Chapter 1

Summary

Information technology Is proving to be invaluable to people of all ages

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Modern society is undergoing profound technological and social changes brought about by what has been called the information revolution. This revolution is characterized by explosive developments in electronic *information technologies* and by their integration into complex information systems that span the globe. The impacts of this revolution affect individuals, institutions, and governments–altering what they do, how they do it, and how they relate to one another.

If individuals are to thrive economically and socially in a world that will be shaped, to a large degree, by these technological developments, they must adapt through education and training. Already there is evidence of demands for new types of education and training, and of new institutions emerging to fill these demands. The historical relationship between education and Government will be affected by the role that Government plays in enabling educational institutions to respond to the changes created by these technologies.

Background

Historically, the Federal Government's interest in educational technology has been sporadic—rising as some promising new technology appeared and falling as that technology failed to achieve its promise. Attention was focused, moreover, on the technology itself and not on the broader educational environment in which it was to be used. In the late 1960's, for example, the Federal Government funded a number of research and development (R&D) projects in the use of computer-assisted instruction (CAI). Interest in the projects waned, however, given the high costs of hardware and curricula and the failure to integrate computer-based teaching methods into the institutional structure of the school.

Over the last decade, Federal funding for R&D in educational information technology has dropped precipitously. At the same time, development and applications of information technology have advanced rapidly in many sectors. Public schools, beset by problems that such technology might mitigate, have lagged behind in adapting to technological changes. In view of this situation, OTA was asked in October 1980 to reexamine the potential role of new information technology in education.

The assessment was initiated at the request of: 1) the Subcommittee on Select Education of the House Committee on Education and Labor; and 2) the House Subcommittee on Science, Research, and Technology of the Committee on Science and Technology.

This report examines both the demands the information revolution will make on education and the opportunities afforded to respond to those demands. Included in its scope are a survey of the major providers of education and training, both traditional and new, and an examination of their changing roles. The full range of new information products and services rather than any single technology is examined, since the major impact on education will most likely stem from the integration of these technologies into instructional systems.

For this report OTA has defined *education* to include programs provided through a variety of institutions and in a variety of settings, including public schools; private, nonprofit institutions that operate on the elementary, secondary, and postsecondary levels; proprietary schools; training and education by industry and labor unions; instruction through the military; and services provided through libraries and museums or delivered directly to the home. *Information technology* is defined to include communication systems such as direct broadcast satellite, two-way interactive cable, low-power broadcasting, computers (including personal computers and the new hand-held computers), and television (including video disks and video tape cassettes).

The assessment was premised on three initial observations and assumptions:

- The United States is undergoing an information revolution, as documented in an OTA assessment, *Computer-Based National Information Systems.*
- There is a public perception that the public schools are "in trouble," and are not responding well to the normal educational demands being placed on them. Public schools in many parts of the country are faced with severe economic problems in the form of rapidly rising costs and reduced taxpayer support. These pressures are forcing a new search for ways to improve the productivity and effectiveness of schooling.
- A host of new information technology products and services that appeared capable of fulfilling the educational promises anticipated earlier are entering the marketplace with affordably low cost and easy accessibility.

Findings

OTA found that the real situation is far more complex than assumed above. In summary, the assessment's findings are:

- The growing use of information technology throughout society is creating major new demands for education and training in the United States and is increasing the potential economic and social penalty for not responding to those demands.
- The information revolution is creating new stresses on many societal institutions, particularly those such as public schools and libraries that traditionally have borne the major responsibility for providing education and other public information services.
- Information technology is already beginning to play an important role in providing education and training in some sectors.
- Information technology holds significant promise as a mechanism for responding to the education and training needs of society, and it will likely become a major vehicle for doing so in the next few decades.
- Much remains to be learned about the educational and psychological effects of technological approaches to instruction. Not enough experience has been gained with the new information technology to determine completely how that technol-

ogy can most benefit learners or to predict possible negative effects of its use. Given this insufficient experience, caution should be exercised in undertaking any major national effort, whether federally inspired or not, to introduce these new technologies into education.

The Information Society

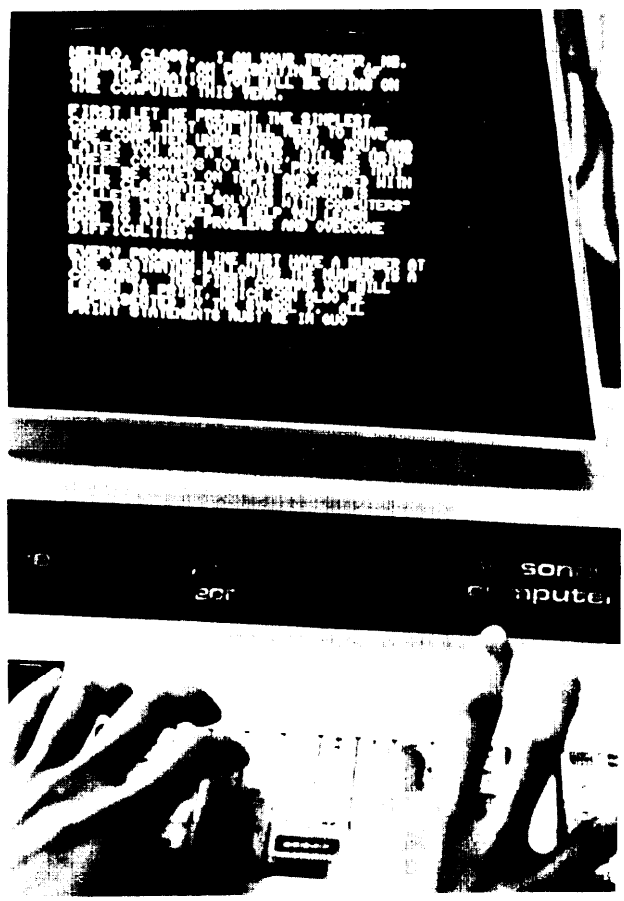
Role of Information

For the foreseeable future, information technology will continue to undergo revolutionary changes. The microprocessor-an inexpensive, mass-produced computer on a chip-will become ubiquitous in the home and office—not only in the easily identifiable form of the personal computer or word processor, but also as a component of numerous other products, from automobiles to washing machines and thermostats. High-speed, low-cost communication links will be available in such forms as two-way interactive cable, direct broadcast from satellites, and computer-enhanced telephone networks. New video technologies such as video disks and high-resolution television will be available. These technologies will be integrated to form new and unexpected types of information products and services, such as videotex and on-line information retrieval systems that can be provided over telephone or air waves directly to the home.

It is impossible to predict which of these technologies and services will succeed in the competition for consumer dollars, or which will appeal to particular markets. It is, however, reasonable to conclude that they will radically affect many aspects of the way society generates, obtains, uses, and disseminates information in work and leisure.

The growing importance of information itself drives and is driven by these rapid technological changes. Until a few decades ago, the information industry—that industry directly involved with producing and selling information and information technology-was relatively small in economic terms. It is now becoming a major component of the U.S. economy. While most economists still talk about the traditional economic sectors—extractive, manufacturing, and service—some now have begun to define and explore a fourth, the information sector. One analysis has shown that this new sector, if defined broadly, already accounts for over 60 percent of the economic activity of the United States.

Many firms involved directly with information are large and growing. Two of the largest corporations in the world, AT&T and IBM, principally manufacture information products



Personal-type computers are used for instruction in many classrooms throughout the Nation

and provide information services. Moreover, business in general is beginning to treat information as a factor of production that takes its place beside the conventional factors of land, labor, and capital. In addition, the Government is beginning to treat information as an important element of national security. While defense officials have always been concerned about the disclosure of military information—such as troop movements or weapons design—they are now also concerned about the international leakage of more general U.S. scientific and technical information that other countries could conceivably use to pursue economic or military goals that are in contrast to our own.

In addition to serving as an economic good, access to information is becoming increasingly important for individuals to function in society effectively as citizens, consumers, and participants in political processes. Relations with government at all levels are becoming more complex—whether they involve dealing with the Internal Revenue Service, applying for social benefits and services, or seeking protection from real or perceived bureaucratic abuse. Individuals are confronted with the need to evaluate more sophisticated choices and to understand their rights and responsibilities under the laws and regulations intended to protect them in the marketplace.

Information Technologies

The rapid evolution of the following technologies in the last few decades has shaped the information revolution:

Cable.–Cable systems–wherein data and programs are transmitted over a wire rather than through airwaves-are growing rapidly. The newer systems offer more channels, and some offer two-way communication.

Satellite Communication.—Satellites have stimulated development of new types of television networks to serve cable subscribers and earth station owners with specialized programming.

Digital Telephone Network.—The shift to digital transmission will allow telephone lines to carry more information at higher speed and with greater accuracy, providing better linkage of information between computer terminals.

Broadcast Technologies.—Some distribution technologies in the entertainment market may also have important potential educational uses. For one, the *direct broadcast satellite can* transmit a program directly to a home or office, bypassing a cable system. For another, *low-power stations,* which restrict transmission to a limited geographical range, provide a low entry cost to licensees and are subject to less regulation than are traditional broadcast stations.

Computers.—The design and uses of computers have advanced to the point where there is now a mass consumer market for computers and computer software. Moreover, networks that link privately owned computers have expanded access to information. *Desktop computers are* becoming more common in the home, the small business, and formal educational settings. The use of *hand-held computers,* cheaper and more portable than desktop computers, has also increased. Along with computer development have come advances in the interface between humans and computers—input/output technology. Input technology is the process of putting information into the computer—either by typing it, speaking to the computer, or showing the computer pictures. Developments in output technology are occurring in the areas of low-cost printers, graphics (particularly color graphics), and voice.

Storage Technology.—Data programs are stored on a variety of media for use in the computer: silicon chips, floppy disks, and hard disks. Improvements are being made in such technology for both large and small computers.

Video Technology.–Significant developments in several areas of video technology are

likely in this decade. *Video cassette recorders are* already important consumer devices. The *filmless camera,* which combines video and computer technology to "write" a picture on a very small, reusable floppy disk, may soon be available.

Video Disks.— Resembling a phonograph record, a disk that stores television programming is of considerable interest to educators. It is durable, inexpensive to produce, and capable of storing a large amount of data and programs.

Information Services. -Several of the aforementioned information technologies are now being integrated to provide new types of services. For example, several countries now use the existing television broadcast medium to bring information services to homes and offices. Using a *teletext* system, the user can select a page for special viewing as it is transmitted in segments over the air. In a videotex system the user can preselect a page from the central system for immediate viewing. Closely related to videotex are the *information networks* that provide owners of desktop computers and terminals with access to computer and data services and to one another over communication networks. Through *electronic conferencing,* geographically separated individuals can participate in meetings. Variations include *audio conferencing,* which uses telephone lines; *video conferencing,* which supplements the voice connection with television images; and *computer conferencing,* which involves transmitting messages through a central computer that then distributes them as requested.

Impacts on Institutions

Impacts from the information revolution are being felt by government at all levels and by the military, industry, labor unions, and nonprofit service institutions. Traditional services provided by these institutions now overlap in new ways and offer a wide variety of new services based on information technology. For example, firms as diverse as investment houses and retail stores now compete with banks by providing a variety of financial services. Banks, on the other hand, are beginning to compete with computer service bureaus in providing more general on-line information services to businesses and homes.

The U.S. Postal Service, along with Congress and a variety of Federal executive and regulatory agencies, is considering the degree to which it should compete with private telecommunications firms in the provision of electronic mail services. Large computer firms such as IBM are moving toward direct competition with traditional telecommunication common carriers such as AT&T for the provision of information. Telephone companies may offer "electronic yellow pages" that could rival the classified advertising business of newspapers.

Those institutions principally concerned with the collection, storage, or transfer of information will feel the greatest effects. They include both private sector firms—in fields such as publishing, entertainment, and communications—and public or nonprofit organizations such as libraries, museums, and schools. How they handle their product—information–may differ from the handling of tangible goods by other institutions because information has characteristics that differentiate it from tangible goods. For example, information can be reproduced easily and relatively inexpensively. It can be transported instantly worldwide and presumably can be transferred without affecting its original ownership. Thus, copyright or other forms of protection for intellectual property—data bases, programs, or chip designs-is important to the growth of the information industry.

While the business of selling information has always existed in some form–e.g., book publishing, newspapers, or broadcasting–the growth of this sector and its movement into electronic forms of publishing will create conflicts with traditional societal attitudes about information. The concept of information as a public good whose free exchange is basic to the functioning of society is inherent in the first amendment to the Constitution and underlies the establishment of public libraries

and schools. This concept conflicts with the market view of information, which recognizes that there are inherent costs in the provision of information. Adopting new information technologies will entail extra costs that must be borne somehow by the users of those technologies.

The conflict between the view of information as a market good and the view of it as a "public good" affects public institutions in a number of ways. Public nonprofit institutions find themselves increasingly in competition with private profitmaking firms that offer the same or similar services. Institutions such as libraries, schools, and museums are beginning to feel pressure to incorporate both nonprofit and income-generating offerings in their own mix of services. To the extent that previously free or very low-cost and widely available information services such as education move into the private marketplace, access to them may become limited, either because of their cost or because of their restricted technological availability. Periodicals previously available at newsstands, for example, may be available in the future only via computer or video disk.

New Needs for Education and Training

The information revolution places new demands on individuals, changing what they must know and what skills they must have to participate fully in modem society. It may also be increasing the social and economic prices that will be paid by those who do not adapt to technological changes. For instance, spurred by increasing domestic and international economic competition, U.S. industry is expected to adopt computer-based automation in a major way. Computer-aided design, robotics, and other new computer-based manufacturing technologies will, within the next decade, transform the way goods are manufactured. Automation will not be restricted to the factory, however. Office automation will, according to some, have an even more revolutionary effect on management and on clerical work in business. Over the longer term, even the service professions, such as law and medicine, will be transformed.

While some sociologists suggest that the effect will be to "deskill" labor by lowering the skill requirements for workers, more anticipate that a greater premium will be placed on literacy, particularly technological and information literacy. The latter argue that an increasing number of jobs will be in the information sector or will require the use of information systems. Moreover, new forms of production and information handling will create new jobs requiring new skills. Vocational education and industrial training programs will be needed to teach the skills for jobs such as robot maintenance or word processing.

An advanced information society will place a premium on skills oriented toward the creation of new knowledge and the design of new technologies. Thus, while there is some current debate about a possible surplus of college graduates, generally speaking many experts see a growing gap between the demand and supply of graduates in engineering and science, and particularly in computer engineering and science.

A key element in all of these educational needs is that they will constantly change. In a rapidly advancing technological society, it is unlikely that the skills and information base needed for initial employment will be those needed for the same job a few years later. *Lifelong retraining is expected to become the norm for many people.*

Case Studies on Information Technology

In addition to using existing information for this assessment, OTA undertook case studies designed to gain insights into the successful application of information technology in education. Accordingly, OTA examined well-established programs in public school systems, industries, libraries, museums, the military, special education, and direct to the home markets nationwide. These case studies are presented in the appendix. Many of the find-

ings presented in this assessment reflect observations made in these studies. *The most important of these observations is that information technologies can be most effectively applied to tasks when they are well integrated in their institutional environments.*

Potential Technological Solutions

OTA found little evidence of current hardware limitations that would limit the applicability of technology to education and, hence, call for major research efforts. Continuing research in the general fields of computer science and engineering, coupled with innovative private sector development will provide the necessary hardware base. The only exception is the area of technology for the handicapped, where it is not clear that the opportunities for developing specialized technology could be met without some Federal support for R&D. There does appear to be a need, however, for R&D focused on developing new techniques and tools for software development, human/machine interface, and improving the understanding of cognitive learning processes.

If properly employed, information technology has certain characteristics that suggest it will be invaluable for education. For one, information technology may be the only feasible way to supplement teaching capability in schools faced with reduced teaching staffs and larger class sizes. For another, information technology is capable of distributing education and training, both geographically and over time. Services can be provided in the home, at work, in a hospital, or in any other location where and when they may be needed.

Many of the electronic media, such as video disks or microcomputers, allow learners to use them at their convenience, instead of being locked into specifically scheduled times. Computer-based analysis, combined with a flexible, adaptive instructional system could diagnose and immediately respond to differences in learning strategies among students and, hence, could be more educationally effective. Finally, much work has been done on using information technology to improve the ability of foreign students and the physically and mentally handicapped to communicate.

Some experts suggest that the use of computers by students teaches them new ways of thinking and new ways of solving problems that may be more appropriate in an information age. They suggest that a generation that grows up with computers will have a significant intellectual advantage over one that does not. Many educators criticize such a view as being too technology-centered. At the very least one can predict, however, that computer and computer-based information services will be ubiquitous by the next century, and that learning how to use them effectively is a basic skill that will be required for many and perhaps most jobs. (In response to this view of future skill requirements, many schools have placed a high priority on computer literacy as the first instructional use of the computer.)

Although experience with educational technologies has demonstrated that they offer a variety of potential benefits, it has also demonstrated that technology cannot, by itself, provide solutions to all educational problems, nor should it be imposed on an educational system without sensitivity to institutional and societal barriers that could prevent the realization of educational benefits. These barriers include:

Institutional Barriers.--New educational technology must be designed for ease of integration into the schools and other educational institutions that will use it. Some adaptations of curricula, schedules, and classroom organization will be needed, but the changes are not likely to be extreme.

Teacher Training.–Widespread use of technology in the classroom will require that teachers be trained both in its use and in the production of good curriculum materials. Too few teachers are so qualified today. Schools maintain that they are already faced with a shortage of qualified science and mathematics teachers (those most likely to lead the way in computer-based education). Furthermore,

there is little evidence that most of the teacher training colleges in the United States are providing adequate instruction to new teachers in the use of information technology.

Lack of Adequate Software.--OTA found general widespread agreement that, with few exceptions, the quality of educational software-curriculum material designed for educational technology-now available was, in general, not very good. Curriculum providers do not yet use the new media to full advantage for several reasons. In the first place, many of the technologies are still new. It takes time to learn how to use them, and the early attempts suffer from this learning process. Second, production of high-quality educational software is expensive. Some large firms that have the necessary capital to produce educational software hesitate to risk developmental money in a relatively new and uncertain market.

Third, the programmers and curriculum experts qualified to produce educational software are in short supply. Finally, some firms cite the lack of adequate property protection —e.g., copyright, patents—for their information products as a barrier to investment in development.

Skepticism About Long-Term Effects.– Some educators are seriously concerned that the long-term effects on learning of substituting technology for traditional teaching methods are not sufficiently understood. While acknowledging that computers or other technologies may have some limited utility in the classroom for drill and practice, or for instruction in computer literacy, they fear that any widespread adoption of technology for education could have deleterious effects on the overall quality of learning.

Cost.–Even though the cost of computer hardware and communication services is dropping, investment in educational technology still represents a substantial commitment by financially pressed schools. Costs of software are likely to remain high until a large market develops over which providers can write off developmental costs. In some cases the cost of information products and services may be passed on to users for the first time.

Policy Issues and Options

Issues

The impact of information technology on education will confront Congress with a number of important policy decisions in several areas:

- *Education and training for economic growth:* OTA found that trends in automation and the growth of the information sector of the economy will probably present the United States with severe manpower training problems over the next decade. These will include a persistent shortage of highly trained computer scientists, engineers, and other specialists; a need for retraining workers displaced by factory and office automation; and a need for a more technologically literate work force. Congress must decide what Federal response to these national needs would be both appropriate and effective.
- *Redressing inequities:* In both the OTA study on national information systems and in this assessment, OTA found concern that a significant social, economic, and political gap could develop between those who do and those who do not have access to, and the ability to use, information systems. People who cannot make effective use of information technology may find themselves unable to deal effectively with their government and to obtain and hold a job. Both social and economic concerns may motivate Congress to take action to improve literacy in American society.
- New *institutional roles:* OTA found that many public educational institutions are

under severe strain, to the extent that many question their survival-at least in their current form. Actions directly related to the use of information technology could also have important impacts on these public educational institutions, both by enhancing their productivity and by helping them offer a modern, computer- and communication-based curriculum. Although the States have primary responsibility for control of the public schools, decisions and policies set at the Federal level have influenced the nature of public education and will continue to do so.

Options for Federal Action

Assuming that Congress decides there is a significant need for Federal action to address these issues, there are a number of possible actions it could take.

- Direct Intervention.—Congress could take action to increase and improve the use of information technology in education. Most of the following options would principally affect the schools. A few would have a broader effect on the provision of education and training in other institutions.
  - –*Provide tax incentives for donations of computers and other information technology:* H.R. 5573 and S. 2281 are examples of such initiatives. They are intended to accelerate the rate at which schools install computer hardware and to respond to possible inequities in the abilities of school districts to direct funds to equipment acquisition. However, some experts have noted that the personal computer industry is on the verge of moving to a new generation of more powerful machines that may have much greater potential for educational application on a more sophisticated level. Donations of older equipment could freeze the schools into dependency on obsolescent systems. Moreover, such incentives do not address problems such as the need for software, teacher training, or institutional barriers to effective use.
  - –*Subsidize software development:* OTA found that the most-often cited barrier to current educational use of technology was the lack of adequate educational software. There may be a role for the Government in reducing the risks software producers currently see that inhibit major investment in quality courseware (educational software). Many of the existing successful packages, such as the Sesame Street programs for television and the PLATO computer-aided instruction system, were developed with partial Federal support. On the other hand, good software may be forthcoming if the producers see a sufficient quantity of hardware in the schools to provide them with a viable market.
  - –*Directly fund technology acquisition by the schools:* The Federal Government could directly underwrite the acquisition of hardware and software by the schools. Such a program would create a market for educational products that would attract producers, and it would accelerate the introduction of technology into the schools. On the other hand, such an approach may promote premature and unwise purchases of technology by schools that are unprepared to use the technology effectively. It is also counter to some current trends and attitudes in Congress concerning the proper Federal role in education.
  - –*Provide support activities:* The Federal Government could assume a leadership role in encouraging the educational system to make more effective use of information technology by funding demonstration projects, teacher-training programs, and the development of institutions for exchanging information about successful implementations. OTA found evidence of a high degree of interest and motivation by both schools and parents that could be more effectively channeled with appropriate Federal leadership. Such a program would not address the financial limitations that currently prevent many institutions from acquiring technology and software.
- Adapt a General Education Policy.—Congress is considering various forms of education-related legislation that may affect, and

in turn maybe affected by, the new informational needs of society. Examples are bills concerning vocational education, veterans' education, education for the handicapped, and foreign language instruction. Such legislation, if drafted with the intent to do so, could encourage the development of more effective and economical technological alternatives to current programs.

- Support R&D.–Federal civilian agency support of R&D in educational technology has decreased substantially over the last decade. OTA found that, to make the most effective use of technology, there was a need for R&D in learning strategies and cognitive development, methods for the production of effective and economical curricular software, and the long-term psychological and cognitive impacts of technology-based education. Congress could consider policies to: 1) directly support R&D in these areas, 2) encourage private sector investment from both foundations and industry, or 3) encourage a combination of both by using Federal funding to leverage private investment.
- Elimination of Unintended Regulatory Barriers.--Some legislation and regulation not specifically directed at education may create barriers to the effective application of educational technology. Telecommunication regulation, for example, can affect the cost of technology, access to communication channels, and the institutional structure of education providers.

  Moreover, protection of intellectual property, principally copyright law, was identified as a major determinant of the willingness of industry to invest in educational software. The current state of the law was seen by many industry experts as inadequate and, hence, as creating a barrier to the development of novel and innovative software. However, to the extent that such a barrier does exist, it is not clear whether its removal lies in new legislation or in the gradual development of legal precedent in the courts.