APPENDIX A

EDUCATIONAL TECHNOLOGY: A TECHNICAL SUMMARY

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INTRODUCTION: THE ELECTRONICS ENVIRONMENT

From "intelligent" heart pacemakers to fully computerized combat fighter airplanes, today electronic information technology has application in almost every arena of human activity. Indeed, it is now impossible to imagine how banking, communications, defense, manufacturing, and medicine ever could have functioned without the vast network of electronics that has been installed in the last 25 years.

A vast and expanding diversity of such applications seems to be changing the relationship between society and technology. Increasingly, people are required to communicate with electronic devices. And it is not uncommon for electronic devices to interact with people, calling them by name, asking them to do things, or thanking them. Throughout their lives children now in school will encounter thousands of such technologies.

The fundamental agent of this change is the technology of microelectronics, which makes possible the miniaturization of electronic circuitry onto tiny microchips. * The maxi m "smaller, faster, cheaper'' has had broad implications. As more electronic devices are compressed into smaller spaces, their operation takes less time. As electronic information technology gets faster, it also becomes capable of a higher density of communication. Together, these two capabilities allow the development of smaller and smaller machines of increasing complexity and power. And as these become cheaper, due

* Microchips, 'chips' or, more properly, integrated circuits~ are collections of electronic components such as transistors or resistors, compressed into a single miniature silicon dioxide wafer less than the size of a small fingernail. Over the past two decades the number of components capable of being integrated into a single chip has grown from tens to millions.

to the falling cost of mass producing microelectronic components, greater general access to increasingly powerful machines becomes possible. At the same time, adding electronic components to traditionally mechanical processes is also encouraged by economies of scale and reliability. This means that putting a microprocessor in a photographic camera, for instance, can increase its capabilities while simultaneously decreasing its price.

Today, microelectronic information technology can be found in automobiles, ovens, credit cards, refrigerators, greeting cards, robots, satellites, talking toys, televisions, telephones, and even blackboards that play notes when touched or that can print out their contents on paper after class. And some electronic technologies, like calculators, have become commonplace for the student population to use at home or in school.

As an indication of how rapid the development of electronic products has become, an Electronics Industries Association publication estimates that nearly half the consumer electronics products on the market today have been introduced within just the past 10 years. [1]

Consumer video technology is another important outcome of microelectronics development. In early 1986, the percentage of American TV homes with VCRs was well above 30 percent, and by the end of the year, this figure was expected to pass 40 percent. [2]

But perhaps the most important development of microelectronics is the computer on a chip, the microprocessor. * Microprocessor chips, which can be used in calculators, watches, and other automatic devices, when put together with memory chips, input-output circuitry, a keyboard and a screen or printer, can become microcomputers.

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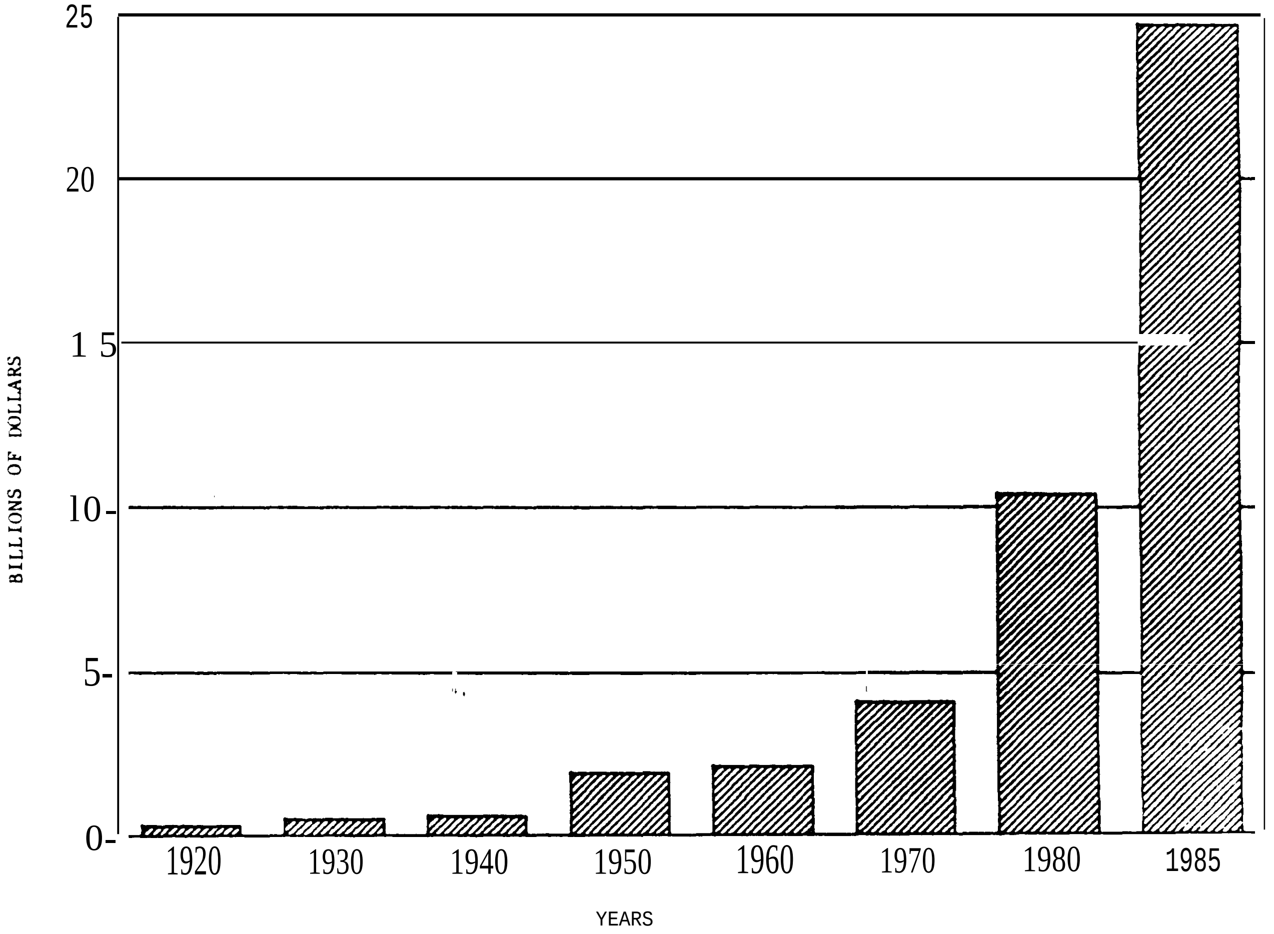
1. Electronic Industries Association, Consumer Electronics Annual Review, 1986, p. 17.
2. Ibid., p. 8.

* Microprocessors contain all the normal components of the central processing unit of a regular mainframe computer — accumulator, registers, stack, and arithmetic logic — on one microelectronic integrated circuit, or chip.

FIGURE 1

CONSUMER ELECTRONICS MARKET
Total U.S. Market



SOURCE : Electronic Industries Association, Consumer Electronics Annual Review, 1986.

It is estimated that, by the end of 1985, 15 percent of all American homes had microcomputers.[3] In one survey, it was found that by mid-year 1985) about one out of five pre-teen or teenage children had access to microcomputers in their homes.[4]

Education, often criticized for adapting slowly to its changing technological environment, has not been left out of this revolution: during the 1985-1986 school year, elementary and secondary schools in the United States spent between $400 and $600 million on computer hardware, and another $130 to $150 million on software. Now less than 5 percent of all schools are without at least one microcomputer.[5]

Falling costs, enhanced microminiaturization, and increased speed of components has encouraged the development of more complex microcomputers.** However, the first commercially available microcomputers, and most microcomputers still used in homes and schools today, have 8-bit microprocessors.*** Since their introduction a decade ago, two further generations of microcomputers — based on 16-bit and 32-bit microprocessors — have been developed, and many new peripheral devices which can enhance and extend the microcomputer's abilities have also become available.

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3. Ibid., p.59.
4. Corporation for Public Broadcasting, Use of Electronic Information Technologies for Non-School Learning in American Households (1986) p.7.
5. Fran Reinhold, 'Computing in America — 1986 Annual Survey," Electronic Learning, vol.6, No. Z, October 1986, p.27.

** Even though extremely inexpensive microcomputers with limited memory have been available for as little as $100. — (e.g., Sinclair, Vic 20) – consumers and other users such as schools, have generally rejected them in favor of the increased capacities of micro computers with more memory and other enhancements such as diskette drives.

*** Eight-bit, 16-bit and 32-bit characterizations refer to the width of data pathof a given microprocessor and determines the number of instructions that a microprocessor 'can carry out and the amount of memory it can address. By 1977, two 8-bit microprocessor chips had emerged as the principal industry leaders, Zilog's 2-80, which was used by Tandy's TRS-80, and MOS Technology's 6502, which is at the heart of Apple II, Atari and Commodore computers. In the early 1980s, a new family of computers was introduced with 16-bit data paths. IBM% PC, XT, and a host of compatible computers are based on Intel% 8088 family of microcomputer chips and, by 1985, had become the de facto standard for small business, and many higher education applications. More recently, the Apple Macintosh, the Commodore Amiga, and new computers by Tandy, Atari, and WICAT, use Motorola 68000 chips, which have 32-bit internal architecture. And IBM has also introduced a 32-bit chip called the Intel 80386 for its AT computer. The advantage in speed and flexibility of these wider data path processors translates into much faster computations, more detailed graphics, and environments that can anticipate the user's necessities (user friendliness).

Today, in corporate, business, and industry settings, such second and third generation microcomputers commonly run multiple programs at once, share programs and data with other computers in Local Area Networks, communicate over telephone lines with worldwide resources, and have the ability to create and print multicolored graphics. Due to constant reduction in the size of components, a computer as powerful as those which used to require a large air-conditioned room can be carried in a briefcase. Today microcomputers are approaching the capacity of full-sized computers of two decades ago, including the ability to have a number of terminals (keyboards with video screens) run from the same computer.

Meanwhile, full-sized computers or “mainframes” have also been transformed by microtechnology, increasing their memory capacity and speed of operation, allowing them to store vast amounts of data and analyze it at speeds of up to 160,000 times faster than a typical personal microcomputer.[6] And whereas very few school children will ever see a large mainframe computer, they may well access a database contained in one from a personal computer at home or at school or interact with one at a bank. Moreover, research in artificial intelligence, expert systems, and cognitive science is beginning to have an effect on microcomputer programs used in schools.[7]

Computer technology is based on binary switching circuitry. This means that all information is processed as discrete yes/no or on/off bits. Other electronic devices such as radio and television were developed as analog technologies which processed information as electronic waves. Each time these waves, or signals, pass through the air, a wire or other electronic component of transmission, storage, or processing system, they acquire "noise" and lose some of their character or fidelity. A major advantage of digital technology is that no loss of signal is encountered, no matter how much processing

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6. Richard A. Jenkins, Supercomputers of Today and Tomorrow, (Blue Ridge Summit, Pa: TAB Books Inc., 1986), p. 18.
7. Lauren B. Resnick and Ann Johnson, “Learning Theory as a Guide to Educational Software Development,” unpublished presentation to Technology in Education in 2020 panel, October 17, 1986, p. 10.

circuitry it passes through. Further, after analog signals are transformed into digital information, they can be manipulated, processed, and stored much more accurately using computer technology. Compact disc (CD), digital televisions, and other digital storage technologies, including telephones, are dropping in cost and increasing in use precisely because of the move from analog to digital signal processing.

ELECTRONICS IN THE CLASSROOM: COMPUTER HARDWARE

Of an estimated 1,036,000 personal computers in public schools today, some 70 percent are Apple or Commodore, which are 8-bit computers with limited graphics capability (a maximum of 16 colors, with a resolultion of about half the detail of a television image and an average of 64 kilobytes of memory.)[8]

As can be seen in Table 1, the overwhelming percentage of computers used in all schools are of this type. It can also be seen that the percentage of 16-bit computers— all IBM computers and a significant percentage of Radio Shack computers— is greater in the higher grades. In light of the predominance of 16- and 32-bit computers in business, it does not appear from these numbers that schools are hurrying to purchase computers with more power and capability.

However, this situation could change in the future. In its Fifth Annual Report, TALMIS contends that 8-bit technology predominates. At the same time, the TALMIS report points out that schools: [9]

> . . . are very aware of the advances taking place both in computer technology and in associated areas such as mass storage, interactive video, communications, and networking. While using mostly supplementary single-concept CAI (Computer Aided Instruction) and generic tool software to support the instructional program, the schools are also aware of the power of the computer to manage and deliver truly individualized instruction as well as to access and manipulate vast amounts of information. If the school

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8. Data provided by Market Data Retrieval, Inc., under contract to OTA.
9. TALMIS Inc., The K-12 Market for Microcomputer & Software (New York: 1985), p.s.

Table 1

PERCENTAGE OF BRANDS IN SCHOOLS OF COMPUTERS, BY GRADE

Schools	Apple	Commodore	IBM	Radio Shack	Others
		1986			
Elementary	62.2	15.0	3.1	9.8	9.9
Junior High	59.5	14.6	3.8	15.1	6.9
Senior High	53*7	8.7	10.2	20.1	7.3
TOTAL	58.3	12.3	6.3	14.6	8.5
		1985			
Elementary	58.0	16.6	2.2	11.1	12.1
Junior High	55.7	16.5	3.1	16.5	8.2
Senior High	51.4	10.0	8.2	22.0	8.3
TOTAL	54.8	13.8	5.0	16.5	9.9
		1984			
Elementary	52.7	18.3	1.3	13.8	13.9
Junior High	50.7	17.5	1.9	20.5	9.4
Senior High	48.4	11.5	5.6	25.2	9.2
TOTAL	50.4	15.2	3.5	19.8	11.2

Source: Market Data Retrieval 1986.

of the future is one in which computers are closely integrated into the instructional process, then the schools will have to make the transition to more powerful equipment better able to support extensive instructional use.

One factor that may affect the introduction or incorporation of more powerful computers in schools is that microcomputer technology does not wear out. Aside from the cathode ray tube (CRT) in video monitors, keyboards that are abused, and the mechanical parts in diskette drives, microcomputers are virtually impervious to wear. Another factor may be that there is more educational software written for 8-bit computers than other types of systems. Even though 16-bit computers are now competitive with high end 8-bit computers in price, there is less established educational computer software available for them. One possible remedy for this is that manufacturers build in "downward compatibility," the ability for new machines to use and operate most software written for earlier models. The Apple IIgs is an example of this approach; however, development costs must be greatly increased to achieve such comparability.

A limited number of schools and districts have opted to invest in a single minicomputer and terminals, rather than multiple microcomputers, for instruction delivery. Such systems, sometimes called Integrated Learning Systems, generally have a central computer unit, about the size of a dishwasher, located in a secure area. Cables extend to one or more classrooms in the school where a computer laboratory with 20 or 30 terminals can be used by any number of students. Remote terminals can also be connected by telephone lines, allowing more than one school to use the system at one time. The benefit of such a centralized system is that it can store many different programs relating to various curricula as well as automatically accumulate student test scores and progress indicators. It is then able to compile and print out individual and group reports. Another benefit is that teachers do not have to be trained cooperate the computer themselves.

There is also a negative side to a centralized system. Programs tend to be unadorned alpha-numeric drill and practice lessons because graphics, especially color graphics, and sound require large amounts of processing time for the central computer. Since the computer has to manage many terminals all at the same time, the speed of its responses can be slower than with dedicated microcomputers, if more than the designated number of terminals are used, which can cause student frustration. Such systems also tend to be more expensive and less flexible than similarly equipped microcomputer labs due to the cost of installing cables, modems, and computer hardware. A typical installation of 30 terminals and software to run a mathematics program cost between $80,000 and $130,000.[10] One school district that installed them in four schools estimated their costs at about 50 percent more than a corresponding microcomputer-based system.[11]

In many schools, however, there is an increasing use of Local Area Networks (LANs), where networks of microcomputers are connected together within a school or laboratory, to provide shared mass storage (disc drives), printers, programs, or other devices like plotters. These systems are similar to but unlike the minicomputer systems, in that the local computer uses its own central processing unit for activities such as computation and word processing, and only accesses shared resources for transferring files, programs or data. Using a single hard disc drive with 20-30 million characters of storage capacity to serve multiple work stations can be very helpful to the teacher who, in a laboratory without networking, must spend a lot of time organizing diskettes, which can usually store only 300,000 to 400,000 characters, and require changing frequently.

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10. Steve Petix, "Computers Turn Doubting Educators into True Believers," The Daily Californian, July 13, 1985.
11. Robert O. Slater and William F. Lynch, "Minis Versus Micros: Points to Ponder Before You Buy More Computers," The American School Board Journal, March 1986, p. 35.

Peripherals

Peripheral devices such as floppy disc drives, color monitors, and printers change the capabilities of computer systems dramatically. For instance, disc drives can load programs or data into the main memory of a microcomputer many times faster than from cassette tape and also have the advantage of random access. Color can be a very effective and educational device; software writers often use it to enhance the meaning and attractiveness of instructional programs. Windows allow more than one screen of text to be examined at once. This ability can aid in programming and allows banners to be created or large spreadsheets to be studied. Once a child has created a composition using a word processor, there is a significant difference between having it printed out on paper and simply looking at it on a computer screen. Some schools are using printers to accomplish desk-top publishing and disseminate classroom or school newspapers. Although floppy disc drives have become standard with most microcomputer installations, the number of printers or color monitors in use has not matched the growth of microcomputers installed in schools.[12]

Instructional effectiveness may also be affected by other peripheral devices such as tablets for graphics, light pens, track balls, mice, CD-ROM, videodiscs, robotics devices, and a number of scientific measurement devices like thermometers, pressure, and sound sensors. Software written for use with such scientific instruments can enable the computer to automatically plot changes over time and gives science teachers new capabilities when conducting scientific experiments. For example, a computer may be left on overnight to monitor changes in temperature in a terarium or a rat’s cage.

12. TALMIS, op. cit., p. 66.

CD-ROM

CD-ROM is a laser-optical technology that can store and retrieve up to 550 megabytes of digital information — the equivalent of more than 100,000 pages of text — on a single 5 1/4 inch disc. For instance, with a CD-ROM player used as a peripheral, a microcomputer can access any entry in the entire 20 volume Grolier Encyclopedia from a single CD-ROM disc.[13]

Used in libraries, the CD-ROM can become a valuable resource for computerized searches of large databases such as the Library of Congress card catalog, Books in Print, Reader's Guide to Periodicals, and many other references now becoming available in this highly compact medium.

CD/I

Another new integrated interactive system, although not yet available, is based on Compact Disc (CD) technology. The Compact Disc/Interactive (CD/1), although announced in 1986, will not come to market until fall of 1987. it will be similar to a CD player and able to play regular stereo audio CD discs, but it will also store still video pictures, animation, text, and software on the same disc. It will have a computer built in and require only the addition of a television set. One writer projects wide applications for education:

> CD/I has the potential to cover the entire spectrum of the general school curriculum. Science, math, history, reading and foreign language will each have a CD/I series. One of the most common drawbacks of using computers to teach general subjects is lack of adequate audio and pictures. CD/I will solve this problem at a hardware price that will be competitive with the Apple line of computers. 14

13. Bradford N. Dixon, "The Grolier Electronic Encyclopedia," CD-ROM Review, vol. 1, No. 1, October 1986, p. 10.
14. Bryan Brewer, "Compact Disc/Interactive (CD/l)," CD-ROM Review, vol. 1, No. 1, October 1986, p. 56.

Interactive Videodisc

Using a videodisc player as a peripheral to a computer creates an interactive video system which can be used to provide television quality pictures and sound as components in an interactive simulation or as part of individualized instruction. The computer calls up moving sequences, still images, audio from one or both audio tracks, on demand, according to its program, which can itself be stored on the videodisc. A total of one half hour of motion video, or 54,000 individual frames, can be stored on each side of a videodisc.

Musical Devices

Computers can also be used to control a growing number of musical synthesizers with a new standardized protocol, called MIDI. The MIDI protocol can be used to record the keystrokes of a keyboard player and then manipulate them and play them back in any number of musical voices. Now children can learn musical theory and play compositions using a computer to help them.

Modems

Modems allow computers to use telephone lines to transfer messages, files, and sometimes programs, from one computer to another. A number of public information services, like CompuServe and The Source have special electronic bulletin boards for students and teachers who have access to computers, modems, and telephone lines.

In some cases, students can conduct research by accessing an online encyclopedia, or swap information with students in other areas of the country using one of a number of private bulletin board systems, or specialized online systems like the Big Apple Bulletin Board which is run by the New York City Board of Education. And in certain demonstration programs, some students can communicate through modem connection from their homes to their schools.

The ease of interfacing, or electronically connecting such peripherals, is also a function of the design of microcomputer hardware. In many cases, more expensive technology offers more potential for expansion. The open architecture of some microcomputers — notably Apple and IBM computers — with six or more slots in their printed circuit boards, allows independent developers or vendors to devise custom circuit boards to plug in many of these applications. Less expensive computers — for example, many Commodore and Radio Shack computers — have a limited number of standard input and output ports on them, but unlike those with open architecture, they do not easily support multiple peripheral devices.

SOFTWARE: HARNESSING ELECTRONICS TO FOLLOW HUMAN INSTRUCTIONS

Software is the set of instructions that makes computers perform their various tasks. Computer programming languages, operating systems, games, word processors, database programs, databases, instructional programs, and spreadsheet programs are all examples of computer software. (Newcomers to the world of computer technology are often astounded that hardware engineers — the people inventing and building computers — frequently know little about software, and that software creators often have little idea about how the circuits make sense of their commands. It helps to make the analogy with television: how many writers, directors, and producers know how to repair their own sets?)

Although attempts to create effective computer software for mainframe computers have been going on for almost two and a half decades, the art of writing microcomputer-based software for instructional purposes is less than 10 years old. Nevertheless, there are now thousands of software programs available for the K-12 software market.* Electronic Learning magazine counted 1,145 new software programs between March 1985 and March 1986, an average of almost 100 programs per month.[15]

Software can be delivered via a number of media; the most commonly used are floppy diskettes, magnetic media about the size of 45 rpm records, wrapped in paper envelopes. Programs can also be delivered on cassette tapes or even printed out on paper and then typed into the computer manually. ! They can be sent and received over telephone lines with the proper equipment and protocols. Although various special “copy protect" routines have been tried, there are very few software protection schemes that can keep programs from being illegally copied. And when software is copied, the copy is identical to the original. It suffers no loss of quality.

It is important to realize that software written for one type of microcomputer operating system will not in most cases run on another. Software developed for Apple IIe, for instance, will not run on Commodore, Tandy, or I.B.M. microcomputers. Software publishers who wish to make their programs available for every system have to adapt them for use on those systems, which usually means rewriting them entirely, which can add significantly to development costs. For this reason, the decision to buy a certain Type of hardware is often based on what software will run on it.

Educational software falls into the following general categories:

1. Operating Systems
2. Languages
3. Utilities (word processors, spread sheets, database management, desk-top publishing)

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* There is a great range of educational software both in quality and price with the median price at about $50 per copy. The market for educational software is relatively small compared to that for business. It is possible that, in the future, severe problems in availability of high quality software can arise from the apparent fact that publishers have difficulty making much profit from educational software production. Writing an effective software program can cost up to $500,000 and as much as $1 to $1.5 million for a year-long curriculum. The educational market seems unable to bear a significant markup on this type of product.

15. Electronic Learning, "Micro Waves – Editor’s Note/’ vol. 5, No. 8, May/June 1986, p.2.

4. Instructional Programs (computer-aided instruction, drill and practice exercises, computer managed-instruction)
5. Simulations and Games
6. Communications

Operating Systems Software

Operating systems software controls the internal workings of a computer; for example, its communication with diskette drives, keyboard, and screen. Operating system software also coordinates the actions of the multiple computers in a distributed network of computers.

Operating systems continue to evolve as new hardware and applications are developed. The need for them to communicate with non-expert computer users has prompted development of simpler operating system instructions. To obtain a listing of the contents of a diskette, for instance, it might be necessary to type "DIR" (directory) for one system and "LOAD $,8" then "LIST" for another. Yet another requires "CATALOG" and another "CAT." One solution, used in the Apple Macintosh, has been to create graphic icons to represent various functions; for example, a trash can to represent the delete function.[16] Although such icon-based systems have had much success in ‘he consumer market, the impact of computer operating systems on educational applications has yet to be effectively assessed.

Computer Programming Languages

In 1965, John G. Kemeny and Thomas E. Kurtz of Dartmouth College developed the BASIC programming language for introductory courses in computer science. Somewhat similar to FORTRAN, the most widely used scientific programming language, BASIC has

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16. Peter J. Denning and Robert L. Brown, ‘Operating Systems," Scientific American, vol. 251, No. 3, September 1984, p. 72.

fallen out of favor at post-secondary levels, but remains the most popular programming for microcomputers.[17] Many are made with BASIC "hard wired" —a permanent part of their architecture.

In elementary and secondary schools, learning how to program in BASIC is a regular part of many programming courses, and is included in many computer literacy programs. Children learn to print out their names on the screen multiple times using a numbered BASIC command list such as:

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1 FORX=1TO1OO
2 Print~Maryn
3 NEXTX
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Such a program can teach the child about the computer's ability to use variables and to repeat instructions to accomplish tasks.

Teachers can also use BASIC to create their own simple programs for record keeping or instruction. However, this appears not to happen very frequently. Creating useful programs is very time consuming, and lengthy BASIC programs typically operate very slowly, causing frustration for those who expect video game-like speed. For this reason, and to make programs more reliable, most commercial programs are written in more sophisticated programming languages or in machine language, both of which require more expertise and technical skill.

Another popular computer programming language was designed expressly for children. LOGO, developed with support from the National Science Foundation (NSF) by Seymour Papert and his colleagues at the Massachusetts Institute of Technology, is a language built around the concept of making a simulated "turtle" robot trace shapes on a

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17. Lawrence G. Tesler, "Programming Languages," Scientific American, vol. 251, No. 3, September 1984, p. 72.

computer screen according to the child% program of instructions, such as "FORWARD 50" and "RIGHT 145". These instructions can be embedded in routines, recalled any number of times, or put into conditional statements. Logo is used in many schools to teach programming concepts and problem solving.[18]

Because BASIC comes built into the most popular microcomputers and LOGO is high on the list of "most used programs" reported by educators,[19] these are probably 'he principal computer programming languages used in schools. Other computer programming languages used in science, business, and universities, such as Pascal, COBOL, FORTRAN, Forth, APL, Prolog, Algol-58, and Lisp, each having its own rules, syntax, conventions, and special area of application, are only occasionally taught in higher grades and/or specialized courses of instruction about programming.

Utilities

Utilities or applications programs allow students to use computers as tools to accomplish certain tasks like typing or processing words, making spreadsheets, maintaining databases, creating computer-aided designs, making music or visual images and graphics.

They generally present no instructional information except menus of their capabilities or help lists. Some incorporate a number of different programs. APPLEWORKS for instance, the most popular utility program, integrates a word processor with a spreadsheet program and a database manager. Such utilities are similar to programs that students will most likely meet in their working lives, in offices, factories, or businesses, where utilities like LOTUS 123 account for millions of dollars of sales every year.[20]

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18. Margie Plock, "Computers in Schools: Can They Make the Grade?" High Technology, vol. 6, No. 9, September 1986, p. 48.
19. TALMIS Inc., The K-12 Market for Microcomputer & Software (New York: 1986), Table 30.
20. Victor E. Fuchs, "Computers and Public Education: At the Crossroads of

Some districts report that utilities are being used more than any other kind of software. A recent Talmis survey of school computer coordinators found that 9 of 10 most used programs were utilities. (See Table 2)

Using a word processor program can give children confidence in writing, as it does with many adults, and separates the effort of composition from the physical dexterity problems of handwriting; using spreadsheets and data base programs can aid students in compiling and analyzing data for science projects. In recognition of the growing use of these utilities in classrooms, software publishers have begun to expand them to include helpful hints and organizational structures for young writers, for instance, to guide them through the pre-writing and planning stages of composition. Some publishers have added curriculum databases to their database management utilities, so they can be used by students to do research. Subjects like U.S. history, government, life sciences, physical sciences, literature, composition, poetry, mythology, world geography, and cultures are now available.[21]

New tools have also been developed to help in analyzing science projects. For example, Robert Tinker and collagues at Technical Education Research Center (TERC) in Cambridge, Massachusetts, have developed several sets of low-cost peripherals and software that enable children to use computers to take data from hands-on experiments and display the data graphically in real time. These microcomputer-based laboratory programs deal with heat and temperature, velocity and acceleration.

Instructional Programs (computer-aided instruction, drill and practice exercises, computer managed instruction)

This category of software is made up of computer programs specifically designed to instruct or to provide drill and practice. Occasionally they also incorporate some testing

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Educational Excellence," Electronic Learning, vol. 4, No.8, May/June 1985, p. 34.
21. Plock, op. cit., p. 48.

Table 2

SOFTWARE TITLES USED MOST FREQUENTLY

Title	Percent of Respondents
Apple Works (Apple)	19
Print Shop (Broderbund)	18
Bank Street Writer (Broderbund/Scholastic)	16
Logo	14
PFS: Write (Software Publishing/Scholastic)	8
Newsroom (Springboard)	7
Magic Slate (Sunburst)	6
Master Type (Scarborough)	5
PFS: File (Software Publishing/Scholastic	4
Math Sequences (Milliken)	3
Microzine (Scholastic)	3

N=119

Source: Talmis, Inc. New York, personal communications, October 1986.

procedures and keep records of progress. When testing is used as part of a program to determine when a student is ready for anew level of instruction, and records of progress are kept, the method is called "computer-managed-instruction."

There are instructional programs to teach almost every subject of the school curriculum — mathematics, language arts, social studies, early education, science, foreign languages, typing, and business education. Some programs are simply "electronic page turners" and present the learner with screen after screen of text with no interaction from the user but to press a key for the next page. Others present simple mathematical problems, giving little help to the learner except to disallow false answers. However, other programs designed for drill and practice exercises are written with added embellishments to provide motivation and variety. For example, QUOTIENT QUEST from Minnesota Educational Computing Consortium (MECC) incorporates an around-the-world theme. Successful completion of division drills allows students to search for chimpanzees, rearrange totem poles, trap a jewel thief, and perform other challenging tasks.

Drill and practice software can be seen to offer certain benefits to the learner. Due to the fact that the computer provides instant feedback, unlike having a worksheet marked and returned the next day, the student learns to find the correct answer immediately. In the words of Mark Grabe, Associate Professor of Psychology at the University of North Dakota in Grand Forks,

> I believe students need to have access to their thoughts, decision criteria, and recollection of other mental activities in order to make the most of feedback. This feedback must be given within moments of the student% original response for full access to these recollections. In a practical sense, I believe the studentts likelihood of being able to operate in this time frame will be greater when engaged in computerized drill and practice.[28]

As hardware has become more sophisticated and as the market has grown, incorporating more colored graphics and sound into programs has added greatly to their

22. Mark **Grabe, "Drill** and Practice% Bad **Rap,"** Electronic Learning, vol. 5, No. 5, February 1986, p. 22.

attractiveness. Some now provide scenarios or game-like settings for these exercises, such as a shopping mall setting for mathematics practice, where students work against time to serve customers in various shops.[23]

John Henry Martin notes:[24]

> Clearly, the natural appeal of games should not be ignored; integrating game theory with the content and skills to be taught has a synergistic effect. Chance and risk, along with graphic evidence of growing skill perceived by the participant, are strong reinforcers. Challenge and humor can be effective lubricants to learning. Nevertheless, covering the stale bread of dull materials with a confection of gaming has not made an educational cake.

Notwithstanding some very innovative and excellent software written for limited systems, the problems of writing new educational software for computers with limited memory and rudimentary graphics capability is substantial. Due to these machines' limited speed, learners can easily get frustrated with programs that do not respond immediately and begin pushing keys at random. For programs that do not have special lockout devices, this can precipitate even more problems and possibly even cause programs to "crash.[N] This encourages program writers to restrict the graphical content of programs because graphics tend to consume much processor time and memory. And the amount of internal memory an 8-bit microprocessor is able to access (64,000 bytes) also limits its ability to offer options to the learner. According to one developer, 'Trying to fit a complex education program into a microcomputer with 64 kilobytes of memory is like trying to park a limousine in a tiny garage without scratching the paint."[25]

Nevertheless, software developers, presently substituting ingenuity for computing power, are hopeful that schools will soon be encouraged by the increased capabilities of new hardware, and the software it can support, to acquire micros with faster speeds,

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23. Larry Pogue, "Math Goes to the Mall," Electronic Learning, vol. 5, No. 8, May/June 1986, p. 55.
24. John Henry Martin, 'Developing More Powerful Education Software," Educational Leadership, vol.43, No.6, March 1986, p. 33.
25. See comments by Virginia Gemmell, Director of Research and Design for Spinnaker Software in an article by Plock, op. cit., pp. 44-45.

more memory, and better graphics capability. One new trend in software development that has followed the introduction of more powerful hardware is the effort to incorporate "intelligent feedback" into instructional programs. TYPING TUTOR III records a user's response time for each key and uses this information to modify subsequent lessons, automatically providing more drill for the user's weakest areas.[26]

Work is now underway at a number of universities and laboratories to improve computer aided instruction by the application of cognitive science and artificial intelligence. One such program at Carnegie-Mellon University, Pittsburgh, uses a mainframe computer (Xerox 1109 Advanced Scientific Information Processor) to help students learn geometry. The designers of the geometry tutor describe its special features:[27]

> At any time in the process, the student can ask the system for help with definitions, postulates, and theorems appropriate to the problem. In addition, if the student is not *on* a proof path, the tutoring part of the system (that is, that part that keeps track of the student% strategic choices) will guide the student back onto a path. Should the student make a logical error in inference, the system recognizes the error and tutors accordingly. The system functions as coach or as tutor, depending on need.

With these features Carnegie-Mellon University researchers believe that in the near future, a mathematics laboratory could become a standard high school facility. These highly sophisticated interactive environments or so-called intelligent computer-assisted tutors could enable students to work productively on their own time at school or at home.

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26. Ariella J. Lehrer, University of California, Los Angeles "Some Hard Words on Software Policy,ff unpublished typescript, July 1984.
27. C. Franklin Boyle, "The Geometry Tutoring Project in Action,'f Educational Leadership, vol. 43, No. 6, March 1986, p. 27.

Simulations and Games

Simulations are programs that generate practice environments in which learners can experiment. They simulate processes, systems, or events. One very popular simulation from MECC is of a wagon train on the OREGON TRAIL. Students of history make decisions about what provisions they will need, what time of year to start their journey from St. Louis, and in what activities to engage, e.g., whether to hunt or trade. Random events like attacks by Indians are also programmed into this simulation for added realism.

Another program called THE MARKET PLACE is an economic simulation for younger students in which the students operate, amongst other things, an imaginary lemonade stand. Typically, a teacher will divide a class into groups, each deciding how much of a limited amount of money they will spend on lemonade, on a sign for advertising, and other variables. The computer will then simulate transactions based on the outcomes of their decisions. Some groups will make a profit and others might find they have gone broke, not having spent enough money making their service known.

There are political simulations of presidential elections, economic simulations of factories, physical simulations of weather systems, automobile simulators, airplane simulators, and space flight simulators. Other simulations allow students to conduct science experiments, such as dissecting a frog or making chemical compounds. Such simulations have many benefits. They can simulate processes that are dangerous, time consuming, or costly, and allow students to repeat them, stop them, or alter variables to find out what happens. In the case of the dissection program, the student is also required to reconstruct the frog, and thus reinforce the learning experience.

Many computer games are also simulations, although often they simulate unreal environments. Games have been used by teachers to encourage students to write, to improve hand-eye coordination, and as a reward.[28]

Researchers and software developers have used the format of games to understand the learning process and to create innovative instructional software. The game DARTS, for example, was developed by Sharon Dugdale as part of an NSF-sponsored research project using the PLATO IV computer-based education system. To give elementary students practice with estimating fractions, balloons appear at random places on a number line on the screen and players try to guess the positions of the balloons. After students enter their guess (whole numbers and/or fractions), an arrow shoots across the screen to the position specified.

Dugdale also produced another game, GREEN GLOBS, to assist student in understanding the meaning and uses of graphs. The student writes an equation so that a curve will be generated through a series of "globs" placed on a graph by the computer program, and make them explode. "Students 'win' by developing a good sense of how to generate curves with particular properties by typing in their equations; thus the students who get good at the game learn the relationship between the algebraic and graphical representations of a function."[29] Another type of simulation, called construction sets," has been the subject of recent development. These programs reflect the idea that, given certain tools, simulated computer environments can be created by the learner, and can encourage a learner to explore a concept or set of concepts. Music construction sets and pinball construction sets, where the player constructs and then plays a simulation, have become commercially successful software programs. The same principles have been used to design geometry and physics programs.

28. Esteben Diaz, Laboratory of Comparative Human Cognition, University of California, San Diego, CA, address to2020 panel, Oct. 16, 1986.
29. Alan H. Schoenfeld, 'Mathematics, Technology, and Higher Order Thinking Skills in the Near and Not-So-Near Future/' presentation to 2020 panel, Oct. 16, 1986.

Communications ‘

With the application of a modem, an instrument that connects a computer to a telephone line, and the appropriate software, a microcomputer can be used to communicate with other computers and thus allow the user to leave messages for other users in the form of electronic mail, to access data from data libraries, or to “download” software from software libraries. Such computer communications can expand the resources of a classroom to include information from worldwide sources. An estimated 40 percent of high schools, 18 percent of junior high schools, and 10 percent of elementary schools have at least two modems.[30]

Hundreds of commercial databases are available for professional and non-professional use. One example is NEXIS, which contains the fully indexed contents of news stories from the New York TIMES and many other newspapers and periodicals; this service can cost over $100 per hour of access time. CompuServe and The Source, which have been set up for a broader consumer market, and which contain educational bulletin boards for educators and students, cost approximately $25 per hour of connect time during business hours, and less than $10 in the evening and on weekends.[31]

Available online resources range from nationally-run information libraries, available through telephone networks designed for computer communications, such as Telenet, Tymnet, and Uninet, to local bulletin board systems that may be set up by amateur system operators using microcomputers. A very wide variety of services can be found on the national systems; news wires, business information, weather, sports, employment services, tax information, computer conferencing, personal mail services, travel, shopping, movie reviews, games, and others. The private bulletin boards tend to specialize in computer information, software (both public domain and pirated), and informal conversation.[32]

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30. TALMIS Inc., New York, personal communications, October 1986.
31. Loy A. Singleton, Telecommunications in the Information Age, second cd., (Cambridge, Mass: Ballinger Publishing Co., 1986), p. 171.

Often used in school libraries, news and information services such as Dow Jones News/Retrieval can be valuable as a reference for world history, literature, and project research. Some schools display world news throughout the day on video monitors in the hallways to keep students aware of world events.[33] Online databases can be a valuable resource, especially where libraries are limited by funds, or where students have limited access to resources because of locale or physical disability.

Also of interest to educators are various software evaluation databases such as EPIE Online, and related computer conferences or forums, where teachers can communicate with hundreds of other teachers, and share experiences, information, and even public domain computer programs.[34] And there are a number of special bulletin board systems, operated by some State education agencies, local school districts, universities, high schools, and computer societies, dedicated to education and educational matters, that welcome teachers and students alike.

Several colleges have already begun delivering instruction using online computer conferencing systems. An organization affiliated with the New School for Social Research in New York has offered eight graduate and two undergraduate courses entirely via computer conferencing to students in California, Nevada, Chicago, Wisconsin, Delaware, Rhode Island, New Jersey, and New York, as well as Singapore, Japan, and the Middle East. A few elementary and secondary schools have begun to use computer conferencing on an experimental basis. It is expected that a number of classrooms will join the Kidnet Project that has been designed by the Technical Education Research Center in collaboration with the National Geographic Society. With funding from the

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32. Mike Cane, The Computer Phone Book Directory of Online Systems (New York: New American Library, 1986)
33. Harold J. Logan, Dow Jones and Co., Inc., personal communication, December 1986.
34. For example, an online database of over 20,000 children's radio and television programs has recently become available. Called "KIDNET," it includes information on air dates, content, target age, grade level, curriculum area, educational goals, ancillary materials, and copyright requirements. See Classroom Computer Learning, 'Industry News/' vol.?, No. 4, January 1987, p.60.

National Science Foundation, Kidnet will involve children across the country in conducting scientific measurements around a unit of study such as environmental pollution. Using computer communications, these measurements will be analyzed with the aid of online science experts. Classrooms will communicate with each other and receive ongoing local and national results.

Communicating by computer seems to provide some students with a special kind of motivation. For example, California students in bilingual and remedial classes become computer "experts" and use computer communications as a way to build literacy and language skills. According to the director of this innovative project:[35]

> The [computer] network virtually allows the world to become a community resource for students in the barrio and ghetto. Students are able to "leapfrog" societal and economic barriers and create a resource network that encompasses the next neighborhood or another country. In this case, the resources provided by the network are opportunities to practice and develop literacy skills in order to communicate with their electronic friends. Friends in Spain, Harlem, or another part of San Diego are all electronically equidistant. Moreover, this means of communication operates from a presumption of equality and mutual respect that is hard to attain in face to face interactions. For students who speak another language, communication with countries in their native language reaffirms their personal heritage and underscores the value of being bilingual and illiterate. Students who participate in settings where access to electronic networks is part of their everyday routine develop different perspectives about themselves and the world. Communication leads to appreciation and understanding of others which then leads to collaboration and cooperation in joint activities of mutual interest.

Using computers for communicating represents a very small proportion of computer use in schools. Perhaps because of the difficulty of getting a telephone connection into the classroom, or because online costs are use related and difficult to project, or because administrators fear abuse or fail to see any academic benefit, instances of computer communications by students in class are extremely infrequent.[36]

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35. Esteben Diaz, ‘Educational Change and Educational Technology,"unpublished presentation to Technology in Education in 2020 panel, Oct. 17, 1986.
36. Hugh F. Cline, et al., The Electronic Schoolhouse: The IBM Secondary School Computer Education Program (Hillsdale, N.J.: Lawrence Erlbaum Associates (1986,) p. 66.

Video: The Eyes and Ears of the Electronic Revolution

Video technologies can bring the outside world into the classroom in a way that the limited visual screens of computers or unwieldy film technology cannot. Videocassette recorders have rapidly diminished in price and in size and increased in availability to the point where almost 40 percent of all television households own them. School use has also vastly increased in the last 3 years, with a total penetration in 1984 of 50 percent, in 1985 of 75 percent, and in 1986 of almost 90 percent of public schools owning videocassette machines.[37] In addition, at least 70 percent of all U.S. schools can receive broadcast instructional television programs from Public Television stations, and, according to a study conducted by the National Center for Educational Statistics, Instructional Television (ITV) school utilization averages 20 minutes per school day, or about 5 percent of available class time.[38]

Clearly, teachers believe that video is an effective adjunct to class instruction. TALMIS reports that the preferences of program purchasers were for instructional tapes and discs in basic skill areas, followed by short-subject demonstrations, simulations, and historical recreations. More than half would like to see more documentaries.[39] Nevertheless there is a large and growing body of pre-recorded instructional and informational video programs available from an increasing number of sources. Of particular note is The Video Encyclopedia of the 20th Century, published by CEL Inc., 75 l-hour videocassette tapes of the social, political, and cultural history of the 20th century. The encyclopedia includes a master index, a ‘reference set', four volumes of background material on each of the 2,217 separate units, including detailed "shot lists" of the important people and places in each scene, and a curriculum guide to aid teachers in incorporating the material in various courses of study.

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37. ‘Microcomputer and VCR Usage in Schools: 1985-1986," edited by Jeanne Hayes, Quality Education Data, Inc., Denver, CO (1986).
38. National Center for Educational Statistics, 1982-83 School Utilization Study (Washington, D. C.: Corporation for Public Broadcasting, 1985).
39. Anne Wujcik, TALMIS Inc., New York, personal communication, October 1986.

This use of videotape represents a relatively new attitude towards video materials and a response to the individual teacher% increasing access to video playback technology. This has also prompted the largest program provider, the ITV organizations of the Public Broadcasting System (PBS), to respond with new services and distribution methodologies. Now, rather than requiring teachers to schedule class viewing time to suit the schedule of the local PBS station, a number of such stations have set up experimental video library systems, where programs are broadcast in a block schedule either in the early morning hours, or overnight, for the school to record on videocassette. A school building can then store and retrieve instructional television programming and make it available to meet the teachers' day to day curriculum needs: Moreover, this experiment has been carried out on a nationwide basis by WNET using PBS satellite ‘downtime’ overnight, making the service more cost effective.[40]

Currently, distribution of ITV programs to schools takes many forms. Programs on tape can be bought, leased, or rented directly by schools. Programs can rerecorded off-air at the time of broadcast and licensed through an agency of the broadcaster. Multipoint narrowcasting, or ITFS (Instructional Television Fixed Service) allows teachers to order programs from a central licensed facility. And virtually all Public Television stations feed their broadcast signals into numerous CATV (cable) systems. Some stations also feed special user locales over coaxial and fibre-optical cables. However, limited use of satellite dishes at school sites – Direct Broadcast from Satellite (DBS)–has been the subject of much study and experimentation among PBS system participants. As of summer 1986, 510 school districts reported having satellite dishes.[41] However, in 1986, the Kentucky legislature funded a new educational television channel and satellite receiving dishes for every school building and public library in the State opening the way

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40. ITV Futures Planning Group, "Learning Technology Issues for the Future," unpublished typescript, Aug. 7, 1985.
41. Quality Educational Data phone survey, "Does your school district have a satellite dish?" as reported in a letter from P,B.S. Director of Elementary/Secondary School Services to OTA, Dec. 17, 1986. (Additional data to come from QED).

for much more direct from satellite programming than ever before. It should be noted that once Kentucky puts its educational material up on the satellite, that material will be available to any dish pointed at that satellite from anywhere in the continental United States. It is possible that other States or individual schools might want to purchase viewing and/or taping rights for their programs.

Teleconferencing, with live, two-way video communication has also been the subject of limited experimentation. Of special note is the East Central Minnesota Educational Cable Cooperative project to link seven rural districts with two-way interactive television, with each classroom able to see the teacher and the other online classrooms. A master teacher can now teach up to four classes in four districts at a time in subjects that were previously unavailable to them.[42]

Nevertheless, the overwhelming use of video technology in public schools is for playing prerecorded cassettes and off-air recording. And even though many useful purposes can be served by employing a video camera along with video recording equipment, such as critical viewing skills, media literacy, taping and archiving school events, recording data from science experiments, and self-analysis in sports activities, very few schools taking advantage of this hardware.

However, this may be changing. Recently developed camcorders, with videotape recorders included in the camera, many of which have solid state pickup devices instead of fragile imaging tubes, and which are becoming less expensive, may have an impact on this type of use. A survey conducted recently by the New York State Education Department shows a dramatic increase of video-related applications, with 5,000 teachers using such technologies to produce video programs with students in their classrooms.[43]

One such program, called the Poetry Video Learning Project, operates in four New York City schools and involves chronic truancy students with practicing poets in making

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42. School Tech News, '2-Way TV Enriches Curricula in 7 Districts/' September 1985.
43. Mary Lee Shalvoy, et al., 'State Briefs: New York," Electronic Learning, vol. 6, No. 2, October 1986, p. 16.

“poetry videos,” similar to music videos. Students write a script, perform, and act as production personnel during taping. As one part of the Dropout Prevention Program, it has increased attendance 15 percent, according to school officials.[44]

Another video technology which may have real potential for instruction is videodisc technology. Videodiscs offer many advantages over videotape players with the exception of the ability to record. A teacher can easily pause the videodisc player on a still frame, slow motion forwards or backwards, and have almost immediate access by frame number to the entire half hour of material on each side of the disc. In addition, the visual and audio quality of videodisc images is vastly better than VHS videotape. Some videodiscs contain thousands of individual frames that can be displayed one at a time and in any order, much like a slide projector with up to 54,000 slides.

New Delivery Systems and Convergence of Technology for School Use

As instructional technologies continue to evolve, many new and powerful systems are being created by the convergence of computer technology with communication technology, especially television and the telephone.

An interactive videodisc system uses a videodisc machine as a peripheral to a computer. The resulting system permits the interactivity usually associated with computers to be enhanced by visual images with the resolution and dynamism of video. According to the responses of the learner, audio-visual sequences can be played multiple times, slowed down, or overlayed with computer graphics, perhaps to enhance an explanation or point out details. Such systems can involve the learner in powerfully realistic simulations, or give intelligent access to libraries of visual images and data never before possible.

The Voyage of the Mimi, a multimedia project in science and mathematics developed by Bank Street College of Education, is a television series plus a computer

44. New York Times, "Poetry-Video as Tool Keeps Truants in School," Jan. 11, 1987.

based science laboratory plus an interactive videodisc. Students watch a 15 minute fictional episode followed by a 15 minute documentary expedition about a scientific principle crucial to the drama. They can then work with the print materials that " accompany the package, and next experiment with provided lab tools; temperature, sound and pressure instruments connected to their computers. With these they can make measurements over time and have them displayed as dynamic graphs on the computer screen. Such activities can then be followed by an interactive videodisc-based exploration of the scene where the drama took place.

Another example of technologies combining to provide educational opportunities is a system that uses audio-graphic teleconferencing. With the aid of a microcomputer, light pen or graphics tablet, modem, and conference telephone, Garfield County, Utah, school officials offer a calculus class in four high schools, though the district may employ only one calculus teacher. Such a system allows a centrally located teacher to speak with all the classroom participants at once through speakerphones. In addition, the teacher can draw or plot on a common video screen. During discussion, any student at any site can also draw on the screen and the rest will observe the change. Prerecorded images can be called up from any participant's computer, and any image can be saved on any participant% computer for further reference.[46] Similar distance learning projects are also underway serving remote communities in central New York State.[47]

Distance learning, or remote learning systems are the subject of much experimentation in at least four States. The need to provide expert teachers in remote rural communities, where there are few qualified teachers for certain subjects, has caused the establishment of some very innovative programs involving such a mix of technologies.

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46. Todd **Stubbs,** 'Long-Distance Chalkboard,"[w] Electronic Learning, vol. 5, No. 1, September 1985, p. 14.
47. Jane **Perlez,** 'Long-Distance Teaching,"[M] New York Times, vol. 135, No. 46,626, Dec. 17, 1985, p. **C1 & C19.**

In Oklahoma, the number of high school students taking German doubled in one year after Oklahoma State University began offering a televised language class to 50 schools in Oklahoma. And students at 26 schools in Utah, Nevada, Colorado, and Arkansas began taking a' satellite Spanish course broadcast from Utah. The difference in these classes is that the teacher broadcasts over the satellite "live" and is also connected to each classroom by telephone. So the students can ask questions, practice speaking the language they are learning and interact with the instructor just as if he or she was in the room with them.[48]

In the Oklahoma experiment, students' homework assignments are sent over modems to the remote instructor for marking. The integration of technologies enhances the learning experience and, because of it, these students are able to take courses completely unavailable otherwise.

The distribution of computer information, programs, and data to remote locations that would otherwise need to spend large amounts of money on long distance telephony to access programs or services in city centers, is also a problem. One experimental program being run by the Center for Mathematics, Science and Environmental Education at Western Kentucky University uses the Early Warning System to broadcast courseware to rural schools. Using a mainframe computer located at the university, 21 schools in 14 districts are tied into the program using microwave relay stations operated by the Early Warning System which are relayed to local telephone lines, saving hours of long distance telephone charges.[49]

Experiments with broadcasting software to schools across the Nation are also being carried out by the Software Communications Service, an organization of 17 State Public Broadcasting systems and five Canadian provinces who are developing broadcast

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48. Francis C. Brown, III, "Televised Classes Help Rural High Schools Offer Fuller, More Demanding Curricula," The Wall Street Journal, Nov. 12, 1985, p. 31.
49. Electronic Learning, "Kentucky's CAI Capability," vol. 5, No. 5, February 1986, p. 10.

television's ability to carry computer information, at the same time as pictures and sound, to distribute instructional software to thousands of classrooms at a fraction of the cost of conventional distribution.[50]

Another area where technologies are converging, and must be considered by educators for the future, is robotics. When a computer is connected to an electromechanical device it becomes a robot. The population of robots in industry is growing steadily, with new applications in many fields arising in many unexpected industries, from candy makers and pharmaceutical houses to underwear manufacturers and plastics molders.[51] And there are some robots especially made for educational purposes. What success they can have in educational settings is yet to be discovered when more are used in classrooms. However, John Primozich, an Ysleta, Texas, primary school instructor believes that robots are perhaps the most efficient — as well as the most fun way for kids to gain experience with technology. The Ysleta schools have 10 friendly robots costing approximately $2,500 each. As they are capable of being programmed, he says, they encourage students to learn programming as well as increase their awareness of the technology around them.[52]

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50. Software Communications Service, "New Nationwide Software Communications Service Formed by Educational and Telecommunication Groups," press release, October 1, 1986.
51. Russell Mitchell, et al., "Boldly Going Where No Robot Has Gone Before, " Business Week, Dec. 22, 1986, p. 45.
52. National School Boards Association, "Robots Make Computer Literacy Fun," New Technologies: Key To More Productive Schools, N. S.B.A. Leadership Report, vol. 1, 1985, p. 26.