Federal Support for Technology in K-12 Education

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Brookings Papers on Education Policy, 2000, pp. 307-343 (Article)

Published by Brookings Institution Press
DOI: https://doi.org/10.1353/pep.2000.0001

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THE FIRST IBM PERSONAL COMPUTER (PC) was released in August 1981; a year later, *Time* magazine named the personal computer its "Man of the Year." A year after that, in 1983, the U.S. government and its research partners implemented the technical decisions that created the Internet. The world has not been the same since.

By 1999, about 250 million people around the globe had personal computers, and about 100 million used the Internet. The computer industry sells tens of millions of PCs every year, and the number of Internet users has doubled every year since 1988. This rate of growth is expected to continue for some years to come, so early in the twenty-first century more than a billion people are expected to be on-line.

This is one of the most remarkable, rapid, and significant technological transitions in history. Not only has a new and uniquely capable technology been distributed around the world, but also work and the economy have been reorganized around this technology, at least in modern societies. This transition is a hinge in human history equivalent in significance to the Industrial Revolution. Computers and computer networks have forever altered the way humans work, communicate, play, entertain themselves, and educate their children.

Nevertheless, despite this immense transformation of modern, industrial societies, and the significance of computational technologies, no agreement exists on how to use this technology in education. Computers and the Internet have spread rapidly in K-12 schools in the United States, perhaps more rapidly in the past few years than in the rest of society. But still no widespread consensus has been reached on whether computers and the Internet will have a large, small, positive, negative, or inconsequential effect on learning in young people. One reason for this lack of consensus may be that, while the proper role of computers and networks in K-12 education is being determined, what learning means is being rethought. And both these trends are set into the context of near-universal public concern that K-12 schools are not performing as well as they should, which has made school reform a potent political issue throughout the United States. Information technologies have become a complex and controversial component of new ideas about school reform.

Furthermore, the Internet is an increasingly controversial aspect of modern life because of the way it can carry objectionable communication such as pornography, hateful and violent speech, information about making bombs and using drugs, dangerous and obscene appeals to young people from pedophiles, and numerous other threats. The Internet is largely unregulated, despite recent attempts to change this; it is global, which means that local means of control are weak or even useless; it can be anonymous and even deceptive; it is a source of hoaxes, fraud, and misinformation; and it can be a tool for illegal activities such as pirating music, software, or movies, or unauthorized entries into sensitive computer systems. All of these problems are vexing enough for adults, but they are particularly troublesome when millions of young people are introduced into cyberspace, a relatively new feature of on-line communication. The tools that teachers, administrators, and parents have for controlling students' use of the Internet are few and relatively unrefined, so far. This means that teachers and parents are faced with a new educational task, in addition to their traditional pedagogical roles: teaching kids about how to use this technology responsibly while exploring ways to use it to improve general learning. The combination of these two pedagogical tasks is a significant burden on the teaching profession as well as on parents.

The current debate about the role of computers and the Internet in K-12 education and in the lives of young people is occasionally acrimonious, but it is healthy. It can be viewed as part of a larger debate over the proper role of technological tools throughout society. The negative features of Internet communication, for example, are counterbalanced by its enhancement of democratic discourse and by its rich and deep resources of information. Computer-based work can be dull and demeaning, or it can be rewarding and creative. Computer-assisted instruction could produce a generation of technological drones or a renaissance of gifted, competent, and diversely talented lifelong learners. The information age could be one of hardening inequalities, a two-tiered society of the skilled and unskilled, or it could be an era of democratic equality and justice. Figuring out how to use new technologies, in proper balance with other normative goals, is a challenge for all institutions and individuals, including K-12 schools and teachers. For all these reasons, the current debate about computers and the Internet in schools is highly important.

The Current State of Information Technologies in the United States

U.S. schools have used personal computers and related technologies since the earliest days of the PC era, beginning about twenty years ago. The Apple II computer was a staple of many schools for a long time. Most schools have gone through successive generations of personal computers of various brands.

The Internet has catalyzed a new push for getting computers and network connections into K-12 schools. In the 1980s the Internet was used almost exclusively by scientists, academics, researchers, and a handful of people in private businesses. It was then a text-based system typically run on large computers using the Unix operating system, which was, and still is, a difficult operating system requiring a good deal of specialized skill. Internet servers were limited to authorized research centers, which restricted the number and kind of people who could get Internet accounts. The National Science Foundation, which took over management of the Internet from the Department of Defense in 1983, prohibited the use of the Internet for commercial purposes, which again limited its use and appeal.

All of this changed in the early 1990s. First came the appearance of the World Wide Web, which introduced both graphics and an easy-to-learn user interface to the Internet. The standards that made Web pages accessible via the Internet quickly transformed the entire system. The Web also introduced hypertext to the Internet, a technology that made the Internet a vast interlinked library of information.

In 1993 the National Science Foundation lifted its prohibition on commercial activity on the Internet, and this had an equally transformative effect on computer networking. Within a few years, the Internet became the most innovative and essential way of doing business in the "new economy." Now, millions of businesses are providing goods and services on the Internet, and "electronic commerce" is expected to explode in the next few years.

The result of these recent developments is that the Internet is now commonly viewed as the basic platform for nearly all future communications, including voice, data, video, music, radio, government services, and commercial enterprise. The United States is moving toward an Internet-based economy. More and more jobs require familiarity with computers; the U.S. Department of Labor estimates that, in the early twenty-first century, three quarters of all jobs in the U.S. economy will entail daily use of a computer.

Because all of this has emerged only within the past few years, the Internet is a new and largely unfamiliar technology to most Americans. About half of all U.S. homes have a personal computer, and about 30 percent of adult Americans, or about 60 million Americans, use the Internet. There are also about 10 million Americans under the age of eighteen in cyberspace. But because of the growth rate of new users, at any given time, only about half of all new users have been on-line more than a year. Consequently, about half of all Internet users are just developing their technical skills and adjusting to a new way of communicating.

"Surfing" the Web—learning how to "point and click" in a Web browser and how to navigate between Web pages—or learning how to send e-mail is not difficult. The ease of use that has become part of the Internet in the last five years is the major reason for its new popularity. But more advanced skills are difficult to acquire and consequently rarer. But these skills are in high demand. Leaders of technology companies are increasingly concerned that the U.S. educational system is not producing enough skilled workers to meet this demand and that the economy will suffer.

The United States will need ninety-five thousand new technology workers a year through 2005, but only 24,553 college graduates received degrees in computer science in 1994, and the trend lines point to a flat or even downward trajectory for that figure. Bachelor's degrees in computer science have fallen more than 40 percent since 1986. In more advanced degree programs, about half of all students in technology and engineering are from other countries.[1] Among mid- to large-sized firms, there was a shortage of about 190,000 information technology workers.[2] The number of Americans seeking technology-related degrees declined by 5 percent since 1990.[3] Many technology workers find their way to high-tech employment through degree programs other than computer science, but the computer science field is the traditional bellwether of skilled worker availability.

Because of this concern in industry, attention has focused on the exposure of young people to information technologies in K-12 education. Most industry leaders believe that early development of skills in computers, programming, and networking is essential to pursuing further education in college, in job training, or in other educational modes before getting a job in the high-tech industry. And most industry leaders—although not all of them—are convinced that fluency and competency with computers and the Internet will be essential skills in the new network-based economy. Industry leaders say that they need "problem solvers," a different kind of worker than in the past, and that skill with computers helps foster this quality in young people.

This message has been echoed by President Bill Clinton. He said in his 1996 State of the Union address, "Our . . . challenge is to provide Americans with the educational opportunities we'll all need for this new century. In our schools, every classroom in America must be connected to the information superhighway, with computers and good software, and well-trained teachers. We are working with the telecommunications industry, educators and parents to connect 20 percent of California's classrooms by this spring, and every classroom and every library in the entire United States by the year 2000."[4]

In 1997 the President's Committee of Advisors on Science and Technology (PCAST) also stressed the economic imperative of training young people in technical fields:

> In an era of increasing international economic competition, the quality of America's elementary and secondary schools could determine whether our children hold highly compensated, high-skill jobs that add significant value within the integrated global economy of the twenty-first century or compete with workers in developing countries for the provision of commodity products and low-value-added services at wage rates comparable to those received by third world laborers. . . .
>
> While a number of different approaches have been suggested for the improvement of K-12 education in the United States, one common element

of many such plans has been the more extensive and more effective utilization of computer, networking and other technologies in support of a broad program of system and curricular reform. During a period in which technology has fundamentally transformed America's offices, factories, and retail establishments, however, its impact within our nation's classrooms has generally been quite modest.[5]

Much of the current attention paid to the use of computers and networks in K-12 schools has been motivated by concerns about the changing economy and the preparation of young people for new kinds of jobs. This trend tends to influence how computers and the Internet might be used in schools. Parents may press schools to use computers to prepare their children for jobs. Local industry leaders often demand training that supplies them with skilled workers. This has led to a debate about the proper balance between education and training, not only in K-12 schools but in universities and colleges as well.

Controversies about the use of computers by young people are at least in part related to diverse opinions about how to deal with inequality and whether the changes in society and the economy brought about by computers and the Internet are beneficial or not. A great many people are ambivalent about the information age, given the upheavals it entails. Many people believe that while information technologies have speeded up things, and perhaps made businesses more efficient, they have not contributed to a great improvement in the quality of life. For many people, the quality of life in the United States has declined in recent years, with more violence, rougher discourse, greater inequality, a dearth of public leadership, and little improvement in race relations. Some Americans believe that the computer and Internet bandwagon in K-12 schools is an expensive distraction from finding solutions to more basic problems confronting society.

Critics point out that numerous technological fads have been evident in schools throughout the twentieth century, most of them ineffective, and that the fundamentals of learning have not changed. Most of these critics are advocates of traditional models of well-rounded, liberal education instead of models driven largely by contemporary technologies. They also argue that the pace of change in the information age makes technical skills exceedingly ephemeral—what young people are taught about computers is likely to be obsolete within a few years, long before they enter the work force. That makes it all the more important, say critics, for young people to build sustainable skills of critical inquiry, curiosity about the world, historical knowledge, scientific literacy, judgment, and other skills that may not be aided by computers.

For all these reasons, educators and administrators face a daunting challenge: to find the proper balance between building job-related technological skills and fostering the "whole person" in K-12 education. This debate is not new, but it is under new intense pressure because of the strong push to get computers and the Internet into K-12 schools throughout the nation. The novelty of these technologies, especially the Internet, means that their potential impact on learning in young people is not yet known. The intensity of the current debate, and the stakes attached to its resolution, make most teachers and school administrators desperate for some guidance. This is the challenge for experts and policymakers.

Information Technologies in K-12 Schools

In contrast to the Internet, personal computers are a conventional and long-established technology in U.S. K-12 schools. Ninety-eight percent of U.S. schools own personal computers.[6] The number of computers in public schools has doubled in six years, to 7.4 million in 1998.[7] About 82 percent of K-12 schools have Internet access, up from 64 percent in 1997.[8] In March 1999 President Clinton announced that more than half (51 percent) of instructional rooms in K-12 public schools in the United States had access to the Internet, and the president repeated his pledge that all classrooms will be wired by the end of 2000.[9]

In 1997 the ratio of students to computers, on average nationwide, was 10 to 1, an all-time low, and was reported as 6 to 1 in a U.S. Department of Education report in February 1999 (from 1998 data).[10] The ratio decreases as the grade level increases, so high school students have greater access than elementary school students.

Spending on educational technology in K-12 schools was more than $5 billion in 1998, up from $2.1 billion in 1992.[11] This is, however, only a third to a fifth of the annual spending figure recommended by most experts, including PCAST.[12]

Many computers in schools are not Internet-capable, however. Even in 1999, about 8 percent of computers in schools were Apple IIs, which were nearly twenty years old.[13] Many old DOS-based machines also were in use as well as computers that cannot run the basic applications required for accessing the Internet. In 1997 the nationally averaged ratio of multimedia computers to students was 24 to 1, or nearly five times the recommended ratio of 5 to 1 advocated by the U.S. Department of Education. The lowest ratio was in Florida at 8.5 students per multimedia computer, and the highest average was in Louisiana, at 62.7.[14]

The biggest deficit in support for computer-assisted learning in U.S. schools is in teacher training. While many teachers are doing innovative and valuable things with computers in the classroom, the vast majority of K-12 teachers are inexperienced users. The PCAST panel on educational technology estimated that only about 15 percent of K-12 school budgets for technology is allocated to training, compared with the 30 percent the panel recommended.[15] In 1997 only 15 percent of teachers had received at least nine hours of training in computing technology.[16] Teachers typically do not have enough time either to take training in computer technology or to develop coursework integrated with the technology. Moreover, technology training for teachers is commonly limited to technical curricula designed to foster familiarity with hardware, software programs, or networks, a limited approach that many teachers find too narrow. Teachers often report being intimidated by the technology, or reluctant to use it, because some students are expert with computers and the Internet, and few teachers are comfortable revealing a lack of competence in the classroom. Keeping up with the technology is also a formidable challenge, given the pace of change in the industry and other demands on teachers' time.

Another problem for teachers is a relative dearth of high-quality educational software. The U.S. Department of Education estimated in 1996 that twenty thousand educational software packages were available for the K-12 market.[17] That number has certainly increased since 1996. But the academic software market is fragmented across many disciplines and grade levels, and software has to work on a wide diversity of machine capabilities. Software developers usually do not create programs for computers that are obsolete, but this category represents a large portion of the installed base of computers in U.S. public schools. Some states require educational software developers to do their own testing of efficacy, which is expensive and time-consuming, adding to the cost of development.[18] Also, educational software that is demonstrably effective requires high levels of funding for research and development, an investment that may be unrecoverable in a highly segmented market. Sophisticated programs may require training for teachers, too, a burden added to the training they may need for basic computer literacy. And all software programs require some level of technical support, an increasingly expensive requirement.

Another technology-related problem facing schools is one that is vexing all institutions in the United States, in the private, public, and nonprofit sectors: the shortage of well-trained technical support personnel. The shortage in software and networking specialists is the most acute. Software and networking specialists are the highest paid salary category of all engineering specialties; they earned an average of $64,000 in 1997. This group was also receiving annual pay increases of 6 percent, higher than any other engineering category.[19] Salaries for such personnel are even higher in technology-intensive areas such as the San Francisco Bay area, Boston, or Austin, Texas. The average pay for teachers from 1996 to 1997, in the country's largest one hundred cities, was $44,649.[20] That is 70 percent of the average for software and networking specialists. Public schools often find it difficult to pay these specialists the salaries they can get in the private sector.

The result is that schools and districts often wind up with fewer tech support personnel than they need, and this makes their technology unreliable and frustrating to many teachers and students. Some schools attempt to supplement their technical staff with student help, but this has liabilities. Schools may be reluctant to entrust expensive equipment to students, labor laws may be applicable, and insurance clauses may also be relevant. There is, unfortunately, no way to skimp on technical support and enjoy reliable computer services or computer security. Such support is very expensive, and likely to get more so.

Most of these technology-related problems could be solved with more money, and that raises the biggest issue of all: equity. Access to computers and the Internet in school is unfortunately correlated with socioeconomic status in the United States, and all the problems that are tied to lack of funds are worse in poor schools. Student-to-computer ratios are higher, teacher training is rare, software purchases are fewer, and technical support is in short supply.

In its 1997 report *Computers and Classrooms*, the Educational Testing Service (ETS) said bluntly, "The data show that students with the most need get the least access." As the percentage of Title I students or minority students goes up, so do the ratios of students to computers. Schools with minority populations of 25 percent or less had, in 1997 data, a ratio of 10 students to 1 computer, on average, while schools with minority populations of 90 percent or more had a ratio of 17.4 to 1.[21] The ETS study went on to say:

> Previous analyses have shown a positive relationship between the percentage of Title 1 students and computer availability. The general trend was more technology in poorer schools. This no longer appears to be the case. While Title 1 funding is designed to help poor schools, these targeted resources are apparently ineffective in getting these schools up to par technologically with other schools. Since much of the technology that currently resides in poor schools is probably due to Title 1 funds, it is hard to imagine what the technology level in these schools would be like without federal programs.[22]

These data follow similar patterns for Internet access. In the Department of Education's report of February 1999, 37 percent of schools with more than 50 percent minority enrollment were connected to the Internet, up from 3 percent in 1994, but this compared with 57 percent in 1998 for schools with less than 6 percent minority enrollment.[23]

Equally important, home ownership of computers, or home Internet access, is also below the national average in low-income households. About 37 percent of households with incomes below $35,000 per year had home computers in 1997, compared with more than 45 percent for households with incomes over $35,000. For households below $10,000 per year, the figure was just under 10 percent. An even greater concern is the relationship between ethnicity and computer ownership, according to the National Telecommunications and Information Administration (NTIA).

> Significantly, the digital divide between racial groups in PC-ownership has *increased* since 1994. In 1997, the difference in PC-ownership levels between white and black households was 21.5 percentage points, up from 16.8 percentage points in 1994. Similarly, the gap in PC-ownership rates between white and Hispanic households in 1997 has increased to 21.4 percentage points, up from 14.8 percentage points in 1994.[24]

This disparity appears to have expanded because of increasing computer purchases among more affluent households, with fewer computers purchased by African Americans and Hispanics. These data may be changing, however, now that PCs are approaching $500 for complete systems. The average income and education level of first-time buyers appears to be lower than in the past, and more first-time buyers are people who do not use a computer at work.[25] Nevertheless, there are huge disparities to overcome, especially in extreme poverty zones. Moreover, for poor schools, sustainability is an issue, because one-time grants or bond issues are not capable of keeping a school technologically current.

Students need ready and free access to computers outside of school hours to do homework, stay in touch with school, and keep up their skills and familiarity with the Internet. When a household cannot afford a computer or Internet access, its members need an alternative. In a 1997 study of racial differences in the use of the Internet conducted by Vanderbilt University professors Donna Hoffman and Thomas Novak, they reported that:

> Overall, white students are more likely than African Americans students to use the Web. But given a home computer, this race difference in Web use goes away. The important difference is among students who lack a home computer: here, whites are more likely to use the Web than African Americans. This may be due in part to the fact that white students, regardless of whether they have a home computer, are much more likely than their African American counterparts to use the Web at places other than home, work or school. This suggests the importance of not only creating access points for African Americans in libraries, community centers, and other non-traditional places where individuals may access the Internet, but also encouraging use at these locations.[26]

Many African American leaders are beginning to view community technology centers (CTCs) as an essential goal. CTCs are public places where people can use computers and access the Internet for free or a small fee. They may be in schools, churches, community centers, recreation centers, youth centers, or dedicated buildings. They are proliferating: CTC-Net, an umbrella organization of affiliated CTCs throughout the United States, lists more than 250 affiliated CTCs throughout the nation on its web site.[27] Break Away Technologies in Los Angeles has a program called 200 by 2000, through which the organization will start two hundred CTCs in Central and South Central Los Angeles by the year 2000; it celebrated its one hundredth center in April 1999.[28] The Clinton administration has proposed a $65 million line-item to support CTCs.

The role of CTCs illustrates an important lesson for schools. Large investments in technology, sometimes in the millions or even tens of millions of dollars, should not be locked up, out of reach, from three or four o'clock in the afternoon until early the next morning, not to mention two full days every week. Schools must explore new roles, new hours, and new programs outside of their traditional pedagogical models to get the most out of their technological investments, especially in communities with low home ownership of computers. Some schools are doing this by creating after-hours computer labs or classes, by cooperating with nonprofit organizations that run after-hours programs, or by venturing into adult education. With large investments in technology, the imperative is to use it as much as possible, in a wide variety of ways. Most schools have yet to make this transition because of staffing limitations, insurance requirements, funding problems, or other obstacles. But this is an opportunity for schools, as well as an example of practicing social responsibility.

In summary, the state of technology in U.S. schools depends on one's perspective. Much has been accomplished in the past few years, in terms of connectivity to the Internet, access to computers, and building of awareness on the part of teachers, administrators, and parents that this technology plays an important part in education today. Many schools are doing innovative things with computers, and studies show positive results on learning.

However, not enough attention has been paid to, or enough money spent on, teacher training, software quality, and equitable access. Most policymakers understand this—these are the priorities in most U.S. plans for technological investment. Much more could be done to break down the metaphorical "four walls" of schools and help them use their technologies for purposes other than traditional grade-based pedagogy, such as by collaborating with communities in CTC-like programs. All public sector institutions, and especially schools, should avoid the limitations of what experts call "stovepipe networking," which means that all the networking takes place inside the boundaries of the institution. Computer networking technology is expensive enough that it should be leveraged for a diversity of community activities and goals, and schools should be cooperating with other groups to maximize technology resources within their communities. Much work needs to be done before an understanding is reached of how to do this well. Unfortunately, schools are typically not great sources of innovation, so they will need help.

Internet-related technology is simply too new to come to any firm conclusions about its value to education, apart from simply learning how to use it. Most policymakers seem to understand this. A period of bandwagon enthusiasm seems to be ending, and a phase is beginning of some sober and rational reflection about whether computers and the Internet are valuable tools for learning, and in what ways. Private businesses have commonly seen their productivity go down after the introduction of computers and networks, or at least stay unchanged, before they figure out how to use these tools effectively. Until just recently, economists spoke of the "productivity paradox," the fact that U.S. productivity had not grown appreciably during the decade when the nation invested most heavily in new information technologies.[29] But this seems to be turning around, primarily because of new forms of commerce on the Internet.[30] Something similar may happen in K-12 education. But many mistakes will be made getting to the point of effective use of this technology, and some of these mistakes will be expensive. And doubters will think that getting computers and networks right may not be what young people need.

The Federal Role in Supporting Technology

President Clinton's Educational Technology Initiative has four goals:

1. All teachers in the nation will have the training and support they need to help students learn using computers and the information superhighway.
2. All teachers and students will have modern multimedia computers in their classrooms.
3. Every classroom will be connected to the information superhighway.
4. Effective software and on-line learning resources will be an integral part of every school's curriculum.[31]

These four goals have become parts of many federal agencies. The U.S. Department of Education's Office of Educational Technology, led by Linda Roberts, has developed several programs to help support K-12 technology programs in U.S. public schools, including these major initiatives: Preparing Tomorrow's Teachers to Use Technology, Technology Innovation Challenge Grants, the Technology Literacy Challenge Fund, the Star Schools Program, and Learning Anywhere Anytime Partnerships (LAAP).

The Technology Literacy Challenge Fund was launched in fiscal 1997 with funding of $200 million; this figure more than doubled the following year, to $425 million, then stayed the same for fiscal 1999. This fund provides grants to schools that are pursuing the president's four goals, based on Elementary and Secondary Education Act Title I criteria. The president requested a $25 million increase for this program in the proposed fiscal 2000 budget.

Preparing Tomorrow's Teachers to Use Technology is also a grant program, for supporting new teacher training. The program will award $75 million in grants in 1999. The grant program requires consortia of groups, such as institutions of higher education, to work with school districts or nonprofit organizations. The fiscal 2000 request keeps this program at $75 million.

The Technology Innovation Challenge Grants are meant to support innovative and effective uses of technology in classrooms in mostly low-income areas. The program was funded with $106 million in fiscal 1998, $115 million in fiscal 1999, and the fiscal 2000 request is for $110 million. These grants range from nearly $1 million per year for five years to $2 million per year for five years.[32]

The Star Schools Program was launched in 1988 during the Reagan administration and focuses on how to improve student learning in disadvantaged and underserved communities and settings through the use of telecommunications, primarily in the subjects of mathematics, science, and foreign languages. The program was funded at $34 million in fiscal 1998, $45 million in fiscal 1999, and the request for fiscal 2000 is the same as fiscal 1999.

Learning Anywhere Anytime Partnerships is aimed at postsecondary education. It provides federal matching grants to consortia exploring educational delivery modes that seek to eliminate barriers of time and space, such as asynchronous distance education. This program is managed by the Department of Education's Fund for the Improvement of Postsecondary Education.

The largest program for assisting schools in Internet access has also been the most controversial: the E-Rate. Also known as the Universal Service Fund, the E-Rate was part of the mammoth Telecommunications Act of 1996, the most significant reform of U.S. telecommunications regulation in nearly seventy years. The legislation provided for a fund that would support discounts of up to 90 percent for telecommunications access for schools and libraries. The fund's program was determined by a new bipartisan Federal-State Joint Board on Universal Service convened by the Federal Communications Commission (FCC). In 1997 the FCC ruled unanimously for a provision that would allow schools and libraries access to a fund of up to $2.25 billion for such discounts, supported by assessments on telecommunications carriers operating in the United States. By April 1998 the first round of grant applications included more than thirty thousand requests totaling $2.02 billion.[33] The program is administered by a nonprofit corporation, originally called the Schools and Libraries Corporation, which is now part of the Universal Service Administrative Corporation.[34]

The E-Rate came under fierce attack in 1998 from Republican legislators, who labeled it "the Gore tax," because of the program's association with Vice President Al Gore. Telecommunications companies announced that they would raise their rates to cover their payments into the fund, and this prompted opposition from some legislators as well as consumer and antitax organizations, including Consumers Union and Americans for Fair Taxation. The E-Rate's critics also objected to the imposition of an assessment by the FCC, which they labeled a tax without the constitutionally approved method of levying taxes.[35] Because of this dispute, the FCC lowered the E-Rate's total target fund to $1.275 billion in June 1998, a sum that was disbursed to applicants beginning in November 1998.[36] But the E-Rate is still under attack in Congress. In May 1999 FCC commissioner William Kennard said he wants the program funded at its previous, maximum level of $2.25 billion per year.[37]

Many other federal programs assist K-12 schools in technology and are found in agencies as diverse as the National Science Foundation, the Department of Energy, the National Aeronautics and Space Administration, the Department of Energy, and the Department of Commerce, among others.[38]

Federal grant programs are available for para-educational programs that offer alternative means of access to computers and the Internet. The Department of Commerce's Telecommunications and Information Infrastructure Application Program (TIIAP) awards matching grants to partnerships exploring innovative uses of telecommunications technology supporting education, cultural activities, health care, public information, public safety, and other social services. This program has helped fund community networks and community technology centers in the United

States. However, the program has seen its funding repeatedly cut from its original goals; in 1998 it awarded $18.5 million in grants, and $17 million was available in fiscal 1999.[39]

The Department of Education also has two programs for after-school learning and community technology education, its 21st Century Community Learning Centers program and a program to support community-based technology centers. The former program, with a huge increase in funding proposed for fiscal 2000, to $600 million, attempts to help schools stay open longer, develop after-school programs, and support after-school learning and homework. The program supporting community-based technology centers makes grants to public housing facilities, community centers, libraries, and other community facilities to make educational technology available to residents of low-income urban and rural communities. It is budgeted at $65 million in the president's fiscal 2000 request, an increase of $55 million over fiscal 1999. The increase is meant to support three hundred new grants, over the forty supported in 1999.[40]

The federal technology budget for K-12 education is immense and diverse, but only a small part of the picture, as the federal government has traditionally left most education funding to states. Federal spending for technology education is not as high as many people think it should be, but it is constrained by the budget caps negotiated in 1997. Nevertheless, the Clinton administration made technology education one of its highest priorities.

The largest deficit in federal spending for technology-based education is for research and development (R&D). The Department of Education's Technology Innovation Challenge Grants are budgeted at $110 million in the president's fiscal 2000 request, $5 million below the fiscal 1999 authorization. The National Science Foundation has programs for R&D in K-12 education, but its grant programs are relatively small and the agency is focused on math and science education.

By contrast, PCAST recommended annual R&D funding of $1.5 billion, or 0.5 percent of all national spending on elementary and secondary education.[41] Officials of the White House Office of Science and Technology Policy have also called for similar levels of funding for technology-related R&D for K-12 schools. Only the federal government could commit this level of funding to this kind of research. However, under current budget constraints, generous funding for educational technology R&D is not likely to happen.

Another recommendation for the federal government to consider is a national clearinghouse of high-quality software and courseware (software for teaching courses).[42] Accompanying evaluations could be done by a national network of educators and education specialists. This idea has yet to materialize.

Finally, the federal government is increasingly concerned about how young people use computers and the Internet, how young people can be exposed to objectionable material on the Internet, invasions of privacy, and so on. Some Web-based resources for educators exist on how students should use the Internet in a responsible way, but these resources are difficult to find and they are often sketchy, weak, and outdated. The Department of Education, perhaps in collaboration with the Department of Justice, should consider implementing a major new initiative on educating young Americans about the ethical and responsible use of computers and the Internet.

Computer-Based Instruction in K-12 Schools

Thousands of teachers in the United States are doing interesting things with computers in their classrooms. Perhaps millions of people are enthusiastic about the use of computers and the Internet in K-12 education. Probably millions—or so it seems—of books, reports, studies, news stories, magazine articles, monographs, and dissertations have been produced on this subject.

What follows is a list of the general arguments used by proponents of computer-assisted education. Not all advocates endorse every one of the points described; some proponents may even have doubts about one or more of them. But on the whole, a core set of beliefs among proponents encompasses most of the points described below.

Computers help young people learn. This is the most important and critical assertion for justifying large investments in computational technologies for K-12 education. Many studies support this assertion, including the commonly cited 1994 source of James A. Kulik:

At least a dozen meta-analyses involving over 500 individual studies have been carried out to answer questions about the effectiveness of computer-based instruction. The analyses were conducted independently by research teams at eight different research centers. The research teams focused on different uses of the computer with different populations, and they also differed in the methods they used to find studies and analyze study results. Nonetheless, each of the analyses yielded the conclusion that programs of computer-based instruction have a positive record in the evaluation literature.[43]

Kulik offered five conclusions from this work:

1. Students usually learn more in classes in which they receive computer-based instruction;
2. Students learn their lessons in less time with computer-based instruction;
3. Students also like their classes more when they receive computer help in them;
4. Students develop more positive attitudes toward computers when they receive help from them in school;
5. Computers do not, however, have positive effects in every area in which they were studied. The average effect of computer-based instruction in 34 studies of attitude toward subject matter was near zero.[44]

Some critics have pointed out that these data were limited to traditional computer-assisted instruction, such as "drill and practice" models; that the reports Kulik studied varied widely in quality; and that the data came from studies done before 1990.[45] The Software Publishers Association commissioned a more recent meta-analysis of 176 studies published between 1990 and 1994, and it concluded, "The use of technology as a learning tool can make a measurable difference in student achievement, attitudes, and interactions with teachers and other students."[46] Studies also suggest that computers help with students' writing and math skills.[47]

Most reviews of computer-based instruction note that evaluations of new models of teaching, such as "experiential" learning, are difficult to assess and that conventional tools for evaluation, such as test scores, may not be appropriate for new modes of instruction using information technologies. As such, reports on educational technology commonly call for more research on evaluation and assessment. A host of methodological problems are involved with evaluating computer-based instruction, not the least of which is that the subject is a moving target because of the rapid changes in the technology itself.[48]

Exposure to computers is a necessary and important element in contemporary education because of the critical role of this technology in today's economy and society. This argument usually motivates parents and business leaders, who are most likely to think of education's task as preparing young people for employment.

Unfamiliarity or incompetence with computer technology is a serious liability in the job market. The majority of jobs in the U.S. economy now require daily use of a computer or related device. Workers with computer skills make more money than people without such skills, they are more likely to be employed, and they often report higher job satisfaction.

A widespread feeling exists that early exposure to computers in school is an important part of young people's preparation for well-paying and high-skill employment. A general consensus is also found that the national aggregate of such skills will be an essential component of future U.S. economic competitiveness in a rapidly changing global economy.

Computers and the Internet are important new tools for promoting social and economic equity. Because of the new significance of computers and the Internet in the U.S. economy, concerns have arisen that new technologies could cause even bigger gaps between the "haves" and "have-nots," reinforcing traditional patterns of inequality by race or ethnicity. Improving computer-related skills in low-income and minority communities in the United States could help attenuate inequality, or at least prevent it from worsening. Herman Lessard, a national African American leader and president and chief executive officer of the Greater Austin Urban League, has called equalizing access to computers, the Internet, and computer training "the new frontier of civil rights."[49] Welfare reform has made it necessary to provide equal access to technology training.

The federal government has focused on low-income, Title I schools in nearly all its funding programs for educational technology and for community technology centers and infrastructure development. The private market seems to be doing a good job of providing technology and network access to most American consumers, but "market failures" are clearly evident in many communities and schools where the federal government has chosen to intervene. While it is too early to assess whether these efforts will help alleviate inequality in the new economy, without such public investments, low-income communities likely would have few alternatives for capital and skill development.

Computers, and especially the Internet, open the world for students and teachers, and they help equalize access to educational resources that might otherwise be unavailable. One feature of the education field that has changed dramatically in the past fifty years has been the proliferation of new subjects, new knowledge, and new specialties that may be relevant to the education of young people. As a result, many schools find it difficult to provide instructors in some foreign languages, for example, or advanced math and science, or specialized topics in literature or history.

New technologies supporting distance education and resource sharing, especially through the Internet, may be a solution for such deficits, many experts believe. In Texas, the most rural of the lower forty-eight states, technologies can support the delivery of courses to students in small rural communities that cannot afford teachers in foreign languages or advanced math and science. The Texas Telecommunications Infrastructure Fund is a ten-year, $1.5 billion public investment program to build Internet connections to all public schools in the state, as well as libraries and nonprofit medical facilities. The federal government is also supporting such efforts through its Star Schools program and its Learning Anywhere Anytime Partnerships.

For all schools, the Internet opens up a wealth of information available worldwide, as well as interactivity with people, both experts and peers, through e-mail or the World Wide Web. Many schools sponsor popular "key-pal" programs through which students communicate with their peers in other countries and learn about foreign places from real residents. Classes can network with each other, sharing experiences or collaborating with each other on projects such as environmental data analysis or tracking the migration of animals or comparing economic development. Students have even used e-mail to communicate with astronauts on the U.S. space shuttle, through which they learned about space travel, space physics, and experiments conducted on the shuttle. Many schools took advantage of the opportunity to learn about Mars when the Jet Propulsion Laboratory offered live pictures on the Internet from the Mars exploration vehicle. The National Science Foundation has sponsored educational

Internet video feeds from underwater exploration vehicles or from its research station at the South Pole.

New uses of the Internet in classrooms have helped "break down the walls" and eliminate the traditional isolation of classrooms, especially in low-income and remote communities. This is a new but no doubt permanent part of learning in K-12 schools, which will expand in the future as schools acquire higher bandwidth telecommunications links and new software applications. The federal government is supporting such innovation, both by encouraging new forms of collaboration and networking and by helping build the technical infrastructure required.

Computers help make learning more fun and stimulating for students, increasing their interest in learning and in subjects that they might otherwise find boring or difficult. Numerous studies on the impact of computer-assisted instruction report positive attitudinal changes in students, with computers helping students enjoy learning. Interactive and graphically rich software programs can engage students in ways that lectures or textbooks cannot. Some teachers and administrators believe that students expect this kind of engagement, given their saturation with television, movies, and computer games, although this belief engenders a good deal of controversy.

Educational software packages often employ visualization techniques, computer simulation, digital animation, music, and other features to offer an educational experience that cannot be matched by textbooks. Interactivity can supply what-if capabilities that allow imaginative explorations of a subject or experiments that contribute to both learning and problem-solving skills. Computer software, for example, allows chemistry students to see visual models of molecular structures and to experiment with different combinations of molecules.

Another commonly cited advantage of computer-based instruction is that "drill and practice" programs allow students to interact with an instructional program that is infinitely patient and that circumvents public embarrassment over mistakes.

The proper use of interactive technologies in the classroom can be the catalyst for comprehensive educational reform and innovation, a transformation essential for schools in the twenty-first century. This argument asserts that one important contribution of computers and the Internet to K-12 education is that these technologies help shift the role of the teacher from the "sage on the stage" to a "guide on the side," relocating the responsibility for learning to students and their peers. In academic circles this model of education is called "constructivist" learning, in which students "construct" their own learning instead of having it "dumped" inside their heads by a teacher. This model is viewed, by its advocates, as an essential reform of U.S. public education with the aim of fostering a lifelong desire for learning and problem-solving skills, rather than producing students with a corpus of received knowledge.

Constructivist education has its passionate proponents and its equally passionate critics. It is a restatement of progressive education. Most experts, advocates and critics alike, admit that it is difficult to evaluate at present, that its outcomes are uncertain, and that it is likely to be at odds with the most widespread methods of assessing student achievement.[50]

The technological application of constructivist models of education typically involves students using computers and the Internet as tools in a learning project whose parameters and content unfold as the students explore the subject themselves. This model is at least in part derived from changes in the way businesses pursue their goals in the knowledge economy, as workers are increasingly expected to be self-directed problem-solvers who know how to find answers using information technologies. It is also a response to the expanding universe of knowledge. Many educators believe that it is hopeless to try to inform students, through lectures or textbooks, about many subjects because the knowledge base has become too vast. The alternative is to help students learn how to find answers to their questions, with help from computers and the Internet. The constructivist model also attempts to foster collaboration and teamwork, additional features of the new workplace but also skills valuable in themselves. Ironically, the fact that most schools have multiple students per computer makes collaboration and teamwork imperative when the learning project requires computer use.

The benefits of constructivism combined with computer-assisted instruction are uncertain. Their realization may require significant changes in educational philosophy, in training, and in the preparation and quality of teachers. Proponents of constructivism tend to believe that such changes will, in part, be imposed by computers and the Internet, or at least accelerated. Their critics reply that changing educational philosophy and preparation at the same time that teachers are required to learn complex technologies may be asking too much and that the results will be mixed at best, chaotic at worst. Educators and specialists in pedagogy also doubt the claims and effectiveness of the constructivist approach altogether, seeing it as yet another rehash of failed progressive practices that work best in theory, not the classroom.

Critiques of Computer-Based Instruction

Critics of the current national program for getting computers and the Internet into K-12 schools run from mild objectors or people with reservations to full-blown rejectionists, such as Clifford Stoll in his 1996 book *Silicon Snake Oil: Second Thoughts on the Information Highway*.[51] Some of the nation's leading computer experts have questioned the current enthusiasm for getting computers into schools. Yale University computer scientist David Gerlernter has called the national campaign to get the Internet into every classroom "toxic quackery."[52] The cofounder and current head of Apple Computer, Steve Jobs, one of the icons of the computer age, told *Wired* magazine in 1996:

> I used to think that technology could help education. I've probably spearheaded giving away more computer equipment to schools than anybody else on the planet. But I've had to come to the inevitable conclusion that the problem is not one that technology can hope to solve. What's wrong with education cannot be fixed with technology. No amount of technology will make a dent.

Jobs added:

> Lincoln did not have a web site at the log cabin where his parents homeschooled him, and he turned out pretty interesting. Historical precedent shows that we can turn out amazing human beings without technology. Precedent also shows that we can turn out very uninteresting human beings with technology.[53]

Underlying nearly all the specific criticisms of the current national effort to get computers and the Internet into classrooms is the feeling, among nearly all critics, that an unbalanced emphasis favoring this particular technology is being created at the expense of more well-rounded education. Computers, say most critics, are good for some things but not for others, and giving too much emphasis to computers in K-12 education pulls educators closer to becoming "tools of their tools," rather than "masters of their tools." Most critics also point out that the evidence for improvements in learning among young people attributable to computers is simply too equivocal to justify large expenditures, especially when schools are having difficulty paying for other essential expenses such as improving teacher salaries and schools' physical plant.

What follows is a list of the basic criticisms of the campaign for putting computers and the Internet into schools. Not all these points will be consensual among all critics. Critics who publish are far less numerous than advocates who publish. Two critics who have stood out recently are William L. Rukeyser, founder and president of Learning in the Real World, and Jane M. Healy, author of the 1998 book *Failure to Connect: How Computers Affect Our Children's Minds—For Better and Worse*.[54] Even more controversial has been Todd Oppenheimer, who wrote a scathing critique of computers in schools in the *Atlantic Monthly* in July 1997, which became the subject of heated debates at several national conferences.[55]

Evidence that computers and the Internet help young people learn is equivocal, uncertain, and methodologically flawed. It remains unknown whether information technologies significantly improve learning among young people. Many research studies call into question the positive influence of computers on student learning.[56] The essential critique of studies finding a positive influence is focused on what social scientists call the "Hawthorne effect," named after a series of workplace studies conducted from 1927 to 1932 at the Western Electric Hawthorne Works in Chicago by Harvard Business School professor Elton Mayo. The Hawthorne effect is a kind of sociological version of Heisenberg's Uncertainty Principle: Mayo demonstrated that worker productivity was influenced more by the attention paid to the workers by researchers than by any changes in the technologies the workers used. This lesson has become one of the standard factors of consideration in studies involving work and human productivity, a lesson taught in every school of business and work organization.

The Hawthorne effect applies to studies of students using computers as well—to any study of students using any technology in the classroom. A combination of factors sets up the conditions for the Hawthorne effect: computers are typically in short supply in most schools, at least in ratios of multiple students per computer, and researchers are interested in student performance in computer-assisted instruction. Therefore, separating the positive contributions of the technology from the positive effects of giving students more attention is difficult. Students in small classes, supervised by trained and motivated teachers who provide a great deal of attention, is a model that improves student performance. How much computers add to this model, when they are part of a study, is unknown. Jane Healy says:

> In short, the research on software's effectiveness is still limited, vague, and open to question. Some computer use appears effective within a narrow set of educational objectives, and it appears to motivate children, at least to use the computer and at least temporarily. Can it actually improve learning? No one really knows. Even if it were possible to measure or equalize the quality of adult interaction, definitive "results" on complex cognitive variables are never easy to come by.[57]

Critics also note that, even though the U.S. educational system has employed more computers than any other country, educational performance among U.S. students has not shown great improvement over the past twenty years. U.S. students still lag behind their peers in many other industrialized nations, especially in mathematics and science, two fields that would appear to be natural and expected beneficiaries of computer-based instruction. Samuel G. Sava, executive director of the National Association of Elementary School Principals, wrote:

> In the U.S., 37 per cent of students use computers in at least some math lessons—nearly triple the international average. Yet this increased use seemed to make no difference to our math results. In sum, if computers make a difference, it has yet to show up in achievement.[58]

Sava pointed out in the *New York Times* in 1997 that:

> In the 26-country Third International Mathematics and Science Study earlier this year, fourth graders from seven other countries outscored American students on the math portion of the test. Teachers in five of the seven countries reported that they "never or almost never" have students use computers in class.[59]

Because of the widespread national concern about school performance, schools are trying a variety of approaches to improve student performance, and many of the promising approaches have nothing to do with computers: enhancing parental engagement; reducing class sizes; implementing tutoring and both peer and adult mentoring programs; exploring a "return to basics"; requiring student uniforms; reforming curricula; increasing discipline; and a host of other approaches. Computers may be a part of the solution, but, critics argue, they are not likely to have the return on investment attributed to them. Some schools, such as David S. D'Evelyn Junior/Senior High School in Golden, Colorado, deemphasize computer instruction and still produce high achieving students.[60]

In general, as Healy notes, educational success is the product of a complex combination of factors, and computers are likely to play only a small role in this nexus. Few critics argue that students should have no exposure to computers at all. Most insist that computers should have a proper, balanced place in a well-rounded curriculum that stresses basic skills, discipline, reading, critical inquiry, and a passion for learning, which are all primarily the product of good personal relationships between students and teachers.

Computers can be an expensive distraction from more important school requirements and a never-ending drain on school resources. Many critics of the computers-in-schools bandwagon have pointed out that this expensive national effort is coming at the same time that public officials have recognized huge deficits in schools' physical plants, in teachers' salaries, and in support for nontraditional sports, the arts, extracurricular activities, and other features of schools that were once the pride of the nation. Many stories are heard of schools cutting back electives, art and music classes, language classes, library hours, and after-school programs to pay for computers and networks.

For example, the Austin Independent School District budgeted $37.5 million for computers, networks, and electricity in a bond package approved by Austin, Texas, voters in November 1998. By December the district's expenses had increased $24 million, or 64 percent, because of cost overruns in the contract. Electricity for computers in 102 campuses was originally budgeted at $16.5 million less than what was required. Cabling was budgeted at $5 million less than the figure that eventually emerged. This $61 million budget is for equipment for only four years, and it does not include money for teacher training, curriculum reform, technical support, or other collateral expenses.[61] This 1998 bond package came after a $26 million bond package for technology was approved by Austin voters in April 1996.[62]

By contrast, teacher salaries in Texas are, on average, $6,000 (15 percent) below the national average of $39,385. In a 1999 poll, 63 percent of Texans reported their belief that teacher salaries are too low.[63] Texas ranks thirty-eighth in the nation for teacher salaries. The average teacher salary does not qualify for a home loan even at the bottom of the housing market in Austin.[64] Ironically, the Austin Independent School District is losing some teachers to the private high-technology sector once these teachers get technical training on computers.

This is just one example of what many people view as skewed priorities in public schools. If school districts cannot attract good teachers, no amount of technology will improve learning. The combination of expensive technology (which is often more difficult to learn and use) and low teacher pay often means that the technology itself is underutilized or never even used at all.

The same can be said of technical support expenses. Most schools cannot afford adequate tech support, which means that school computers are often broken, in repair shops, or simply unused. Patrick Welsh, a high school English teacher in Alexandria, Virginia, wrote in *USA Today*:

> The two computer specialists assigned to the school to provide training are so overwhelmed fixing glitches that many staff members are afraid to ask them for help. Early last year, I made the mistake of turning my laptop in for repairs. It has been over a year now, and I am still hearing promises that I will be getting it back soon. I am told that the company not only won't service them, but also has run out of spare parts.
>
> Perhaps half of the school's teachers don't have these problems. They simply never use their laptops.[65]

This story unfortunately is not uncommon. Tech support is a nightmare for well-funded companies, let alone cash-strapped schools. Large networks of computers are difficult to maintain, even when the users are experts. When the users are novice teachers and children, the task becomes manifestly more complicated and vexing. And the more a school becomes dependent on computers and the network for its teaching mission, the more important it is that the equipment operate reliably. Unfortunately, computers are among the least reliable technologies in everyday use.

Finally, this technology is obsolete by design and therefore must be replaced constantly and repeatedly. A kind of symbiotic relationship exists between computer hardware and software that makes upgrades imperative for those who want to stay current with new operating systems and software applications. Windows 98, for example, will not run on older PCs, and the current Macintosh operating system will not run on early Macs. Windows 2000, a promised replacement to Windows 98, will require a fast Pentium II or III machine. Again, an irony of these developments is that such machines are in all respects pure overkill for the kinds of applications schools need—a Pentium III computer could run a large hotel or a small hospital. But school boards will have to buy these machines if they expect students to learn the latest in technological features.

In short, computers are expensive. They may add up to only a small percentage of aggregate school expenditures. But they are still a significant expense when many schools have difficulty finding enough money to repair buildings or facilities, raise teacher salaries, offer professional development to teachers, or sponsor elective courses, after-school programs, and a diverse array of sports and arts. Critics point out that, when the magnitude of expenses for computers is added to the uncertain character of the evidence about whether computers improve learning, the wisdom of the investment is questionable.

Computers engender a certain style of learning, which can shorten attention spans and lead to deficits in other, perhaps more important, styles of learning. Computers are often touted by technology proponents as devices that support the development of imagination and critical inquiry because of their interactive capabilities.

But technology critics point out that instructional software is, because of the way computer programs are built, in reality tightly scripted. Computer programs impose boundaries on inquiry and on the information they offer, an inherent limitation of the technology. Massachusetts Institute of Technology sociologist Sherry Turkle discusses this phenomenon in her 1995 book *Life on the Screen: Identity in the Age of the Internet*.[66] She describes how students commonly view the assumptions built into computer simulations as givens, inaccessible to criticism, and now a tendency "to take things at 'interface' value."[67] Todd Oppenheimer wrote in his *Atlantic Monthly* article:

> Indeed, after mastering SimCity, a popular game about urban planning, a tenth-grade girl boasted to Turkle that she'd learned the following rule: "Raising taxes always leads to riots."[68]

Often, the way computers work is beyond the understanding of teachers. If a teacher is asked by a student, "How does a computer know how to alphabetize?," that teacher is unlikely to know the answer, because explaining sorting algorithms is nontrivial even for computer science students. When teachers cannot answer such questions, the impression left with young students is that the computer "just knows" how to do things, that it is a "black box" with near-magical powers, and that asking such questions is irrelevant to learning. This tends to close off critical inquiry rather than open it up.

Another concern is that the current paradigm of computer use may devalue books in the minds of students. Computer software is usually rich with graphics and interactivity, features that some technology advocates say appeal to students because of their exposure to television and computer games. But reading long passages of text on a computer is difficult, something that even adults are reluctant to do. Web publishers often report that the maximum length of text Web readers will read is about fifteen hundred words; consequently, most articles on the Web are tailored to this length, and novels or other book-length materials are rarely found on the Web. Book publishers attempted to enter the CD-ROM market, but the effort never took off because few people are willing to read book-length material on a computer screen. The fear is that, by asking young learners to regard the computer as their primary instructional device, their reading skills will be constrained to short lengths of text, which have limited value. Such students may in turn be reluctant to tackle long works of fiction, history, or other subjects, many of which are essential for a well-rounded education.

Critics are also concerned about an apparent preoccupation with the Internet's ability to deliver information to students, without an adequate evaluation of this information. A great deal of information on the Internet is of questionable value, inaccurate, or misleading. Sometimes such deficits may be subtle enough to escape a teacher's competence. Moreover, say some critics, no one can argue that a lack of information is a problem for most schoolchildren; most kids are saturated with information. What they need is information relevant to learning, and teachers, especially in colleges and universities, commonly express astonishment over how little young people know about basic facts and how much they know about popular culture. In other words, kids are learning, but they are not learning or remembering the right things for educational achievement. The Internet can make this problem worse because its growing commercial character tends to emphasize popular and ephemeral trivia.

Finally, educational software vendors usually enhance the appeal of their products by attempting to make them fun or entertaining, features that some teachers say students now expect from software. But, some critics argue, learning cannot always be made fun or entertaining, and it may suffer by comparison, leading to an erosion of important learning discipline. "Maybe I'm the weird one," said Clifford Stoll to the *New York Times*, "but I never thought learning was supposed to be fun. It requires discipline, responsibility and attention in class. Learning is work. Turning scholarship and class work into a game is to denigrate the most important thing we can do in life."[69]

A good deal of friction currently exists between people who believe that books will be a lasting and important part of learning for young people and technophiles who believe that books are a technology that will soon be superseded by computers, CD-ROMs, and "electronic books," a new technology only now appearing. This debate seems to be masking a much larger and deeper debate about what the content of education should be: whether education should be "classical," with attention paid to great works of literature and history found in books, or whether it should be oriented more toward "information" conveyed through the most efficient and appealing means. How this debate will be resolved will influence the penetration of computer technology in K-12 schools. In other words, some debates about the appropriateness of technology in schools are really debates about what education in general should look like.

Teaching kids how to use computers may be useful in preparing them for a job, but not in preparing them for being well-rounded citizens, the true goal of education. Neil Postman, a technology and education critic, has said that the mission of schools is to teach young people "how to make a life, which is quite different from how to make a living."[70] Some technology critics believe that an overemphasis on teaching computers and the Internet in K-12 schools will teach students how to "point and click," but not why these skills might be valuable to them or to their future.

Few schools, if any, teach students anything about the role of computers and the Internet in modern society, as opposed to the mere technical skills of how to use these technologies. If any "social" component exists to the technological education of students, it is typically about the "dos and don'ts" of computer use, limited to what can get students in trouble if they use a computer in a way not approved by the school or parents. This kind of education, as such, is too often limited to a documented list of approved activities, usually part of an Acceptable Use Policy (AUP) that students are given for their parents to sign and return to the school. AUPs are usually drafted by attorneys, not educators, and are designed principally to protect a school or district from liability should a student encounter a disagreeable experience using the Internet. AUPs rarely help educate students or parents about the social context of using information technologies.

However, this social context arguably is the most important thing students can learn about new information technologies. The basic technical skills required for using computers and the Internet, other than typing, can be learned in a day or two. Most students already have these skills because of the widespread presence of computers and the Internet in homes. What students typically lack is judgment about what they will experience using computers or the Internet, such as exposure to objectionable material; copyright laws; privacy violations; "netiquette"; and how computers and the Internet are reshaping the economy, jobs, politics, media, and society as a whole.

Computer-based instruction in public schools in the United States is often too focused on narrow technical skills or on using commercially produced educational software packages. What is currently neglected is helping students understand how the use of computers and the Internet is transforming society and shaping their future. Computer civics classes are needed, which should be regarded as equal in importance to the development of basic computer skills. And an expanded idea of computer literacy would be beneficial, one that ventures beyond mere technical skills to a grasp of how computers operate in society in general.

An Attempt at Synthesis

Computers in K-12 schools still have passionate advocates and equally passionate critics, but most educators and parents fall somewhere in between the two extremes, and this is a healthy sign. A new middle ground still needs articulation, however, especially by government officials. What follows is an abbreviated attempt at a synthesis of advocacy and critique.

Computers are an important part of modern education, and all children should be exposed to this technology because it is changing the economy, jobs, education, politics, and society. All high school graduates should know how to use a computer, how to type, how to use a mouse, how to drive an operating system, and how to use several basic software applications such as a word processor, a spreadsheet, a database program, e-mail, and Web applications. Ideally, graduates should know generally how a computer works and how new technological developments are integrated into the technologies used today. In addition, graduates should have some grasp of how computers are influencing the economy, education, politics, and society, and how people use information technologies at home and at work. They should be exposed to some of the more pressing public policy issues surrounding the technology, such as netiquette, copyright, privacy, censorship, and the equitable use of technology by those in poverty or those with physical handicaps.

High school graduates should know how to find information on the Internet and, equally important, how to evaluate the information that they find. They should know how to behave in cyberspace, such as by observing rules of netiquette or refraining from unauthorized break-ins of computer systems or copyright violations.

Students should be comfortable using this new and valuable tool for work, further education, entertainment, and enhancing the quality of their lives. Using computers and the Internet should be as natural as using the telephone or watching television.

Computers do not need to be a central or dominant part of students' education. Computers and the Internet should be regarded as means to an educational end, not as ends in themselves. The biggest deficits among U.S. public school students are in basic skills and knowledge, and in their motivation for learning, not in their technical skills or their access to information. A pressing need exists for educational reform to address these deficits, but that educational reform does not need to, and should not, focus on technology. The biggest obstacles to educating students have nothing to do with a dearth of technology. They include poor teacher pay and preparation, low parental engagement, low expectations, poverty, and the overwhelming influence of popular consumer culture. Computers should be viewed mainly as tools for implementing reform, not as the reform itself. A complex combination of reforms likely will be required before significant improvement becomes evident in educational outcomes, and technology likely will play only a small role.

The federal government's focus on getting computers and the Internet to low-income students is the right approach for the most important problem involving technology. However, no rational reason exists for the federal government to promote a computer and Internet connection in every classroom in the United States. The U.S. government is right to focus on where the private market cannot or will not provide technology to certain segments of the population, such as in low-income or remote and underserved communities. Low-income communities must have access to information technologies, especially the Internet, and the federal government's approach to helping solve this problem is admirable, although the effort could always use more money. It is especially encouraging to see federal support for community technology centers, because computer and Internet access outside of school hours and off-campus is just as important as access in school.

However, the benchmark set by President Clinton for getting a computer and an Internet connection into every classroom in the United States has no rational basis. It is mostly a political pledge, a slogan, and a tool for counting steps toward the goal itself. There is no reason to believe that a computer in every classroom should be a desired goal for schools. Computer labs, for example, available to teachers and students from all fields, may be a better way to organize technological resources. One computer in a classroom does little to enhance learning—that number is too small and mostly symbolic—while multiple computers in some classrooms can distract from proven models of learning. Putting a symbolic computer into each classroom may foster low use, or no use, of the technology, the opposite of the government's intentions.

Concentrating computers in a school can be a huge cost savings, too, while attempting to get a computer into each classroom can entail unnecessary expenses. In general, schools should feel free to experiment with how they introduce and use computers, with how many computers are appropriate, and with what they are used for. No single approach or configuration of computer networks is going to work for all schools. Schools with only a small number of computers, used well, can perform as well as schools with lots of technology. Conversely, schools with many computers may not see improvements in learning if the technology is used poorly.

The federal government is correct in its current focus on teacher training, although this task will be much larger than most people expect. The government should also implement ways for schools to afford technical support personnel. Also, the government should consider implementing a national clearinghouse for educational software, explore and promote new and nonmarket incentives for developing educational software, and foster far more professional expertise in evaluating software. The current paradigm for training teachers in technology is far too narrow. Most teachers are trained only in the basic skills required for using a computer and the Internet. Teachers are rarely taught how a computer works or exposed to the public policy controversies they are likely to encounter when their students use the Internet. Teachers need time for this training, which is expensive.

Not enough attention has been paid to the need for qualified technical support personnel. Insufficient tech support personnel is a factor that will quickly kill enthusiasm for computers in education or anywhere else. At the same time, many school officials either go faint when they contemplate how much it costs to hire sufficient and qualified personnel, or, in many school districts, they cannot even find such people. The federal government should work with states and school districts, as well as professional societies, to address this problem. Volunteer support is not an adequate solution. Nor is relying on student help.

The quality of educational software is somewhere between insufficient and horrendously bad. A school can have all the computers it can fit into its buildings and do a bad job using them if the software is poor. The federal government can and should explore ways to promote better educational software, such as developing a national clearinghouse for educational software programs, a new network of unbiased professionals qualified to assess software, and perhaps new nonmarket approaches that provide alternative incentives for experts, including teachers, to develop better software. One promising approach is the Open Source model of software development, which has recently taken the software industry by storm.

A pressing need exists for a computer civics approach to educating young people about the use of computers and the Internet in modern society, but this kind of education is rare. The federal government should consider implementing a major new initiative, perhaps involving cooperation across agencies, such as between the Department of Education *and the Department of Justice.* The April 20, 1999, tragedy in Littleton, Colorado, in which two high school students killed a dozen of their classmates and a teacher, raised the Internet as a possible negative influence in the lives of young people because the two perpetrators used the Internet to distribute a message of hate, anger, and threats. Few events in recent memory have had as much effect on the minds of Americans, and the Internet's part of the story has disturbed many parents and even some young people.

However, few examples are available of teaching kids responsible use of the Internet in a comprehensive and well-rounded fashion. Schools have tended to rely on AUPs.

The federal government should help teachers educate students about the sociological, political, and historical issues surrounding the most influential technology of the current time. Even apart from issues surrounding the development of norms in cyberspace, most kids have no idea where the Internet came from or how it works. This is true of many teachers, too. Teachers are not trained in this kind of thinking about technology, business leaders are not encouraging it, and parents are not demanding it, even though they are all worried about the results given the absence of such education.

Because most young people either already have well-developed or adequate computer skills or will pick them up in the course of their schooling, the most important missing element is a social context for how this technology will shape their future and that of the nation. The federal government could help foster a solution to this problem, possibly through interagency cooperation between the Department of Education and the Department of Justice, a collaboration that has produced guides for computer ethics in the past.[71] A much broader, deeper, and more effective national program is required now.

Conclusion

The federal government has, on the whole, done an excellent job, especially since 1996, in fostering the use of technology in K-12 public schools in the United States. The Department of Education's focus on getting computers and Internet access to low-income schools and communities is the right approach. This effort has struggled with budget constraints and with the traditional limitations of the federal government's influence on educational policy, but a great deal of progress has been made.

The federal government has also been somewhat responsible for overselling computers and the Internet to school officials, teachers, and parents, especially via the president's goal of getting a computer and network connection into every classroom. This almost certainly stems from the political requirements of selling a national program in an era of suspicion about federal spending, and to a somewhat hostile Congress. Nevertheless, teachers and parents should know that the effect of computers on achievement is uncertain. Federal officials have a tough balancing act: to do things they can do, such as promote technology through federal grants and other programs, while acknowledging that computers are only part of the solution, perhaps only a small part. Mostly for political reasons, federal officials have tended to overstate the case for technology.

Access to technology will be more or less ubiquitous within ten years, and most students will have the basic skills required to use computers and the Internet. Colleges and universities rarely run into students who are completely incompetent or even unfamiliar with computers. Unfortunately much less rare are students who cannot write well, cannot speak well in public, or have vast and alarming gaps in their basic knowledge about science, math, literature, history, or current events. This is the biggest educational problem facing the nation, and computers are unlikely to have a major impact on this problem.

It is time to redirect attention regarding education technology to the problems that schools face. Those include teacher training, technical support, equity, and a broader, more civics-oriented approach to educating students about information technologies. The federal government has recognized some, but not all, of these issues. Officials have tackled the training and equity issues, but not the tech support and civic education deficits.

While all students should know something about computers and technology issues, the most important challenges facing K-12 schools have little to do with technology. The best of all possible worlds would be for computers and the Internet to become part, and probably only a small part, of a thriving academy of motivated learners whose time in cyberspace is significantly exceeded by time spent reading, visiting interesting places and people, having fascinating conversations, helping their peers, developing their physical and artistic talents, and enjoying life.

Comment by Tom Loveless

I enjoyed Gary Chapman's paper on federal policy promoting technology in education. The paper summarizes the role of technology in the growth of the American economy, offers an exhaustive account of current federal programs, and presents, in a balanced fashion, the arguments for and against a larger role for technology in American schooling. Chapman concludes by splitting the difference between advocates and critics of technology, endorsing middle-ground proposals that include increased aid to low-income and rural areas, an emphasis on teacher training and technical support, a national clearinghouse for software, the establishment of community technology centers, and a "computer civics" program that would teach responsible use of technology and its historical and social context.

No one will argue that technology is a rapidly growing component of the economy. The dawn of the "new economy" is truly remarkable. In the spring of 1999, for example, the total market value of stock in America Online (AOL) reached $150 billion, three times that of General Motors. In June 1999 the contribution of Internet-related business to the nation's gross domestic product was estimated at more than $300 billion, roughly equivalent to the auto industry. Considering that it took the auto industry almost the entire twentieth century to grow to this size and that most Internet companies are only a few years old, the industry's rate of expansion is astounding.

Enter the policy problem. Chapman cites a Department of Commerce study that the United States will need ninety-five thousand technology workers annually through the year 2005. Studies of this sort were used by the Clinton administration to campaign for several technology programs in the 1990s. Essentially, the administration argued that a federal effort would help prepare children for employment in the twenty-first century. I am not an economist, but I am suspicious of using projected economic trends as a rationale for new education programs. After all, the founders of AOL, Microsoft, Cisco Systems, Amazon.com, and today's other high-tech companies seem to be doing well without the benefits of such an initiative when they were in grade school. Moreover, a recent study by the Labor Department estimates the greatest employment demand in the next several years will be not for technology workers but for home health aides, human service workers, and personal home-care aides. This study also estimates that, in sheer numbers, more sales clerks will be hired than any other occupation, about 700,000 of them between now and 2005. The point is that labor economists are not unanimous on what the labor market will look like two or three decades out. Technologically savvy workers will be in demand, but workers with other skills will also be needed.[72]

Paul Krugman of the Massachusetts Institute of Technology observes that technology can have the paradoxical effect of lessening demand for specialized skill. He notes that the value of an innovation typically increases when it makes complex tasks more simple. In the 1980s, for example, most skilled computer users possessed at least a cursory knowledge of computer operating systems. High school computer courses taught students DOS protocols and programming in BASIC. Not anymore. The Macintosh and Windows environments rendered this knowledge obsolete. And yet accurate and speedy keyboarding remains indispensable. In "Technology's Revenge," Krugman describes what this selective obsolescence may mean for future labor markets: "The time may come when most tax lawyers are replaced by expert systems software. But human beings are still needed—and well paid—for such truly difficult occupations as gardening, house cleaning, and the thousands of other services that will receive an ever-growing share of our expenditure."[73]

Chapman accurately points out that a federal technology program rekindles a long-running dispute over the purpose of education, whether schools should emphasize giving students marketable skills or disciplinary knowledge. The history of the school curriculum suggests that society should proceed with caution. Whenever vocational ends have assumed the same urgency as knowledge in mathematics, science, literature, and history, the intellectual underpinnings of the school have been undermined. In 1917 a landmark document, known as the *Cardinal Principles of Secondary Education*, elevated vocational training and satisfying students' personal interests to the same status as disciplinary knowledge. Educational progressives believed these pursuits would make schools more relevant and interesting to students. Historians David Angus and Jeffrey Mirel have shown how the widespread application of this idea precipitated a decline in the rigor of academic coursetaking extending over several decades. Not until the 1980s, when Americans awoke to the fact that students were leaving school without a basic grasp of academic subjects, was the trend reversed and disciplinary content recognized as important again.[74]

A fundamental principle of policy analysis is at work here. How policymakers define "the problem" technology is intended to solve will affect how it is used. Chapman takes the eminently reasonable position that computers and the Internet should be regarded as means to an educational end, not as ends in themselves. I would specifically apply this logic to the school curriculum. If schools use technology to improve the teaching of traditional knowledge, it may yield benefits for education, but to emphasize students' technological competence for the sake of future job preparation is a questionable enterprise.[75]

Even if a consensus is reached that schools need more technology, the question arises whether the federal government is the best vehicle for getting more of it into schools. During the 1980s, it did not take long for the percentage of schools with personal computers to skyrocket. This was accomplished without federal intervention, although Chapman is correct that Title I monies had much to do with the purchase of computers by schools serving poor children. Chapman offers an excellent summary of current federal efforts, but I wish he had cast a more critical eye on how these programs are administered within the federal bureaucracy. Take the issue of fragmentation. Ten federal programs are described, several housed within the Office of Educational Technology in the Department of Education. Programs are also run by the Department of Commerce, the Department of Energy, the Federal Communications Commission, and the National Science Foundation. Doesn't spreading programs over this many agencies make a coherent federal effort more difficult? How can officials be held accountable for producing concrete results when this degree of overlapping authority exists?

Questions pertaining to federalism are equally important. Why run a program involving schools and classrooms out of Washington? After all, states and localities finance 93 percent of K-12 education in the country; the federal government, only 7 percent. Simply identifying a good idea for educational funding is not enough to warrant federal action. More analytical thought is needed about the areas where federal involvement is justified and where it is not, not as an ideological exercise, but from the practical standpoint of finding out which level of government can deliver services most efficiently.

Chapman endorses federal intervention to ameliorate “market failures,” when the private market cannot provide technology to certain segments of the population, such as low-income or rural communities. This is an argument for using policy to redistribute educational resources, a mainstay of federal policy since the 1965 passage of the Elementary and Secondary Education Act (ESEA)—in particular, Title I of that act. ESEA channels funds to communities lacking the resources to acquire technology on their own, which makes sense. As a simple matter of fairness, why should children in poor communities be left behind while middle-class and wealthy children experience the wonders of scientific discoveries and new inventions? A big federal technology program is not necessary for redistribution to occur, however. Augmentation of the Title I program would accomplish the same objective. Washington could also assist local governments in issuing bonds to build a technological infrastructure—laying cables and wires for broadband Internet access, upgrading the electrical wiring of buildings, installing the hardware needed for distance learning.

It is a different matter, however, for the federal government to get involved in deciding how schools use technology. I doubt that Washington is the best place to find answers to these questions. If I were looking for the nation’s top experts on technology, I would look in Silicon Valley, Austin, Boston, or the D.C. suburbs, not in the Department of Education. If I wanted to find experts on teaching, I would talk to successful classroom teachers. So I do not agree with Chapman’s call for teacher training and technical support, a national clearinghouse on software, community technology centers, and a computer civics course—or, at least, I have not seen compelling evidence that the federal government should be the one to initiate these projects. These programs might be appropriate in some local districts, but each district should be left to decide the relative need for each reform. Some might need hardware, some might need technical support, and others might decide that they have more pressing concerns than technology. Many high schools do not offer a civics course, let alone a computer civics course.

There is a deeper problem. Micromanaging instruction through policy has never worked, no matter what level of government has tried it. Teachers respond to the practical—and particular—circumstances of their classrooms, including the characteristics of students and curricula, the demands of parents and administrators, and the reality of local resource constraints. By necessity, policy is based on generalities, what happens to most people most of the time. It also reflects an idealization of what should happen if everything is just right, instead of the messy circumstances in which teaching and learning typically occur. These gaps are evident anytime policymakers attempt to regulate classroom instruction. When the regulation comes from Washington, and is based on the latest fads instead of careful science, the policies are not only intrusive, they are also unhelpful.

Unfortunately, the camel's nose has already slipped under the tent. Federal reports on technology in education show a propensity for condemning "traditional" forms of teaching and endorsing "progressive" pedagogy. The basic tenets of progressive education have been around for a long time, but every generation of educational thinkers puts its own spin on four or five key planks. Frowned upon are basic skills, learning through memorization and practice, and curriculum organized by separate disciplines. For example, the *Report to the President on the Use of Technology to Strengthen K-12 Education in the United States*, issued by the President's Committee of Advisors on Science and Technology (PCAST) in 1997, laments that teachers use computers for "individual instruction in isolated basic skills, most often in a 'drill and practice' mode" and that lessons are "focused on a single content area rather than on the integration of a wide range of skills to solve complex problems."[76] The irony is that PCAST goes on to cite research showing that computers are effective when used in the same way that it condemns—providing basic skills instruction, often through drill and practice, in discrete disciplinary subjects.

Today's progressive education is known as constructivism, the guiding philosophy of the PCAST report. Constructivists believe that students construct their own knowledge, instead of that knowledge exists in an objective form, independent from the learner. If PCAST had its way, technology would be used to completely revolutionize classrooms, with student-centered instruction, cooperative group work, and multidisciplinary projects assuming prominence. The report admits that constructivism's ideas are largely untested. And Chapman is right that constructivism is extremely controversial, questioned especially by parents and teachers who value traditional forms of education. Although it is not appropriate to debate the merits of constructivism here, a critique of the science cited by advocates of constructivism was offered by John R. Anderson and other Carnegie Mellon researchers in *Brookings Papers on Education Policy 1998*. It offers an important lesson for technology policy. Federal pronouncements on how technology should be used in classrooms is an iffy proposition to begin with, but PCAST has compounded the error by endorsing a set of practices that are dubious at best and potentially even counterproductive to academic achievement.

Comment by Linda G. Roberts

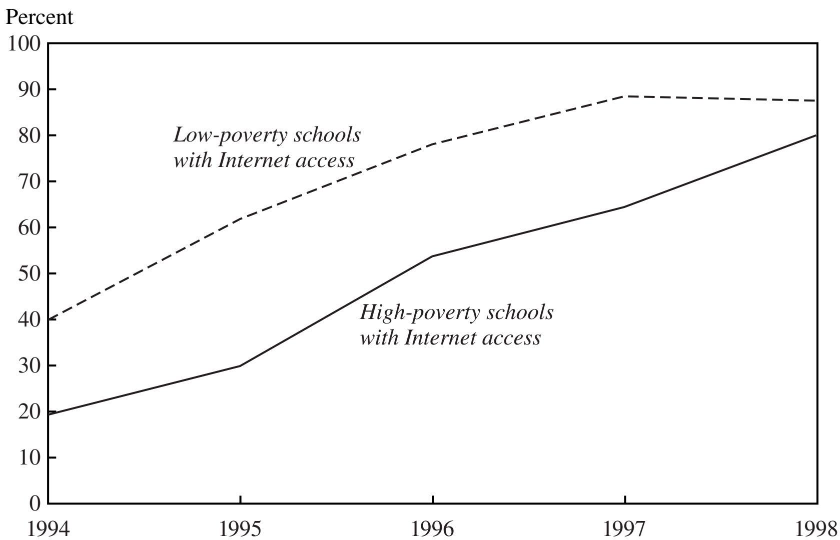
My perspective on Gary Chapman's paper comes from more than a decade of policy analysis on technology and learning for the U.S. Congress Office of Technology Assessment (OTA), coupled with many years of experience as a teacher and university professor and now as director of the Office of Educational Technology and senior adviser to Secretary of Education Richard W. Riley. I have played a key role in initiating and developing the U.S. Department of Education's educational technology policies and programs.

Chapman raises critical questions about how technology is used in American classrooms and its impact on teaching and learning. Programs and policies must be focused on the end result. But attention must also be paid to access, because without access, or even with limited access, much of the promise of technology falls short. The question at all levels of policymaking is not whether technology should be used but how full advantage can be taken of these new tools and resources to provide benefit to all learners. Therefore, policymakers must be concerned about disparities in access as well as disparities in teacher training and operational support. All schools have some computers, and more than three quarters already have some Internet access. But school access cannot be the goal; computers and on-line resources have to come directly to the classroom, just as curricular reform and new teaching materials matter little if they fail to reach students.

In examining technology access, the gap between rich and poor schools has decreased, but the digital divide in classrooms is still real (see figures 1 and 2). The recent Department of Commerce report *Falling through the Net* makes clear why students in poor schools have the most to gain by federal policies and programs that address classroom needs. Those same students are the least likely to have access to technology at home or in their communities.[77] An impact has already been seen of the first round of the E-Rate telecommunications, in which the greatest discounts were targeted to the schools and libraries with the highest concentrations of poverty. In addition, almost 60 percent or $1 billion of the total amount of the E-Rate funds went to the neediest applicants.[78] Moreover, new data confirm that federal technology programs, such as the five-year, $2 billion Technology Literacy Challenge Fund and other programs targeted to disadvantaged students, have helped reduce the technology disparity that would have been far greater without them. For example, while all schools have continually added and upgraded their base of computers, half of the new computers purchased by high-poverty schools were purchased with federal funds.[79]

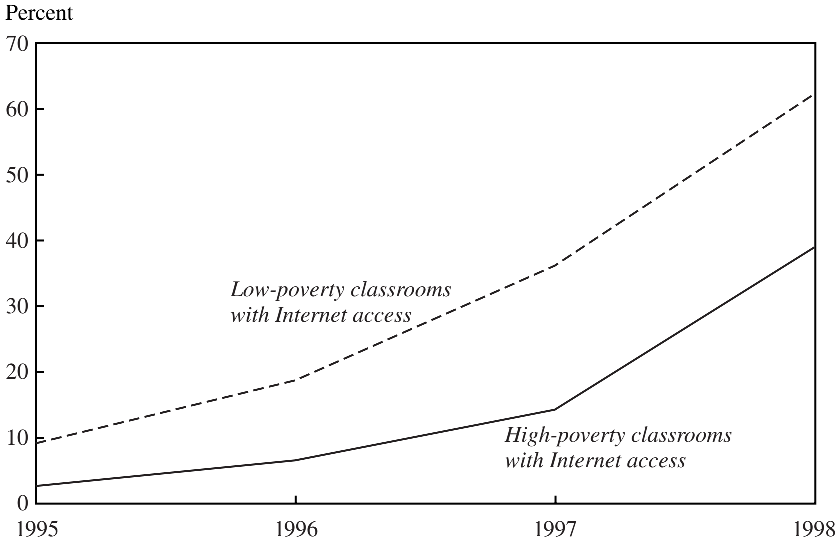
In addition to building the infrastructure and keeping it up-to-date and operational, no technology strategy would be successful without focusing on effective and compelling use of these resources. Here is where teachers and the quality of the content and applications are

Figure 1. Internet Access: Low-Poverty versus High-Poverty Schools



Source: Department of Education, National Center for Education Statistics, *Internet Access in Public Schools and Classrooms: 1995–1998* (Washington, February 1999).

Figure 2. Internet Access: Low-Poverty versus High-Poverty Classrooms



Source: Department of Education, National Center for Education Statistics, *Internet Access in Public Schools and Classrooms: 1995–1998* (Washington, February 1999).

absolutely key. Four equally important goals are part of the National Educational Technology Plan. They are:[80]

1. Provide all teachers the training and support they need to help students learn through computers and the information superhighway.

2. Develop effective and engaging software and on-line learning resources as an integral part of the school curriculum.

3. Provide access to modern computers for all teachers and students.

4. Connect every school and classroom in America to the information superhighway.

As OTA's study and numerous other studies demonstrate, teachers need training, not only in operating equipment or getting on-line, but also in linking the technology resources to curriculum goals, content, and pedagogy. And, yes, this takes time and is not easily accomplished.[81] Recent data from the National Center for Education Statistics are not encouraging. Only 20 percent of full-time K-12 teachers report that they are "fully prepared to integrate technology" in their classrooms.[82] However, the 1998 survey conducted by the University of California at Irvine and the University of Minnesota indicates teachers who use technology have moved well beyond drill and practice, and an increasing number are using computers and the Internet for complex, curriculum-based tasks.[83]

The substantial funding in technology and more recently the investment of both dollars and time for teacher development require evidence that they make a difference. It is time to move beyond the evaluations and analyses that were completed more than a decade ago, because their data and the designs are outdated, given today's technology and new capabilities for teaching and learning.

In the past year, a number of studies have offered new evidence of impact or lack of impact, and they raise important questions. The recent analysis conducted by researchers at Columbia University's Teachers College on West Virginia's grade-by-grade introduction of computers for reading and math shows gains in student achievement, especially for the lowest performing students.[84] Furthermore, these gains are cumulative over time. However, a recent analysis of the National Assessment of Educational Progress mathematics achievement among fourth and eighth graders raises questions about the value of drill and practice, especially for eighth graders, but show positive impacts for problem-solving and math simulation applications.[85]

OTA's 1988 report *Power On!: New Tools for Teaching and Learning* called on Congress to invest in educational research and development (R&D), with levels comparable to the Manhattan Project.[86] More recently, the *Report to the President on the Use of Technology to Strengthen K-12 Education in the United States* called for concentrated broad-scale initiative.[87] Up until now these calls have had little influence. What factors contribute to a concerted effort now? Given the large and growing base of technology, and the significant level of investment at all levels, local educators, state leaders, members of Congress, and the research community are demanding results, and there is so much more to analyze.[88]

I have five recommendations that would advance the nation's use of computers, new interactive tools, and on-line resources and telecommunications in powerful and beneficial ways. These recommendations underlie the Department of Education's proposed Title III, Technology for Education, in the reauthorization of the Elementary and Secondary Education Act (ESEA).

1. Close the digital divide. With full funding for the E-Rate ($2.25 billion annually), all schools and libraries can have affordable access to telecommunications services, the Internet, and internal connections to the

classrooms. The Department of Education proposes to target funding to the poorest and low-performing schools in the Technology Literacy Challenge Fund and other related programs.

2. Focus on teaching and quality teachers. While technology must be a component of teacher training and teacher preparation, the quality and preparation overall is critical. Increased emphasis on professional development that incorporates technology can help reach more teachers in the field. The opportunity to reach the next generation of teachers must not be missed. As programs prepare teachers in their content areas and provide prospective candidates with field experiences, technology applications must be integrated. Preparing Tomorrow's Teachers to Use Technology is a new program that needs to continue.

3. Raise the standards for content and high-quality software and Web-based learning resources. Technology development is largely the responsibility of the commercial sector, and software publishers look to the education community for guidance. An increasing number have begun to build products around state and national content standards, especially in areas where broad consensus and agreement exist over the standards. Research studies, such as the recent National Research Council report *Preventing Reading Difficulties in Young Children*, can have broad influence, especially if the states and districts bring these findings to the attention of developers and provide clear signals about market demand.[89] The federal government can help bring the parties together. Reading instruction is one of the most promising areas for new development, not only because of the substantial knowledge base about reading and its acquisition, but also because new technological capabilities, such as speech recognition, are coming into development. Now is the time to merge insights from research with the creative minds in the software industry.

The federal role can also encourage much broader development of content, from teachers and students in classrooms to faculty on campuses in research centers, with tools that enable collaborative and shared development. Several efforts already highlight teachers' lesson plans, and many federally funded projects share their content development on-line, but much more can be accomplished.

4. Help the education community look to the future; invest in research and development. All projections of technology suggest that costs will decline while power and capability will increase. Education ought to be at the front line, involved in new development, with schools serving as test

beds for new technology and applications. As the federal government invests in information technology R&D, learning applications have to be part of the mix of the R&D portfolio. The Next Generation Innovation Awards Program in Title III of the ESEA reauthorization proposal could help accomplish that goal.

5. Fund evaluation. The time has come to ask hard questions, gather serious data, improve the tools for assessment and evaluation, and conduct serious evaluations.[90] Student achievement must be determined, using both traditional measures and tools that capture new skills and new ways of learning. The imperative now is to develop better diagnostics, better tools for student and teacher self-assessment, multiple-site classroom evaluation protocols, and other new tools, many of which can be imbedded in the technology applications.

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