

Cable and Satellite Connections

Teachers have an increasing number of sources of video programming beyond prerecorded cassettes, educational broadcasting, and recordings made at home. Between 1991 and 1993, there was a 25 percent increase in the proportion of schools with direct cable connections,[32] so that now as many as three-fourths of all schools have cable somewhere in the school building. Another survey found that roughly one-third of all teachers in the sample reported having cable TV service in their own classroom.[33] "Access to cable" can mean different things to different schools, however, depending on the channels carried by the local cable provider and the type of service to which

[30] CPB survey, op. cit., footnote 3. The large difference between mean and median suggests that while most schools have a few television sets, a small minority have made a substantial investment in televisions, enabling most teachers to have one in their rooms.

[31] NEA Communication Survey, op. cit., footnote 4.

[32] Market Data Retrieval, op. cit., footnote 13, p. 140.

[33] NEA Communications Survey, op. cit., footnote 4.

Unlike videotape, which must be played in a linear fashion, videodiscs allow students and teachers to browse through, capture, and play video images in any order

the school subscribes.[34] One study, for example, reported that, although 61 percent of schools reported having access to the Public Broadcasting System (PBS), and almost as many had access to national commercial broadcast networks, far fewer had access to commercial cable channels that offer a number of educational programs, such as the Discovery Channel (35 percent) or the Learning Channel (16 percent).

An increasing number of schools and districts are obtaining satellite dishes, giving them a wider selection of programming than that offered by their local cable distributor. According to one report, the proportion of schools directly accessing satellite broadcasts nearly doubled between 1991 and 1993.[35] As of 1993, 50 percent of all school districts reported having a satellite dish as did 17 percent of all public schools. High schools are more likely to have satellite dishes than are middle or elementary schools (see figure 3-4).[36]

One contributor to the recent growth of satellite dishes in middle and high schools has been the Channel One project created by Whittle Communications, Inc. (and now owned by K-III Communications). Whittle installed satellite reception systems in schools that committed to show students "Channel One," a daily 12-minute news program, which includes two minutes of commercials. Each participating school also received two VCRs and enough 19-inch television sets to put one in each classroom.

By the spring of 1993, three years into the program, approximately 12,000 schools were receiving Channel One, according to Whittle. A three-year evaluation report of Channel One translates this to mean an audience of over 18 million teens, or almost 40 percent of the 12-to 18-year-olds enrolled in school.[37] With these participation numbers, the Channel One offer seems to have contributed substantially to the installed base of video technologies in middle and high schools throughout the country. Some evidence suggests that this impact may be greater in poorer school districts. One survey found Channel One participation to be higher among districts with a poverty rate exceeding 25 percent than in districts with poverty rates under 5 percent (42 percent vs. 25 percent).[38]

Videodisc Players

Teachers use instructional videodisc differently than they use videotapes. Teachers commonly videotape programming to show in a linear format; for example, to have students watch a 10-minute instructional television segment or an hour-long program from beginning to end. An

34 Andrew Russell, CPB, personal communication, Dec. 9, 1993.

35 Market Data Retrieval, op. cit., footnote 13. The specific rate of increase reported was 85 percent.

36 Ibid., and CPB survey, op. cit., footnote 3.

37 Jerome Johnston and Evelyn Brzezinski, *Taking the Measure of Channel One: A Three Year Perspective* (Ann Arbor, MI: University of Michigan, Institute for Social Research, January 1994).

38 MDR, op. cit., footnote 13.

instructional videodisc, by contrast, usually contains many thematically related but short (under 3 minutes) discrete segments of action and still video. The teacher or student can access and directly control the segments of visual and audio materials. Using a remote control, barcode reader or computer equipped with hypermedia software, the teacher can browse through, access, and play different segments of video in any order—using them, for example, to illustrate and enhance a presentation or discussion.

The number of public schools with at least one videodisc player doubled between 1991 and 1993, to 41 percent.[39] During that period the variety of educationally appropriate videodisc software increased substantially, and at least two states allowed videodiscs to appear on the list of "texts" approved for adoption as options to printed textbooks. As with many other technologies, more high schools report having a videodisc player than do middle and elementary schools (see figure 3-4).

Still, in terms of access, the question is not whether a school *has* videodisc equipment but, rather, what proportion of teachers *can use* the videodisc equipment without difficulty. In a 1991 survey of teachers, only 12 percent reported that they had videodisc players readily available to them in their schools. Furthermore, less than half of those teachers reported actually using the videodisc regularly for instruction (see figure 3-1).[40]

Camcorders

Camcorders and other video equipment allow students and teachers to undertake new kinds of learning activities, such as making their own video reports or recording student presentations. Most schools have at least one camcorder; as of 1991, this was true of 80 percent of elementary schools and 90 percent of middle and high schools. Some 8 percent of all schools even had their own TV studio in 1991, including 22 percent of high schools. But not every school makes this equipment available to teachers or students. According to one survey, just slightly more than half of the schools with camcorder or studio facilities used these for student instructional activities, including giving students production experience or feedback on their own performance in a classroom activity.[41]

How Much Are Video Technologies Used in Schools?

Available data on teachers' use of video resources reflect conditions in the spring of 1991.[42] For televisions, VCRs, and other video resources whose use has been reasonably stable over time, the 1991 information is still useful; for videodisc, CD-ROM, and emerging technologies where use is expanding quickly, the 1991 data are clearly insufficient.

Most teachers in the United States make some use of video-based instruction during the year.[43] In the CPB survey, about 80 percent of U.S. teachers said they had used instructional television or video some time during the school year. About one-half of all teachers (51 percent) said they had used TV or video in teaching in the past month. The teachers most likely to have used video recently are elementary school teachers and secondary science and social studies teachers.

Estimates derived from the CPB data suggest that across all subjects, secondary students, on average, spend one and-one-half hours per week watching video material in school. The average

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[39] MDR, op. cit., footnote 13, p. 81

[40] NEA, op. cit., footnote 6, pp. 53-54.

[41] CPB survey, op. cit., footnote 3.

[42] Ibid.

[43] Although the survey questions specifically asked about "video," use of film media was not explicitly addressed in instructions to teachers, making it difficult to know how much film use is incorporated into these statistics.

elementary student is estimated to watch video in school for slightly more than one hour per week.

Technologies for Two-Way Communication

The instructional technologies discussed above are used primarily to transmit information or to help develop student competencies. But it is another function of instructional technology where applications are expanding rapidly—to facilitate two-way communication, allowing teachers and students to share their ideas, questions, and productions with the world outside of their school. **As schools attempt to make learning more meaningful to students and to anchor it in "real world" examples and experiences, more and more educators are looking for technological tools that help teachers and students to communicate with the outside world.**

Schools are acquiring and exploring a range of technologies and tools that facilitate two-way communication. These include new ways of using older technologies such as telephones, facsimile machines (fax), and modems; combinations of different technologies, such as distance-learning systems; and new kinds of telecommunications hardware, software, and services. Because many of these latter applications are so new in schools and are expanding so rapidly, up-to-date survey data about access are not available. However, some data have been collected about telephones, modems, fax machines and distance-learning technologies in schools; these are discussed below.

Telephones and Fax Machines

Telephones and fax machines are two communications resources with great potential for teaching and learning; too often, however, they usually are accessible only to school administrators. Access to telephones, in particular, is currently a major technology issue being discussed by teachers' organizations. **Although one-third of all teachers in a recent survey felt it was "essential" to have a telephone in their classroom, only one teacher in eight had a telephone in the classroom that could be used for outside calls**. Less than 1 percent had access to voice mail. Most teachers have to make calls from the school office or a faculty lounge, where many colleagues share a phone and most conversations cannot be held in private. Sixty-three percent of teachers surveyed felt it is "essential" for parents and teachers to be able to contact one another during the school day; almost three-quarters of teachers feel that having telephones in the classroom would improve parent-teacher communication at least "somewhat."[44]

Among the reasons for restricting teachers' access to phone services are concerns about costs and unregulated use. Installation and monthly charges tend to be prohibitive for a restricted school budget, in part because phone companies often charge schools higher-priced business rates for installation and message unit charges.[45]

Teachers seem less interested in having access to fax machines. Although approximately one-fourth of teachers had access to a fax machine in their school, most did not view it as an important instructional resource.[46] Since fax machines are relatively rare in schools, it is likely that most teachers are not aware of their instructional or administrative potential.

Modems

Modems, which allow computers to communicate electronically across a telephone line ("telecomputing"), have been available almost from the be-

[44] NEA Communications Survey, op. cit., footnote 4.

[45] Edmund L. Andrews, "MCI Plans To Enter Local Markets," *The New York Times*, Jan. 5, 1994, p. D1; and U.S. Congress, Congressional Budget Office, *Promoting High-Performance Computing and Communications* (Washington, DC: U.S. Government Printing Office, June 1993), pp. 39-43.

[46] NEA Communications Survey, op. cit., footnote 4.

ginning of personal computing.[47] Although many districts have modems, they were originally dedicated primarily to administrative uses. With the advent of new educational applications of electronic networking, however, modems have become an important gateway to telecomputing.

In recent years schools have begun installing more modems for teachers to use for instructional activities. For example, in the 1989 IEA survey, slightly more than one-fourth of U.S. schools had a modem that could be used by teachers or students. By 1992, that percentage had grown to 38 percent overall, including 60 percent of all high schools, 35 percent of middle schools, and 33 percent of elementary schools.[48]

As with other technologies, the presence of a modem in a school building does not tell much about the average teacher's access to telecomputing. Many teachers may consider access to a modem anywhere in the school sufficient for the occasional special project. Over the long run, however, if telecomputing is to be used regularly, classroom access to a modem or alternative connection will be necessary.

Distance-Learning Technologies

The most established educational technologies for two-way communication are those used in distance learning. For more than a decade, schools have used live one-way video technologies via satellite or broadcasting in conjunction with two-way audio (via phone lines) or other two-way media such as computer networks or fax machines to expand learning opportunities. Some distance-learning projects also involve two-way video communication through microwave or fiberoptic transmission. Distance learning is most often used by schools in remote, rural, or sparsely populated areas and by other schools that lack traditional educational resources, such as a qualified teacher for a low-enrollment course. Distance-learning technologies allow high schools, for example, to offer courses, such as advanced calculus, Japanese, and Russian, that may not be available otherwise.

The prevalence of distance learning is difficult to estimate, in large part because its definition is inexact and inconsistent. In a 1991 survey, about 17 percent of districts reported having some capacity for live video with interactive capabilities.[49] Another survey found that in the 1992-93 school year, 28 percent of districts had some distance-learning capability and that 11 percent of all schools were involved in distance-learning—double the number from their data taken two years earlier.[50] In this survey, high schools were much more likely to have distance-learning capabilities (25 percent) than either middle (10 percent) or elementary (8 percent) schools, probably because high schools use it to offer advanced courses for which they may not have enough students to hire a qualified teacher.

In about 70 percent of the districts with distance-learning capabilities, two-way interaction is limited to voice-only interactivity through dial-up telephone lines,[51] an arrangement that allows only a small number of the participating classrooms to communicate on-air with the studio video instructor during a given class period. About 20 percent of districts' distance learning employs two-way video. Available surveys do not assess the number of classes or students using distance learning for a portion of their instructional time.

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[47] Wireless modems, using cellular technology, are also now available. Their use in schools is still very limited, due to the expense of initial purchase costs and the costs of per minute charges when used for connecting to networks outside the building.

[48] IEA data, op. cit., footnote 2.

[49] Calculated from CPB data, op. cit., footnote 3.

[50] Market Data Retrieval, op. cit., footnote 13. District percentages from the MDR file are, however, questionable because of the low response rate in that survey.

[51] Ibid., and CPB Survey, op. cit., footnote 3.

A camera mounted on the computer takes pictures or videos of learners at one site and sends them to students at other locations, adding a personal touch to collaborative group work.

However defined, the use of distance learning in K-12 settings has increased considerably in the last several years. While fewer than 10 states were participating in distance-learning projects in 1987, virtually every state is now involved with distance learning in some way. In addition to using distance learning for student instruction, many states and districts use it for videoconferencing, teacher training, and professional development (see chapters 4 and 5).[52]

Technologies for Linking to Wide Area Networks and the Internet[53]

There are several possible ways schools can link up with wide area networks (WANS) in general, and the Internet in particular (see box 3-3). The options for telecommunications connections are shifting, as individual modem dial-up connections give way to more sophisticated and higher speed connections to WANs and the Internet; these options include connections via LANs, high-speed phone lines, dedicated connections, and so forth. Other models of connectivity include Integrated Services Digital Network (ISDN), satellites, digital cable, or other linking technologies. Several connectivity formats are described briefly below; however, no national data are currently available regarding how many schools and districts are using any of these options.

Direct single modem dial-up

Connectivity often begins with a pioneering individual teacher making personal connection to a network through a dial-up modem-in some cases a regular telephone line and a computer outside the classroom, in the principal's office or the library. The teacher might access any of several services with different features: one aimed primarily at Internet connection (e.g., the World Wide Web); one that seems easy to use, such as America Online; a state-level network, such as The Texas Education Network (TENET); or a special interest network such as EcoNet for ecology. Most dial-up services now offer some form of Internet connectivity, and through that, access to other services, a factor that is gradually reducing earlier problems with unconnected networks.[54]

LAN-Internet (director indirect) without video

To reach the Internet directly, a user must go through an Internet node. Nodes are allocated by regional network providers who provide networking hardware as well as the electrical connection.

[52] Market Data Retrieval, op. cit., footnote 13.

[53] Much of this section is taken from TERC, "Review of Research on Teachers and Telecommunications" contractor report prepared for the Ofice of Technology Assessment May 1994.

[54] However, it is important to note that "Internet connectivity'' comes indifferent levels, starting with e-mail only and progressing through access to file transfer, Wide Area Information Servers (WAIS), and other services. Dial-up services have to support each major server function like these separately, and are quickly augmentig their services. However, "full" Internet connectivity of the kind that would support video may not be practical through dial-up providers for some time.

Some schools have established their own Internet node and server at a school and connect that to the school's LAN. The server can be a point of presence on the network where resources of value within the school can be published. As of December 1994, there were 189 Internet sites in K-12 schools.[55] For example, the Ralph Bunche School in Harlem has its own Internet server. A single low-speed data-only line (e.g., 56 Kilobits per second (kbps)) is sufficient to support multiple users, providing they do not require video or heavy use of high-bandwidth services, such as the World Wide Web (WWW).

Other schools avoid the costs of an Internet node by using an indirect connection; that is, connecting their LAN to another one nearby that has Internet connectivity. This nearby connection could be a district headquarters, a college, the high school, or a friendly business. Again, a 56-kbps dedicated line can support a few dozen teachers who use relatively simple applications.

LAN-Internet with video

Sending video images over networks requires substantial bandwidth and entails higher costs than other options. Networking capacity that handles digital video will also increase the performance of all other kinds of networking. In addition, there are new kinds of network-based multimedia presentation software, such as WWW browsers like Mosaic,[56] that can be used only over networks with video capacity, even if they do not use video. An Internet connection through a "T-1"1.5 Mbps (megabits per second) line connected to a school LAN could support the entire school.

Although many network services are currently offered via single modem dial-up, dedicated access to the Internet is becoming increasingly attractive because, although it entails higher costs up front, it may be more cost-effective and certainly less limiting in the long run. Furthermore, these connections can support multiple users simultaneously, offer access to many of the most innovative and high-powered telecomputing innovations, and serve as a common mode of access to a broad range of electronic communities.[57]

Despite the advantages and growth of alternative connectivity scenarios, few schools currently have any connectivity options. In those that do, most are still using a single phone line connected to a dial-up modem and computer. **A lack of telephone lines in schools and especially in classrooms is cited as the greatest barrier to teachers' participation in electronic communities**.[58] As discussed above, many of the telephones that do exist in schools often serve administrative purposes and are not available to teachers for classroom use or for making outside calls to networks. For example, a recent study of TENET reports that "84,683 phone jacks were in Texas' 1,058 school districts. However, only 2 percent of the classrooms had access to a phone line."[59]

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[55] Gleason Sackman, Coordinator, SENDIT, North Dakota State University, personal communication, December 1994.

[56] *Mosaic* refers to a class of software tools that originated with the National Center for Supercomputer Applications' Mosaic. Several software tools are now available with similar functions.

[57] For example, see Yvonne Marie Andres, "Hello Internet: Tools for the Classroom, Comparison of Internet Connectivity Options," Global School Net Foundation, Bonita, CA, May 1994.

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

[59] WEB Associates, "TENET After One Year," paper presented at the annual meeting of the Telecommunication in Education Association, February 1993.

BOX 3-3: Telecommunications Terms and Concepts

The creation of networks for microcomputers ushered in a new era in the development of computers. Computer networks use electronic pathways (wired or radio-based) to connect one computer with other computers, enabling a person at one terminal to communicate with other people, to transfer information electronically, and to use computers in a distant location.

Local area networks (LANs) consist of computers connected together in the same physical area, usually within one building. LANs can be connected to other LANs, expanding the people and computers with whom users can communicate. Networks of computers able to communicate over larger distances are called wide area networks, or WANs. LANs are often a building block for a WAN. WANs may span cities, states, or even continents; most are closed systems set up for a specific group of users (e.g., private corporate networks or state networks). The Internet is neither a LAN nor a WAN but an "Internetwork"---a network of networks that share a common set of protocols. It provides access to databases and networks around the world. LANs are typically used to share resources, such as printers, and to deliver instructions; schools typically use WANs or the Internet to access external resources. '

The most common network connection for K-12 educators to state networks or the Internet is typically made by using a modem and a telephone line. The modem modifies the digital information used by the initiating computer so that it can pass across telephone lines. Another modem at the other end restores the information to a digital form that can be used by the receiving computer.

Information Services

A variety of information services with varying levels of sophistication are available to help people communicate and transmit information across computer networks. To use an information service, a computer must have client software to communicate with the server software at the other computer.

The most common services of computer networks are electronic mail (e-mail), transfer of computer files, and remote log-in. E-mail allows the user to send messages to another person, a group of people (a list), or an electronic forum (also called an electronic bulletin board) where many people can read them. Computer networks also let users copy and transfer electronic files from a computer where they are stored, called the server, to the user's machine. These files may be written documents, maps, graphics, images or video, or software files. Remote log-in enables a user at one location to use a computer at a distant location for such activities as searching through library catalogues or making airplane reservations. These three services are the building blocks of more sophisticated applications of networks. Some types of connections may support only one or two of these three basic uses; for example, a connection may permit sending e-mail to a distant colleague but may not support transferring files from that colleague's computer.

One popular service is a chat room. In a chat room, messages entered by any user immediately show up on the screen of all users, and a written record of the conversation is maintained. Chat rooms are a form of synchronous communication (participants must be available at the same time); e-mail, by contrast, is an example of asynchronous communication (users can communicate on their own schedules).

A small but growing number of teachers are gaining access to other kinds of information services available through the Internet, such as Gopher, World Wide Web, and Wide Area Information Servers (WAIS). These services enable people with Internet connections to view and transfer files or to access extensive databases (e.g., articles, graphics, software, current weather and weather forecasts, or stock market prices). The basic prerequisites for access include the appropriate client software and a modem or other

[1] See Denis Newman et al , "Local Infrastructures for School Networking Current Models and Prospects," Technical Report No, 22 (New York, NY Bank Street College of Education, Center for Technology in Education, May 1992)

BOX 3-3 (cont'd.): Telecommunications Terms and Concepts

connection to a WAN; in addition, the WAN must support the desired service. "Internet connectivity" can take place at many different levels. Some WANs have restricted connections to the Internet that allow only certain kinds of services, such as exchanging e-mail or using Gopher but not using World Wide Web or WAIS.

A IAN or WAN that is fully connected to the Internet will support any of the varied and growing services that follow Internet protocols—procedures defining how to make new services work over the Internet—and will allow users to link with any other computer that is also fully connected.

Organization and Support Structure

As yet, there is no one organization responsible for administering or supporting the Internet, so getting support in the use of Internet services has been a problem for teachers. Organizations that currently provide teachers with connections have only limited support for beginners and have given little thought to helping beginners acquire the necessary client programs. Some help is available, however, in the form of books, electronic documents, and commercial products that combine books and ready-to-use software.[2]

Some support structures do exist. For each electronic community of teachers, whether organized around a curriculum project or a topic of mutual interest, there is typically a group that provides the organization and a support structure to help define that community. Typically, the group provides such elements as a name, a registration procedure, a framework of expectations, a timeline, print or electronic materials, and support services. Examples of organizing structures include: curriculum projects, such as AT&T Learning Circles, NGS Kids Network, and TERC's Global Laboratory; discussion groups, such as the Consortium for School Networking (CoSN); and programs, such as NASA's Spacelink.

Educators can access information services through either commercial service providers, such as America Online, CompuServe, Prodigy, Delphi, and Apple's eWorld; or through nonprofit service providers, such as state-supported networks. Both commercial and nonprofit providers are actively soliciting participation of teachers, schools, and districts. While these organizations do not presently provide full connectivity to Internet resources, they do offer extensive support to users. Some of the state networks have text-based menu systems. Commercial providers use graphical software to support inexperienced users and provide extensive user support through e-mail, answers to frequently asked questions (FAQs), and an "800" number. They also have designed ways to minimize connect time (the time when the phone line is actually in use), thereby keeping down the cost of their services.

[2] For example, Ventana Media has published the "Internet Membership Kit, " which includes a set of Internet client programs, required protocols, and documents for both Mac and Windows platforms Purchase entitles the user to free Internet account setup, one month's free service, and SIX hours of free online time through an Internet service provider.

SOURCE: TERC, "Review of Research on Teachers and Telecommunications," Office of Technology Assessment contractor report, May 1994

Faster modems and LANs that enable multiple users to connect to outside networks at the same time are not yet commonly available in schools. A 1990 survey of 485 California schools reported that only 11 percent had access to wide area network services as well as a local area network; none of these schools used their LAN to distribute data from the WAN.[60] Although these data are surely

[60] Denis Newman et al., "Local Infrastructures for School Networking: Current Models and Prospects," Technical Report No. 22 (New York, NY: Bank Street College of Education, Center for Technology in Education, May 1992).

out of date by now, they suggest a problem that remains significant nationally:

> Teachers' and students' access to the educational services now appearing on the Internet is problematic, because few schools have information infrastructures capable of routing data to individual classrooms. Unlike higher education, K-12 institutions typically have neither host computers powerful enough to allow direct access to the Internet nor a web of telephones and modems that could enable individual Internet usage through dialing up a provider. Further, many schools do not have networks that transmit data around the entire building, and the networks in individual classrooms often have such low bandwidth that sending educational material from computer to computer is very slow. Interconnecting different types of networks within a school or district is also a complex technical challenge.[61]

State-Level Networks

An increasing number of states are organizing and funding state networks for teachers and students and sometimes for other public agencies and businesses. In a 1993 survey, 33 states reported supporting one or more telecomputing networks, for K-12 instruction.[62] Six more states had a partially operational network, and nine more had one in the proposed or planning stages (see figure 3-6).

Some of these networks use a design whereby teachers dial into local computers, which in turn process and store messages. These local computers are placed to maximize the number of teachers who can reach them through local rather than long-distance telephone calls. Most state networks aim to provide services at little or no charge to teachers. For teachers who are not local—a significant proportion—"800" numbers are often provided at substantial expense to the state.

State networks vary considerably in their scope, purpose, sophistication, and support services. Among the most ambitious are Virginia's PEN (see chapter 5), which aims "to guarantee access to the Internet to every public school educator at no charge,"[63] and TENET (see box 3-4).

Many states have established networks with gateways to other networks. For example, Florida's Information Resources Network (FIRN) provides free electronic (e-mail) to all educators and a menu that offers access to many Internet-based services. FIRN also supports distance-learning services, an automated card catalog, a technical assistance system, staff development teleconferences, and satellite-delivered training for teachers.[64]

Other states have established less ambitious networks, offering such services as e-mail lists, news groups, and computer conferencing. Indiana, for example, supports both a statewide fiber-optic network for education called Intelnet, and a bulletin board called IDEAnet for educator communications, conferencing, and database access. Montana administers the Montana Educational Telecommunications Network (METNET), connecting individual schools with Distance Learning Centers, Regional Training Centers, and Compressed Video Sites. Oklahoma encourages schools to link up to SpecialNet, a network designed to facilitate special education. New Jersey Link (NJLink) served over 4,000 teachers in 1993,

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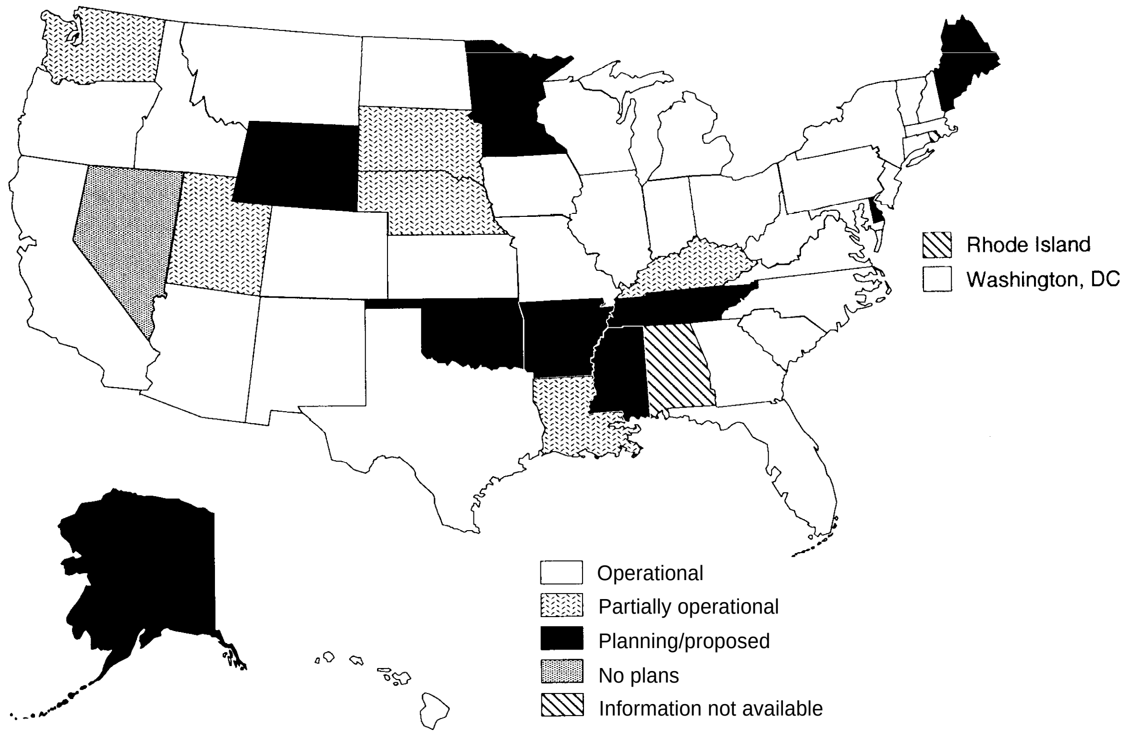
[61] Chris Dede, "The Technologies Driving the National Information Infrastructure: Policy Implications for Distance Education," paper commissioned by the Southwest Regional Laboratory in connection with the U.S. Department of Education's Evaluation of Star Schools, October 1994, p. 11.

[62] Educorp Consultants Corporation, *Networks Now: The 1993 Survey of How States Use Telecommunication Networks in Education* (Roanoke, VA: Educorp, 1993).

[63] Glen L. Bull et al., "Considerations Underlying the Architecture of a State Public School Telecomputing Network," *Consortium for Educational Telecomputing: Conference Proceedings*, Robert F. Tinker and Peggy M. Kapisovsky (eds.) (Cambridge, MA: TERC, Apr. 18-19, 1991), pp. 121-134.

[64] Anderson, op. cit., footnote 19.

FIGURE 3-6: Status of State Support for K-12 Instructional Telecomputing Networks, 1993



SOURCE: Educorp Consultants Corp., *Networks Now. The 7993 Survey of How States Use Telecommunication Networks in Education* (Roanoke, VA: 1993).

offering free information resources, communication with other educators, and other network services.

Other Networks

Other networks in which educators participate have been organized by school districts, communities, and the private sector. School districts use networks to foster districtwide educational goals and to link with local and out-of-town electronic network resources. While district networks often include only such services as exchanging e-mail within the district, posting messages on bulletin boards, and reaching the Internet with e-mail, some are more ambitious. The Boulder Valley Internet Project, for example, is a collaboration of the local university and the school district that aims to link as many schools as possible with high-speed connections and to encourage teachers to use these resources. Similar efforts are under way in other districts.[65]

Community-based electronic networks link many of the functions of community life with one another. In these electronic communities, anyone in the geographic area served can participate. As of January 3, 1995, there were 130 of these local

[65] Rrports about other district projects can be found in Kenneth M. King and John Clement, EDUCOM, "Toward a National Network Infrastructure for K-12 Education: Final Report on a Fact-Finding Mission," unpublished manuscript, 1990.

BOX 3-4: The Texas Education Network (TENET)

With 40,000 participants and a 1993 average of 100,00 log-ons per month, the Texas Education Network (TENET) is among the largest and most successful state efforts to open the world of telecommunications technology to teachers. Established in 1989, TENET aims to provide connectivity to all educators and students in the state via a local or 800-number telephone call. The University of Texas in Austin operates TENET via the THEnet (Texas Higher Education Network) backbone and houses its central resources and operations staff.

Teachers in grades K-12 pay $5 per year for an account; university faculty and teacher education students pay $25. Participants receive such services as e-mail, news groups, conferencing, file transfer, curriculum guides, Internet gateway, and access to national, state, and local user groups.

Several aspects of TENET support preservice education and professional development for teachers. Through special interest groups, teachers can share information and discuss educational issues. TENET also has online training and maintains information files on a range of topics pertinent to teachers.

Among the most notable features of TENET is its major teacher training component. The network maintains 80 master trainers from all regions of the state. Master trainers provide support to school technology coordinators, Regional Education Service Center (RESC) support staff, and others. They also communicate regularly on a TENET special interest group and provide workshops and other training sessions for teachers. Among the training issues addressed are how to join electronic teacher groups for professional development, how to locate and download instructional materials, and how to use telecommunications to involve students in global projects or collaborative writing.

The state has steadily increased its financial commitment to TENET since its creation, and in FY 1994 invested about $2.5 million in the network's operation. In FY 1995, the state will spend $4.5 million on the network. As TENET becomes more popular, Texas is grappling with how to meet demands for additional phone lines and storage space at reasonable cost.

SOURCES: J.R. Mergendoller et al., "Case Studies Exemplary Approaches to Training Teachers To Use Technology, " Office of Technology Assessment contractor report, September 1994; Educorp Consultants Corp., *Networks Now: The 1993 Networks in Education* (Roanoke, VA: Educorp, 1993); Connie Stout, Director, TENET, personal communication, November 1994; Geoffrey Fletcher, Interim Executive Deputy Commissioner for Curriculum, Assessment, and Professional Development, Texas State Department of Education, personal communication, January 1995.

FreeNets in 42 states, according to an online survey.[66] These networks offer bulletin boards for students sharing work, expedite inquiries to local public agencies, facilitate information sharing and research, provide local databases, and so forth. With over 35,000 registered users and over 10,000 log-ins per day, the Cleveland FreeNet, operating out of Case Western Reserve University, is probably the largest community network in the world and a model for community-based networks.[67] The network provides users with everything from e-mail services, to information about health care, education, technology, recreation, law, auto mechanics, or just about anything else the host operators would like to place on the machine. Anyone in the community with access to a home, office, or school computer can connect to the sys-

[66] Elizabeth Reid, National Public Telecomputing Network (NPTN) survey, Jan. 3, 1995.

[67] Doug Schuler, "Community Networks: Building a New Participatory Medium," *Communications of the ACM*, vol. 37, No. 1, January 1994, pp. 40-48; and Sister Dolores Stanko, National Public Telecomputing Network and Community Computing, distributed over e-mail by the Cleveland FreeNet, on Dec. 12, 1992.

tem, 24 hours a day, and use these services. All of it is free and all of it can easily be accomplished by a first-time user.

Not surprisingly, community-based networks face the challenge of developing viable models of low-cost network services that are accessible to all community members. Some keep costs low by offering users access to larger networks for the cost of a local telephone call.

Use of Telecommunication Networks

Reasonably current national survey data provide some information concerning the school use of telecommunications hardware and software for information gathering, electronic mail, and collaborative instructional work. In the 1992 IEA survey, data collected at the school level indicated that in 10 to 15 percent of schools at least one teacher used electronic mail/information networks (e.g., Compuserve); usage was higher at the high school level than in elementary schools. Approximately the same percentage of high schools reported using online databases such as Dialog. IEA also asked separately about two instructional programs involving telecomputing—AT&T Learning Circles and the National Geographic's Kids Network. According to the survey, AT&T Learning Circles had been tried in about 4 percent of schools nationwide at all levels, and the K-8-oriented Kids Network garnered participation in 6 percent of elementary schools and 3 percent of middle schools. Altogether about 20 percent of schools reported using one or more telecommunications service. However, no information was available about the number of teachers using the service at any given site.

A year later, the 1993 NEA Communications Survey inquired of its sample how many teachers had ever participated in a "learning network at school, such as the AT&T Learning Network or the National Geographic Society's Kids' Network" (6 percent had); whether the respondents were currently engaged with their students "in an on-line collaborative teaching or distance learning [activity]" (4 percent were), and whether they "had access to" public electronic mail and information utilities such as Prodigy (19 percent), Compuserve (14 percent), America Online (7 percent), and Dialog (9 percent). In addition, 4 percent said they had access to the Internet through their school. Altogether, nearly 25 percent of the NEA sample of responding teachers reported having access to at least one of these telecommunications services. While the NEA sample is not representative of the U.S. teaching population,[68] if the same percentage were applied to all U.S. schools, it would mean that as many as 600,000 teachers nationwide were involved in telecomputing.

The extent of telecomputing activity among teachers is not well understood—especially now as potential opportunities for participation are mushrooming. Furthermore, although the number of telecomputing teachers is growing rapidly, these data indicate that the great majority of U.S. teachers still do not have access to telecommunications services.

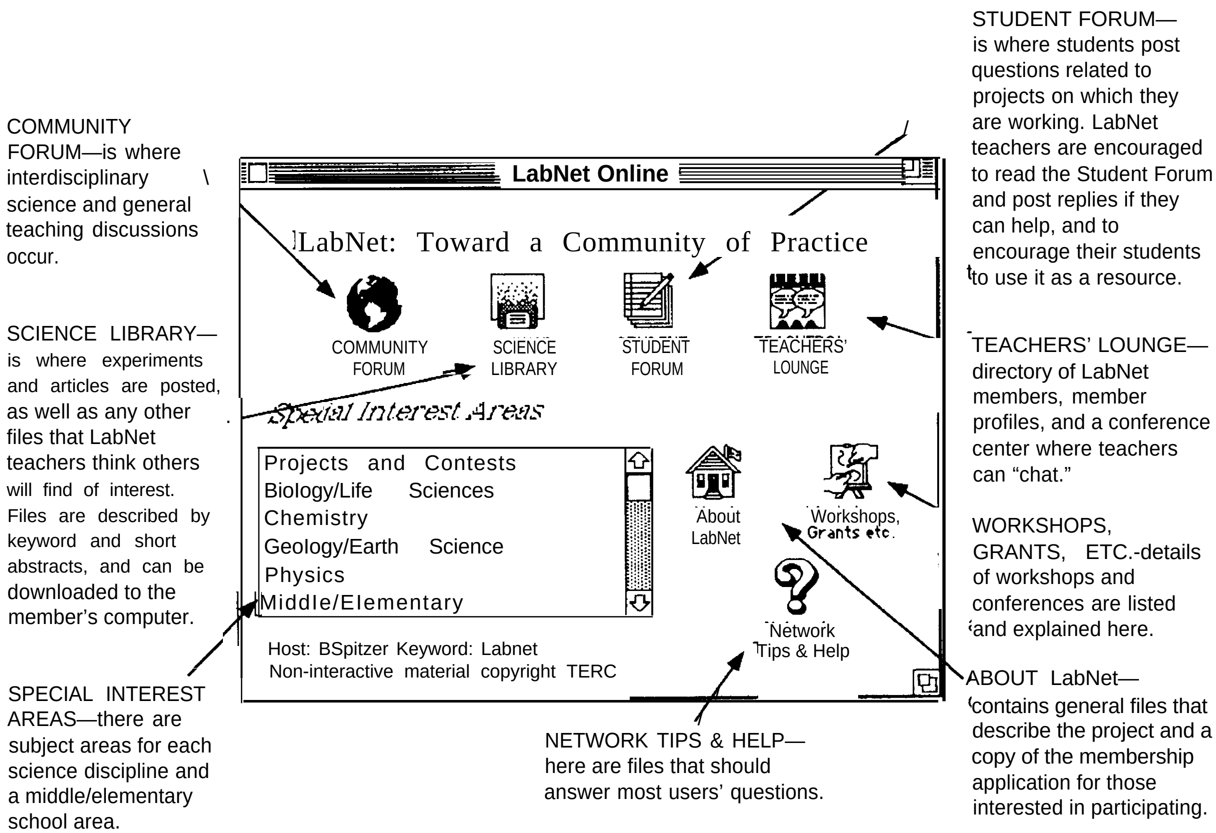
Telecommunications Software[69]

In addition to access to hardware, teachers' participation in electronic communities is often determined by the ease of use and functionality of available telecommunications software. According to TERC, to meet the needs of teachers, telecommunications software should have the following features: a user-friendly ("point-and-click") interface (see figure 3-7); network connectivity among multiple computer systems (MS-DOS, Macintosh, etc.); multiple options for connectivity, including the Internet; the capacity to send formatted nontext enclosures, such as graphics, spreadsheets, and data video images; the ability to enable the *same* message or formatted data to be sent to multiple parties who use diverse

[68] The NEA survey excludes teachers from most large city districts and others that are not NEA members (see appendix B).

[69] Much of this section is taken from TERC, op. cit., footnote 53.

FIGURE 3-7: America Online's LabNet Main Screen



SOURCE: TERC, "Review of Research on Teachers and Telecommumcations," contractor report prepared for the Off Ice of Technology Assessment, 1994

software and hardware configurations; the ability to download and manipulate files at user computers without re-formatting; and be capable of being easily updated.

There are a growing number of Internet-based telecommunications software tools for information searching and retrieval. NCSA Mosaic and other similar tools are among the most powerful because they provide a user-friendly means of connecting with World Wide Web and Gopher resources on the Internet. The Web includes online documents that consist of text, images, sounds, video, and animation on a range of topics, such as Gaelic texts, art exhibits, movie clips, and electronic magazines. Documents can include footnote like links to other files, so that by pointing and clicking, the user can move from one document to retrieve relevant information from other documents located elsewhere on the Internet. In addition, the telecommunications functions in the Mosaic interface are automated so as to be nearly invisible to the user. However, Mosaic is useable only through a direct, relatively high-speed connection, and this type of connection is still rare in school settings.

Telecommunications, with the access it can provide to resources beyond the classroom walls, has considerable educational potential. Yet the evidence reviewed here indicates that most schools are not equipped to participate in these opportunities.

STATE POLICIES ON ACCESS AND USE

State policies can be an important influence on teacher use of technology. A telephone survey and review of state literature done under contract to OTA indicates that states have taken diverse approaches to addressing the challenge of educational technology.[70] This section summarizes some of these data. (See, also, chapter 4 for discussion of state technology policies related to inservice teacher training and chapter 5 for state policies on teacher certification and technology.)

State Staffing for Technology

One way that states can influence local technology use is through state staffing and support for educational technology. Staffing policies vary considerably across states. In one state, the educational technology coordinator is an associate commissioner; in others, a part-time consultant. Some coordinators are located within a media division, others in an instructional technology unit, and some in a telecommunications office. Some state educational technology units have budgets in the many hundreds of million dollars; other states fund little more than a single staff person.

Technology Integration

All but seven states reported that they require or recommend integrating computers or information technology into the curriculum (see table 3-2). About 25 percent of the states actually mandate the integration of computer technology across the curriculum. For instance, the Iowa Legislature in 1993 established an Educational Technology Consortium charged with developing technology plans for the state that ensure "equity of access" and assist schools with the integration of hardware and software into their curricula. However, the way technology is to be integrated is less clear. **In fact, some states continue to equate technology policy with mandating courses about computers rather than assisting teachers to learn to teach with a range of technologies.**

Computer Courses for Students

Twelve states require that public schools offer computer-related courses such as keyboarding or computer literacy, while an additional 20 states recommend to districts that such courses be offered. For example, since 1984 Arkansas has required high school students to take a one unit course in "computer science;" a new plan to be implemented in 1996 requires Arkansas schools to offer more advanced, elective computer science courses as well. Washington State law requires that each school district provide an opportunity for high school students to take at least one course in "computer education," or allow students to take it in another district.

Student Computer Competency

Today 19 states mandate computer competency requirements for graduating seniors. Additionally, as states define and set new achievement standards consistent with the Goals 2000: Educate America Act (see chapter 6), many are attempting to address skills students will need to work with technologies. Maine law stipulates that schools make instruction in the use and application of computer skills available to secondary students and requires each student "to demonstrate proficiency in the use of computers that include loading, operating, and applying fundamental skills. This may include word processing, keyboarding, developing a data base, accessing data, and using software."[71] Maine recommends that technology be built into the curricula in grades 7 or 8, but leaves it up to the districts to establish their own plans and procedures. Utah requires that every high school student be computer literate before graduating, which students may demonstrate by

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[70] Anderson, op. cit., footnote 19.

[71] Dennis Kunces, *Planning Guide for High School Diploma Computer Proficiency Requirement* (Augusta, ME: Maine Department of Educational and Cultural Services, 1989).

TABLE 3-2: State Education Technology Policies, September 1994[a]

State name	Promotes technology integration in curriculum (1)	Requires computer course for students (2)	Mandates computer competency for students (3)	Requires computer training for teacher certification (4)	Requires inservice technology training (5)	Students per computer (6)
Alabama	✓		✓		✓	17.7
Alaska	✓					8.6
Arizona	✓			✓		12.3
Arkansas	✓	✓		✓		14.0
California	✓			✓		19.5
Colorado				✓		11.2
Connecticut	✓					13,8
District of Columbia	✓		✓	✓	✓	12,9
Delaware	✓					18.5
Florida	✓					11.3
Georgia	✓					12.8
Hawaii	✓		✓			18.8
Idaho	✓					14.5
Illinois						15.9
Indiana	✓					11.1
Iowa	✓					10.2
Kansas	✓			✓		9.9
Kentucky	✓					12.0
Louisiana	✓		✓			19.5
Maine	✓		✓	✓		14,4
Maryland	✓		✓			13.8
Massachusetts	✓			✓		16.3
Michigan	✓			✓		13.4
Minnesota	✓					11.1
Mississippi	✓	✓	✓			17,9
Missouri	✓					13.4
Montana	✓					10.6
Nebraska	✓		✓			10.4
Nevada		✓	✓			13.6
New Hampshire	✓	✓		✓		22,0
New Jersey	✓		✓	✓		15.4
New Mexico	✓		✓	✓		12.4
New York	✓					12.3
North Carolina	✓		✓			13.1
North Dakota						10.4
Ohio	✓			✓		16.0
Oklahoma	✓	✓	✓	✓		13,5
Oregon	✓		✓			13,0
Pennsylvania	✓		✓			14.7
Rhode Island	✓	✓	✓			16.2

TABLE 3-2 (cont'd.): State Education Technology Policies, September 1994[a]

State name	Promotes technology integration in curriculum (1)	Requires computer course for students (2)	Mandates computer competency for students (3)	Requires computer training for teacher certification (4)	Requires inservice technology training (5)	Students per computer (6)
South Carolina	✓					13,7
South Dakota	✓	✓	✓			10,4
Tennessee	✓	✓		✓		18.4
Texas	✓	✓	✓			12.1
Utah	✓	✓	✓			13.3
Vermont	✓					19.9
Virginia	✓		✓			13.0
Washington	✓	✓		✓		10,9
West Virginia	✓	✓		✓		11.2
Wisconsin	✓			✓		11.4
Wyoming				✓		8.1

[a] An ' ✓ ' in the column means a state has that policy A blank cell means that the policy does not exist.

The definitions of the column check lists areas follows:

(1) State requires (or recommends) that public schools integrate computers or information technology in the curriculum

(2) State requires that public schools offer computer-related courses such as keyboarding or computer literacy

(3) State has a mandate for computer competency or performance standards for students related to information technology

(4) Teacher certification in the state includes a requirement for training in computers or technology (see chapter 5)

(5) State has a requirement for inservice computer or technology training (see chapter 4).

(6) Microdensity is defined as students per computer. (Data from QED, 1994 report on Technology in Public Schools, QED, Denver, Colorado.)

SOURCE: R.E. Anderson, "State Technology Activities Related to Teachers," OTA contractor report, Nov. 15, 1994

taking a computer literacy course or passing a test of technology-related skills and knowledge.[72]

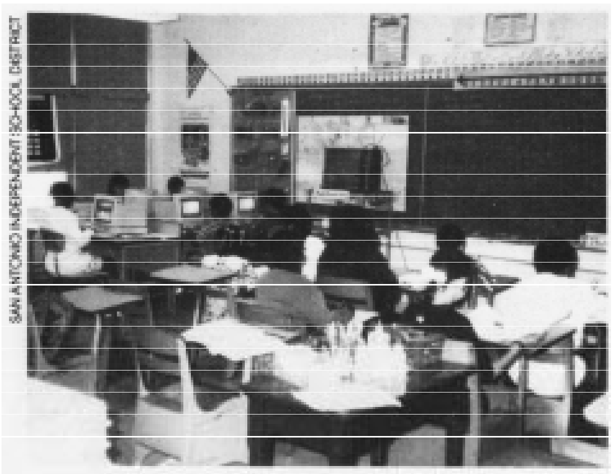
Many states, like Vermont, do not mandate technology competency, but recommend that districts make computer competency a graduation requirement. North Carolina recently has designed an innovative, detailed competency-based curriculum in technology including considerable emphasis upon "information skills." Beginning in 1995, students will have to pass a performance-based competency test.

The state survey suggests that the amount of educational technology hardware in a state is not correlated with the state's tendency to establish requirements in either student technology competency or in teacher technology training. Therefore, OTA finds that the relative amount of computer technology available in a state should be used with great caution as an indicator of that state's commitment to technology in instruction (see table 3-2).

CONCLUSION: ISSUES WITH POLICY AND RESEARCH IMPLICATIONS

The data examined in this chapter suggest several themes, issues, and questions that have implications for future policy decisions and research

[72] Utah State Board of Education, "Elementary and Secondary Core Curriculum Standards," Instructional Technology, Utah State Board of Education, Salt Lake City, UT, n.d.



Classrooms such as this one, with five computer workstations as wall as a television monitor, offer teachers flexibility in teaching with technology Many states are seeking funding to provide this level of technology access in all classrooms.

agendas. This section discusses the importance of developing anew definition of access to technology, the importance of two-way communication, additional research needed for policymaking, and strategies for better understanding effective instructional practices.

■ A New Definition of Access

One overarching theme emerging from the data presented throughout this chapter is the need to begin thinking differently and more critically about what constitutes "access" to technology by teachers and students. Conventional data on infrastructure-numbers of computers in a school, student-computer ratios, and school ownership of various kinds of video and telecommunications equipment—are insufficient measures of meaningful access to technologies. **What is called for is a new way of defining access that examines the kinds of infrastructure, organizational arrangements, and other supports teachers need to use technology effectively in the classroom.**

Under such a definition, a first step might be to look at the availability of hardware and software, but in a more discerning way than just counting computers. Key factors include the age and power of hardware and the kinds of peripherals and software the equipment can support. Also crucial are the presence of connectivity hardware, software, and services. As the earlier discussion suggests, it is now possible to use the same technology in several different ways, depending on what the purpose of the user is, which kinds of software and peripherals are available, and how multiple technologies are combined or connected. It is also important not to overlook older technologies, such as the telephone (see box 3-5).

A second step might be to examine whether existing technologies are arranged and organized in a way that is conducive to frequent and effective use by teachers and students. Are different kinds of technologies located in a central place or in individual classrooms? Can existing equipment be made more mobile? Is there a LAN, and could it be used for more purposes than at present? Are certain kinds of technologies "reserved" for certain kinds of teachers and students, such as advanced-level science students or business education students? Is the hardware situated so that it can be used effectively for different kinds of instruction, such as group projects, buddy learning, or individual study or research?

A third step might be to examine the kinds of support that teachers need to use the infrastructure effectively: to integrate technology into their everyday teaching, to use technologies for two-way communication, and to use technologies to encourage the best instructional practices. These supports, discussed in more detail in subsequent chapters, might include exposure to innovative uses, high-quality professional development, and ongoing technical support and expert advice.

■ The Importance of Two-Way Communication

The potential of new technologies to facilitate two-way communication has changed dramatically in recent years and holds great promise for changing teaching, learning, and professional development. Telecommunications and networking technologies, in particular, create incomparable opportunities for teachers and students. And new hardware, such as videodisc or CD-ROM players, makes it possible to combine the excitement of

BOX 3-5: Planning for School Technology Use: Two State Examples and Cost Estimates

Technologies are used by schools for many reasons and to accomplish different goals. Technologies for teaching and learning vary in key characteristics: how richly they convey information, how suitable they are for whole classroom versus individual student use, how many pieces of equipment are required for simultaneous use by an entire class, how portable they are, how interactive and adaptable they are to individual student or teacher needs, and how flexibly they can be used by teachers in a school setting. These characteristics affect which technologies schools acquire and how they use them.

To some extent, therefore, the amount and type of hardware and software a given site "needs" depends on the educational goals it expects to meet using technology. As a part of this planning process, some states and districts are trying to designate some basic levels of technology to which each building and classroom should have access and to estimate the costs of such an infrastructure.

For example, Kentucky's Master Plan for Education Technology calls for a communication system for voice, video, and data that will interconnect all computer workstations in the classroom, school, district, office, public library, and Kentucky Department of Education with other statewide and national education networks. ' Goals for instructional technology include a telephone in every classroom, a portable teacher workstation for each of the 36,000 teachers in the state, and a computer workstation for every six students. About 100,000 additional workstations will be needed to meet the student workstation goal. Taking into account existing infrastructure that meets the standards of the Master Plan, the state estimates that $560 million will be needed to implement the plan over a period of six years.[2]

Implementation of the Kentucky plan began in 1992. The one-time costs of hardware and software will be shared equally between the state and local districts. The ongoing maintenance and operations costs at the state and district levels will be funded by the state, while local school districts will bear the maintenance costs of the system's school, classroom, and family/school connection levels.

A recent initial planning document from the New York State Department of Education outlines the potential costs of implementing a vision of an even more advanced technological infrastructure for K-1 2 schools in that state. This plan outlines the costs of putting a basic amount of new technology in every public school building throughout the state and networking them.[3] A three-stage deployment is envisioned. The first stage would put five workstations with multimedia and network links in the library-media center of each of the state's 4,016 public schools. The second stage would put one workstation in each of an estimated 187,000 classrooms and network them to a wide area network and the Internet via a broadband T-1 connection (1.5 mega bytes).4 The third, full-blown model adds four more workstations in each classroom. The table displays the technologies and costs for this three-stage deployment, as well as the estimated

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[1] Kentucky Department of Education, "Master Plan for Education Technology, " Council for Education Technology, Apr. 30, 1992

[2] Revisions to Master Plan for Education Technology, adopted by Kentucky State Board for Elementary and Secondary Education, November 1993.

[3] Existing hardware, software, and networking in schools were Ignored in this cost model. In addition, this model reflects an estimate of the total life-cycle costs, exclusive of consumable materials (e. g., printer toner and paper) and furniture for a five-year period. The Iife-cycle cost analysis takes into account not only hardware and software, but also maintenance, technical support, training, networking, and other "hidden" costs. This model particularly emphasizes the staff development and technical support components of successful technology implementations. Basic list prices are considered in the cost model, since the model's author considered it Impossible to estimate any discounts that would be applied on such a large-scale purchase. M. Radlick, "A Cost Model: Implementing Technology in New York State Public Schools—A Paper for Discussion," New York State Education Department, Albany, NY, November 1994

[4] Building wiring would be fiberoptic cable to all classrooms, and copper from thereto the desktops. Every workstation should be networked to the Internal LAN resources and out to the wide area network, including the Internet Networking and network resource must be able to support high-bandwidth applicatlons, including multimedia and interactive video from other sites. Included in the multimedia capability IS videoconferencing at the workstation level Radlick, ibid.

(continued)

BOX 3-5 (cont'd.): Planning for School Technology Use: Two State Examples and Cost Estimates

Proposed Five-Year Cost Model for Implementing Technology in New York State Public Schools

Stage of model	Technologies	Network infrastructure (per building)	First-year cost	Additional cost for the 4 remaining years in hardware lifecycle[c]	Total cost
Stage 1 Put in the library-media center of each public school building (total = 4,016)	▪5 workstations with software,[a] IAN, and Internet connections ▪1 laser printer ▪1 CD-ROM tower ▪1 color LCD projector unit	▪56 kb link to Internet ▪1 router ▪1 server ▪initial cost of network connection to library/media center[b]	$371,593,000 includes about $73 million for training and support personnel	$436,991,200 includes about $233 million for training and support personnel	**$ 808,584,200**
Stage 2 Put into each classroom (total = 187,000)	▪1 workstation with software, LAN, and Internet connections ▪1 laser printer ▪1 color LCD panel	▪T-1 network link ▪initial costs of network connections to classrooms	$3,627,350,000 includes about $769 million for training and support personnel	$2,616,200,000 includes about $1.7 billion for training and support personnel	$6,243,550,000
Stage 3 Add into each classroom:	▪4 workstations with software, IAN, and Internet connections		**$2,992,000,000**	$1,047,200,000 no additional training and support	$4,039,200,000
Total costs			**$6,990,943,000**	$4,100,391,200	$11,091,334,200

[a]Total cost of each workstation estimated at $3,500. Workstation includes a 486 (DX2) or Pentium or Macintosh Power PC 7100 with CD-ROM and color monitor Basic operating system (Windows or System 7) assumed to be bundled. Cost = $3,000, Additional application software cost = $500

[b]The cost of network Connections is assumed to average $7,500 per Classroom, The initial network connection to the Ilbrary/media center is assumed to average $15,000

[c]Includes hardware and software maintenance (1 O percent), training, support, and cost of service across T-1 and 56-kb links

SOURCE: M Radlick, "A Cost Model Implementing Technology in New York State Public Schools—A Paper for Discussion, " New York State Education Department, Albany, NY, November 1994.

BOX 3-5 (cont'd.): Planning for School Technology Use: Two State Examples and Cost Estimates

costs for operating, maintaining, upgrading, training, and support over a five-year life cycle. The estimated total cost comes to just over $11 billion over five years.[5]

The New York state annual education budget for 1992-93 was slightly more than $21 billion. In 1992-93, New York schools spent an average of 2.2 percent of their total education budgets on technology, which includes hardware, software, network technical staff, instructional staff, and supplies and material. The total amount spent across the state that year was about $360 million.[6] Thus, fully implementing this cost model, even across a 10-year period, would require a substantial increase in the percentage of the education budget invested in technology.

[5]About 37 percent of the total is for Instructional hardware and software; 17 percent for building the network infrastructure; 21 percent for ongoing costs such as maintenance, upgrades, and line charges; 9 percent for training; and 16 percent for staff support personnel.

[6]Michael Radlick, "Technology Expenditures in New York State Schools, " unpublished draft, New York State Education Department, Dec. 7, 1994.

SOURCE: Office of Technology Assessment, 1995, based on Kentucky Department of Education, op. cit., footnotes 1 and 2, and Radlick, op. cit., footnotes 3 and 6.

video with the information transmission power of the computer and the communication capabilities of high-speed telephone.

Given these trends, connectivity is likely to become the major technology issue of the next several years. Although few up-to-date data are available, it appears that a very small percentage of teachers have access to the kinds of telecommunications and networking technologies needed, for example, to participate in a global science project, or contact distant colleagues for advice on attention-deficit disorder.

Policymakers might respond by developing new kinds of guiding principles for access to and use of telecommunications. This is already occurring in discussions at the federal, state, and local level about educator access to a "National Information Infrastructure." Other issues to be addressed include the issues of copyright, confidentiality, funding and subsidies, and limiting student access to some forms of information (see chapter 1).

Framing policies in these areas will not be an easy task, since the field of educational telecommunications is still so young and fluid. New uses for telecommunications are emerging all the time, and it is not yet clear what classroom applications are possible or most effective.

▮ Additional Research Needed for Policymaking

Help in framing policy could come from more extensive research. Available data are weak regarding the very newest technologies available to teachers—new forms of analog video and digital multimedia technologies like videodisc and CD-ROMS and new opportunities for telecommunications via computers. There are few data on how much or in what ways teachers are taking advantage of existing network access. In what ways are student-learning routines affected by the availability of telecommunications access to the outside world? How is a teacher's professional life affected by these resources? Future studies of educational technology should focus on the uses of those new media—not simply their presence, but how they affect the learning of students and the jobs of teachers.

Having access to technologies does not ensure that they will be used well. **As** noted in this chapter, more comprehensive use could be made of

the current technology inventory in schools. Evidence for restriction in current usage can be found in the persistence of drill-and-practice, games, keyboarding instruction, "computer classes," and certain kinds of video viewing. It is hard to draw clear conclusions about how existing resources could be used more comprehensively, however, because teacher use is an area where data on educational technologies are weakest. Surveys to date have collected only minimal data directly from teachers about their own access to and use of technology. Knowing that technology resources are in a school is insufficient to understand whether and how teachers are using them. Observations of and interviews with teachers could help to provide the kinds of contextual information that would illuminate many of the questions surrounding the gap between access and use.

New research might examine several issues regarding teacher use. How and why do teachers use technology in instruction across the various curricular areas? How do teachers integrate videotaped presentations, for example, in different subject matter? How are teachers using camcorders, telephones, or telecommunications links? Which resources are effective for which educational goals? To what extent do teachers use technology for other parts of their job, such as carrying out administrative tasks, participating in professional development, communicating with the world outside school, or involving parents in the schooling process?

Furthermore, the discrepancies between teacher and student reports about how many minutes students use computers, and between teachers and district-level educators about how many teachers are "computer-using" teachers, suggest the need for deeper analysis of what constitutes technology "use." How long or how intensive must an interaction with various technologies be to constitute a meaningful learning experience for students? How many learners can use various technologies at the same time in a beneficial way? Is tracking occurring in how students are permitted to use various technologies? What constitutes teacher "use"?

Effective Instructional Practices

Currently the most common uses of technologies in schools reflect educational philosophies of instruction that view students as recipients of information dispensed by the teacher (or by the technology) and the acquisition of specific skills and knowledge. **However, many technology experts feel that the real potential of technology lies in its capacity to support pedagogical approaches that encourage students to become active participants in their own learning and to acquire critical thinking skills and more complex understandings**.

The potential for more than an electronic blackboard is one of the most compelling reasons for pursuing educational technology (see chapter 2). Right now, however, a gulf exists between the ambitions of technology experts and software developers and the practice of teachers in classrooms. Helping teachers use technology to facilitate different educational philosophies and teaching practices will require substantial change in curriculum, instructional methods, and teacher understanding.

In addition, further study is needed about the quality and relative effectiveness of various instructional uses of technologies and their applications. How effective are instructional computer games in helping students acquire specific skills and knowledge? What is the effectiveness of various kinds of video viewing experiences? How effective is browsing of digital libraries as a research tool? What elements make for a quality multimedia program? What is the most effective use of distance-learning technologies? For example, distance learning can vary greatly in quality and instructional philosophy, from teacher lectures transmitted by satellite, to more interactive learning sessions where students can conduct experiments with the distant teacher looking on or exchange observations and data in real time.

Finally, OTA finds that access to any technology in a school is just a starting point. The next chapter will explore the barriers teachers face as they try to use technology, as well as some implementation models and lessons from places actively attempting to overcome these barriers. As the next chapter suggests, to use technologies effectively, teachers and administrators must have a vision of how they can best be deployed; they need the appropriate hardware, software, and training to pursue these goals and applications, and continuing support to overcome the obstacles presented in adopting technology for instruction or teacher support.