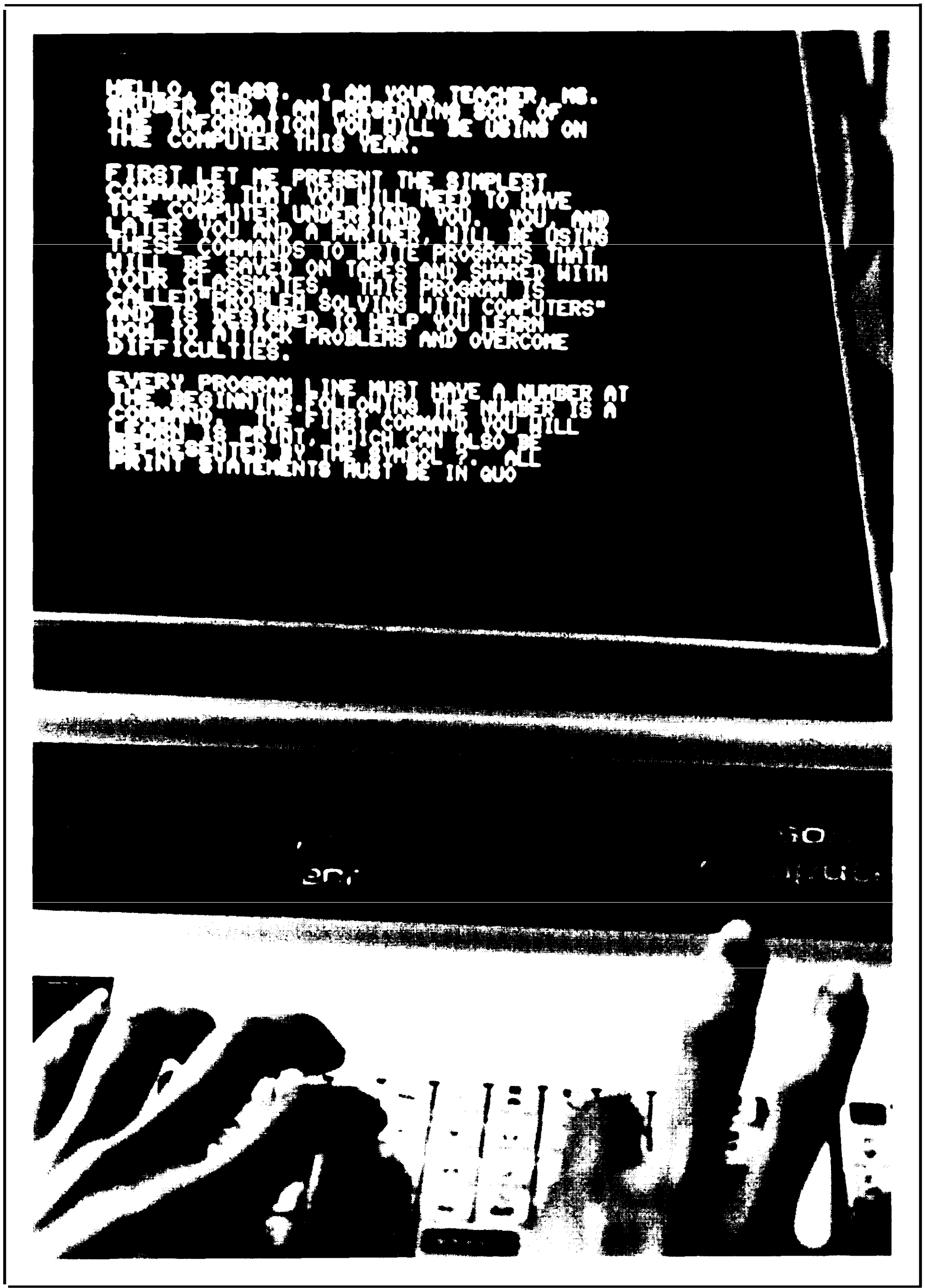
Chapter 5

Educational Uses of Information Technology



An elementary school teacher in Lexington, Mass., prepares a program for presentation to her students

Chapter 5

Educational Uses of Information Technology

Since the development of the radio, people have proposed that communications technology provide major improvements in the delivery of education. Research on "teaching machines" dates back to the 1940's, before the general introduction of computers into the marketplace. Since that time, there has been continual research, development, and implementation of techniques for using information technology in various aspects of education.

OTA investigated what is known and what has been proposed about possible applications of information technology to education.

Findings

- Information technology is capable of becoming a major resource for the delivery of educational services over the next decade:
  - It can be an effective delivery mechanism for most existing forms of education.
  - It provides capabilities for responding to new demands that traditional schoolroom education cannot meet adequately.
  - The cost of information products and services for educational applications will continue to drop with respect to other items in the educational budget.
- The principal benefits will be realized from combinations of new technologies rather than from any single device.
- Most educational applications will be based on hardware technology that is originally developed for a broader consumer market. The only exceptions will be devices designed for specialized industrial uses–e.g., flight training for airline pilots-or education and training for the handicapped.
- It is impossible to predict with certainty the technological base that will exist for educational use. Some of the products and services now projected for the next decade, and described in chapter 4, may not survive the competition for the consumer's money. This uncertainty may inhibit the rapid development of software and services particularly oriented to the education market.
- The provision of high-quality, reasonably priced educational software is the principal technological challenge. Low-cost hardware will be widely available to most homes, offices, and schools.

Functions of Educational Technology

There are a variety of ways in which computers and communications technology can provide educational services. In some cases, different types of applications will require different technologies; in other cases, the same type of technology can be used to provide different types of services.

Passive Instruction

The oldest instructional use of information technology is simply to present information. The textbook is the traditional passive instructional system. Projection media-slides, filmstrips, overhead transparencies, and pictures

—are more modern forms. Educational radio and television have experienced quiet but steady growth since the late 1950's and early 1960' s.' Video cassettes and video disks will provide even more flexible tools for presenting video-based instructional material.

The best known recent examples of passive instructional programing are the "Sesame Street" and "Electric Company" programs produced by The Children's Television Workshop with partial Federal support. These programs were intended to supplement, not replace, normal schooling. Sesame Street is intended to teach preschool children some basic concepts and learning attitudes. Electric Company is principally aimed at supplementing reading instruction at the grammar school level.

At the other extreme, a full alternative to traditional education is the "Open University" in Britain, which has conducted a full college degree program for over 11 years, based principally on passive instruction using the broadcast networks. In the United States, the Corporation for Public Broadcasting is developing an educational program along similar lines in cooperation with universities across the country.

New technology for video production is also having an impact on educational uses. *Computer animation* systems have become considerably less expensive than older, hand animation techniques. *Video processing* uses computers to perform elaborate modification of video images. Both of these technologies are widely used in commercial television and motion pictures, but they are also particularly attractive for instructional application in which concepts and processes that are subtle and difficult to visualize need to be illustrated. Complex physical processes, such as fluid flow or load stresses on structures such as bridges, can be simulated on a computer and displayed as dynamic graphic images. In addition, video cassette recorders (VCRs) and video disks promise to relieve students from the dictates of schedule. The VCR, in particular, allows—copyright law permitting-instructors and students to copy instructional programs off the air and play them back at some later time. Video cassettes and video disks will provide alternate modes of broadcasting for the distribution of instructional material.

Passive instruction systems have the following characteristics:

- All educational decisions are in the hands of the providers; what information is to be presented, for how long, in what sequence, and even—in the case of such current instructional broadcasting—the schedule—when it is shown.
- The boundaries between entertainment, public information, and educational services can become blurred. A Shakespeare play, a concert, or an informational series such as the successful Cosmos series carried by the the Public Broadcasting System, may all be considered important instructional resources as well as entertainment.

Interactive Instruction

This technology is used to teach a specific subject or skill directly to a student, guiding the learner through a sequence of steps involving the presentation of information, drills, and exercises designed by an instructor. Interactive instructional systems require the student to communicate with the device, allowing the system to vary the pace of instruction, select among alternate sequences of presentation, test for understanding, and alter the content according to the specific needs of the individual.

Computer-assisted instruction is the best known interactive technology. A student sitting at a computer terminal works through a series of "frames" that teach and test understanding.* If the student is progressing slowly, the computer branches to an alternate style

IP. J. Dier and R. J. Pedone, Uses *of Television for Instruction, 19761977,* NCES/CPB, 1979.

*A "frame" is a display on the television screen in a SAI system. The term dates back to programed learning research in which a frame was a unit of material presented at one time.

Capitol Children's Museum, Washington, D. C.—Consternation is a constant in the first phases of instruction . .

. . . but the student's discovery of wrong responses . .

. . . is followed by the sense of reward for right responses which makes the anxiety of exploring the unknown bearable

of presentation or a remedial section. If the student has mastered that section, the computer jumps ahead to more advanced material.

The Plato system was one of the better known experiments. It was developed by researchers at the University of Illinois and Control Data Corp. With principal funding from the Federal Government, the system originally combined a new type of interactive graphics terminal with a large multiterminal computer system and an elaborate language specifically designed to create instructional programs. While Plato was originally a very expensive experimental system, most of its underlying concepts survive in commercial instructional systems now marketed by Control Data.

Four factors have more recently revived interest in interactive instruction: 1) the rapidly declining costs of computers and the advent of the desktop computer, 2) the escalating labor-intensive costs of traditional schooling, 3) an improved understanding of how to create instructional packages, and 4) the development of alternative delivery mechanisms that link the computer with other technologies, such as video disk and interactive cable.

The video disk is a good example of how new technologies can be combined to form instructional systems. The video disk contains an extensive data base of text, still images, and film. The computer controls the sequence of presentation and, using an educational program contained on its floppy disk and information stored in the remote data base, interacts with the student.[2]

The video disk, for example, might contain several thousand images of microscope slides. The data base would have full descriptive information on the subjects illustrated by the slides, indexed in various ways. Educational software on the computer would take a student through sequences of slides and text presentation, providing information and administering tests. While the computer program would be designed to achieve a specific instructional purpose, the slide catalog and data base would be intended to be more widely applicable for research and education.

[2]L. F. Eastwood, "Motivation and Deterrents to Educational Use of 'Intelligent Videodisc' Systems, " *J. Ed. Tech Systems, vol. 7(4), 1978-79, PP. 303-335.*

Several experiments are under way to develop instructional packages using combinations of video disks and personal computers. The Minnesota Educational Computing Consortium is developing a series of video disks in basic economics. The first disk of a planned 6-disk series has been produced and tried in the classroom with favorable results. Other companies are developing products aimed at the industrial training market; and a few firms, such as IBM, are already using interactive video disks for employee training.

Interactive instructional technology has the following characteristics:

- It allows the system to customize teaching to the particular level of understanding, learning style, and ability of each individual student.
- The system can be designed so that students can pace themselves.
- Because individualization and self-pacing may not fit well with traditional schooling, large-scale implementation of interactive instructional technology in the schools may engender substantial institutional resistance.
- Instructional software is often divided into discrete packages, each designed to teach a specific skill or item of information. An instructional curriculum (say, a fifth grade mathematics course) is a collection of these packages, which, for a full course, may number into the hundreds.
- Extensive design effort is needed to create each module. The material to be taught must be broken down into frame-sized pieces. Tests of understanding must be devised, and the paths that students are most likely to take in going through the material must be anticipated.
- Because they are so carefully tailored, interactive curricular packages are inflexible. They are not generally useful for any purpose, clientele, or environment other than the specific one for which they were designed.
- The skills required both to produce software and to assist students with its use are substantially different from traditional teaching skills.
- Some experts suggest that smaller instructional modules can be designed to fit into the regular course of instruction, permitting a gradual introduction of educational technology. Others maintain that the principal educational benefits of technology are lost with such an incremental approach.

Learning Environments

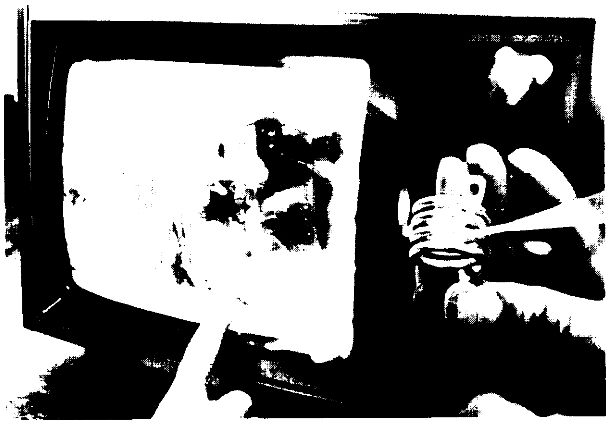
The interactive instruction technology described above can be used to create a special environment-a language, simulation, or data base–that can be manipulated by the student.

For example, special computer languages, such as LOGO, can help learners gain particular problem-solving skills. Languages such as VISICALC, a system designed for business users of small computers, can be a powerful tool in teaching accounting principles and financial planning techniques.

Another form of learning environment is the simulation. A simulation of a laboratory experiment for a physics course, for instance, might present on a television screen a variety of weights and springs. The student would be allowed to “connect” them in various configurations, to apply forces of prescribed amounts at different points in the arrangement, and to measure and record the results. Working with this system for only a few days, a student would learn some basic principles of mechanics. As another example, large-scale simulations can be made of physical processes or of equipment that might be too expensive or dangerous to use in person. Simulated nuclear powerplants provide vehicles for training new operators; simulated aircraft are used for pilot training.

For medical education, computer-controlled robots can be used to simulate injured or ill human beings. A small computer presents the student with an instructional sequence where proper techniques are illustrated using a computer-controlled video disk. The student then

At Fort Gordon, Ga., Signal Corps Center, video simulation is used to teach repair techniques. If instructors were to use actual equipment, it would have to be returned to a repair shop for costly work and expensive 'downtime'



The actual coil shown on right, whose removal and respacing would require costly downtime for the instructional radio set. The student is given the learning experience by TV instead, testing his notion of the proper technique against solutions stored on the random-accessed video disk

practices on a dummy equipped with sensors monitored by the computer, which, in turn, presents the results to the student.

Simulations of economic and social systems are used to teach political science, economics, and management. Business management games are one of the earliest educational applications of computers, and they have been deeply integrated into the curricula of many business schools. Other educational applications range from simple economic simulations on small computers to elaborate simulations of city management and international politics that require very large computer systems. The Defense Department makes extensive use of computer-based simulations to train senior decisionmakers in crisis management.

Using information technology to provide a learning environment has several implications:

- An instructional program can be applicable over longer course periods and for a greater variety of educational uses than can an interactive module that concentrates on a single teaching unit.
- Since the interaction is so flexible and is directed in large part by the students, instructors and students need documentation and supplemental curriculum materials appropriate for using the system to meet their particular educational objectives. Except for large simulations (such as flight trainers) that may require special hardware, the principal cost of "learning environment" applications will be in developing these supplemental curricular materials. Developmental costs for the programs will, in general, be written off against a much larger customer base.
- Because it fundamentally changes both content and the way materia'– is presented, use of an automated learning environment may require extensive changes in course content or even a broader redesign of an entire curriculum.

Information Resource

General information literacy is needed for all individuals to work and to participate fully in an information society. In addition, for most professions, specialized computer and communication-based systems are rapidly becoming indispensable tools of the trade. Students must learn how to use these services as part of their early training.

For these reasons, in addition to being an instructional tool, the computer in education is viewed as an intellectual and problem-solving resource, akin to the library or laboratory. Information services will need to be both broad enough to support general education and specialized enough for particular subject matter. Examples of specialized systems include computer-aided design systems for industrial engineering students, on-line legal or medical information retrieval systems for use by law students or doctors, and automated accounting and financial analysis systems for business students.

In addition to these specialized resources, students in all fields will need constant access to information services and computer facilities for their work. One engineering school is experimenting with providing a desktop computer to some of its entering freshmen, with a view toward giving computers to all students in the future. A graduate school of business has already adopted a similar policy for its entering students. The leader of the movement to provide all undergraduate students with computer access has been Dartmouth College, which, for well over a decade, has operated with a policy of universal computer literacy and free student access to computer terminals.

The role of the computer as an educational resource on campus is blending with the view of libraries as automated information centers.

Software Library of the Columbia University Computer Center. Software is placed into the computers on an hourly basis to the department utilizing the computer

Many college and university libraries have been among the leaders in this movement—first in automating their management, then in providing users access to computerized bibliographic services. Their ultimate goal is to provide full-text, on-line retrieval. As these trends continue, the computer center and the library will actually merge into a single, automated information utility.

Regional and national networks will provide scholars with access to information and computational resources anywhere in the country. EDUCOM, a nationwide consortium of universities and colleges, has been developing this concept for several years and now offers its members access to EDUNET, a nationwide resource-sharing data communication network.

Administration and Instructional Management

Information technology can be used by the teacher to help plan coursework and manage the classroom. Computers not only assist with mundane daily tasks such as grading and recordkeeping but can also help keep closer track of the daily accomplishments and problems of individual students. Teacher attention can, thus, be more focused on individual student needs. Teleconferencing via radio, television, or computer allows teachers to exchange experiences, develop curricula, and coordinate educational programs among a number of schools in a district.

Distribute Education

The distribution of services to those who need them has always been a difficult problem for the educational system. For as long as education has been provided by schools, the distribution problem has been responsible for institutional constraints of both time and location on the student. That schooling takes place on a physical campus, attended principally by young people, may be more reflective of the limitations of the traditional schooling system than it is of the current needs of society for education. Chapter 6, which examines the state of the educational system, concludes that

At the Oxford High School, Oxford, Mass., students operate the Digital Equipment Corp. mainframe computer that controls the student records system for the school district

a significant gap may exist between the forms of educational needs of a modern information society and the traditional institutional forms of educating.

Information technology is a tool that can address these two distributional problems–distance and time. In the past, television and radio have been used for this purpose, often to good effect. However, their applicability has been limited both by the need to use expensive and scarce broadcast facilities to serve a relatively small clientele and by the inability to provide interactive services.

Modern technology removes these barriers. Communication facilities such as cable, direct broadcast satellite, low-power television, and video cassette and video disk will greatly increase the number of information channels coming into the home and office. Two-way cable, remote conferencing facilities, and optical video disk microcomputer systems provide the capability for interactive education.

Among the particular applications of information technology for distribution are the following:

- *General educational services to dispersed populations:* Some geographical regions need to provide schooling to a sparse population spread over a large area. Communications technology such as direct broadcast satellite or low-power television allows educational programing to be broadcast at low cost to small rural communities and even to individual residences. Video cassettes, video disks, and personal computer programs can be distributed physically by mail.
- *Specialized educational services to small populations:* Some groups in society that have very specialized needs for educational services are not concentrated geographically. Only by providing courses regionally or nationally can a critical mass of students be assembled to justify the expense of the course. Information systems provide that wider market. For example:
  - Advanced professional training, especially continuing education in such fields as medicine, law, and engineering, in which knowledge advances at a rapid rate.
  - Unusual educational needs, such as accelerated science programs for the gifted or courses conducted in a foreign language.
  - Instruction in subjects for which experienced teachers are scarce or courses conducted by outstanding scholars and leaders in a field.
- *Education for the homebound:* For a number of reasons–e.g., illness, physical handicap, or age—many individuals in society cannot travel physically to attend a class. Information technology can provide educational services directly to the home, hospital, or workplace.
- *Job-related education and training in the workplace:* There are a number of barriers to workers who wish to take job-related instruction. Attending regular classes is difficult due to competing demands on their time, travel to a campus maybe burdensome, and there is reluctance on the part of some older individuals to sit in a classroom and compete with younger students.[1] Information technology, by bring-

[1] R. L. David, "Adult Higher Education: Thinking the Unthinkable," *Adult Continuing Higher Education Conference, Region V,* Appalachian State University, April 1977.

ing the course to the workplace, can remove some of these constraints.

Testing and Diagnosis

Computers have been used for some time to grade and analyze the results of college admission exams, intelligence tests, and a variety of psychometric examinations designed to explore the values, attitudes, and thinking patterns of individuals. Educational testing can be thought of as having four basic roles:

- *Strategic:* Testing helps assess a student's general levels of understanding and learning strategies. It is used to determine what classes and courses of study a student should pursue, and what instructional approaches would be most effective for him. After a course, testing measures the skills and knowledge that the student.
- *Tactical:* Testing also takes place during instructional sequences to determine how the student is progressing through the course and to detect and diagnose difficulties the student might be having.
- *Gatekeeping:* Testing plays an increasingly important role in supporting decisions on admissions to institutions and to programs of study. It is a basis for allocating scarce resources (e.g., admission to a prestigious college or university) and for the granting of licenses to practice professions.
- *Certification:* Testing plays an important role in certifying the-knowledge and skill of individuals, qualifying them to pursue professions such as medicine or law, or attesting that they have progressed along certain educational or training paths.

Modern information technology will likely have several effects on testing:

- Continual testing of students' progress and levels of understanding is an important pedagogical tool, even in a nonautomated teaching environment. However it is very demanding of a teacher's time. Automated systems will allow much closer monitoring of student and class progress in a normal classroom environment.
- Automated teaching systems depend on continual testing and evaluation to direct the presentation of material.
- Automated instruction may lead to a decoupling of instruction from institutions —in the sense that a student moves freely between home, job, and school for coursework. This trend will create greater need for strategic testing to determine appropriate instructional programs for students.
- Institutional decoupling will also require more testing for purposes of certification. Traditionally, an engineering degree was obtained by following a course of study at one department. Certification was the degree earned by successfully completing the program.
- The accelerating growth of knowledge is pressuring professions such as medicine, law, and engineering to require retraining and periodic renewal of certifications.
- If traditional forms of education become increasingly expensive and, hence, scarce, gatekeeping requirements will inevitably continue to grow in importance. The current competition for entry into medical school illustrates this trend.
- On the other hand, automated learning systems may make certain types of education and training far more accessible and affordable. If that occurs, gatekeeping may take place not on entry to the education program, but in licensing to practice.

Capabilities of Educational Technology

None of the technologies and services described in the chapter 4 overview has the capabilities required to support all of the applications listed above. Hence, the growth of an extensive automated education network will depend on the integration of information technologies.

Each particular technology-cable, personal computers, etc.–has some but not all of the capabilities necessary to provide effective education. Thus, the basic message is that different information technologies will need to be linked in order to provide all of the capabilities needed for extensive automated learning systems to be developed. As shown in chapter 4, such integration is already taking place for other applications.

Cost and Effectiveness

For many years, the cost and effectiveness of educational technology has served to circumscribe the debate about whether and how it should be used. OTA found that:

> There is a substantial amount of agreement that, for many educational applications, information technology can be an effective and economical tool for instruction.

This conclusion is based on a number of observations:

- Research exists, some of it dating back years, to suggest that students do learn as well or better from educational technology than from conventional means. Little evidence exists to the contrary. Much of the past debate centered around whether technology was *more* effective than conventional means and hence warranted substitution for traditional classroom instruction.[4]
- Costs for labor-intensive education and training methods continue to climb faster than the inflation rate, while costs for information technology continue to drop precipitously. These trends will result in a steadily growing number of applications in which technology-based instruction is clearly the most cost-effective method.
- For many educational and training needs —e.g., educational services to the homebound, to geographically isolated regions, or to the workplace—there are few viable alternatives to the use of technology, provided that it works adequately. In a growing number of instances, teachers qualified to teach in certain fields—such as science, mathematics, or bilingual education —are difficult to find. In these cases, technology may be the only means by which such education can be provided.

This is not to say that there are no potential limitations or dangers in the uncritical use of educational technology nor that there is no need for additional research in the field. In fact, in the eyes of some critics, a number of questions remain unanswered.

- Will access to computers reduce the ability to practice and learn basic skills? Some parents and teachers are concerned that student use of hand calculators may lead to the atrophy of simple computational skills. Some modern word processors incorporate spelling correction facilities, and future systems will probably incorporate simple grammatical analysis and correction. Will use of such technology decrease a student grasp of writing mechanisms?
- Does the medium have characteristics that, when exploited, distort the educational message or produce subtle side effects? Some observers, for example, have suggested that television educational programs such as Sesame Street may reinforce short attention spans. A similar example *is* the finding of some developers

[4]See, for instance, W. L. Schraumm, *Big Media, Little Media* (Beverly Hills, Calif.: Sage Publications, 1977); A. Bork, "Interactive Learning, ' *Amer. Journal Physics 47(l),* January 1979, pp. 5-10; L. J. Seidel and M. L. Rubin, *Computers and Communications Implications for Education (New* York: Academic Press, 1977); J. Edwards, et al., "How Effective is CAT? A Review of the Research, " *Educational Leadership,* November 1975, pp. 147-153; and R. Dubin and R. A. Hedley, *The Medium May Be Related to the Message: College Instruction by TV,* Center for the Advanced Study of Educational Administration, University of Oregon, Eugene, 1969.

of interactive computer-based reading programs that, in order to maintain student attention, shorter passages must be used on video screens than would be needed to maintain student attention for reading exercises on paper.

- Most research on technology-based education has focused on the development of well-defined skills, such as arithmetic computation or foreign-language vocabulary. While proponents argue that computers can encourage the development of new problem-solving skills,[5] critics suggest that education of the more general conceptual skills could suffer.
- If, over the long term, education is provided principally by technology, what are the unintended long-term impacts on social, cognitive, and psychological development? Very few answers to this important question are known. However, since it would take several years before technological and institutional changes could create such a possibility on a massive scale, there seems to be adequate time to study it.
- Do particular characteristics of information technology subtly favor some types of students psychologically or cognitively? Do differences exist that tend to favor performance by sex, age, social class, or values? These questions are important when dealing with issues of social equity.

‘S. Papert, *Windstorms (New* York: Basic Books, 1980).