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ABSTRACT

Projected technological developments are described and analyzed for their relation to education, including very large scale integrated circuits and microcomputers, videodiscs, instructional networks, Dynabook, electronic publishing, devices for creative expression (word processor, electronic palette, music composition aids, computer-aided design), learning prostheses for the handicapped, and authoring facilities for course materials. Four strategic issues are raised, whose resolution will influence the way instructional technologies are developed and integrated into American education: (1) whether new technologies should be used to deal with new or with existing problems; (2) how the behavioral sciences can respond to the paradigm shift occurring with regard to cognition, from an emphasis on fact and skill acquisition methods to the study and development of intelligent, knowledge-based instructional systems; (3) how talents can be mobilized to produce sufficient high-quality instructional materials; and (4) how educational organizations can adapt to capitalize on the new technologies. Finally, future goals are discussed, and current formats which may utilize the potential of the new technologies are listed. A 27-item reference list is included. (LMM)

INSTRUCTIONAL TECHNOLOGIES OF THE FUTURE

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ABSTRACT: Future developments in computers and telecommunications have far reaching implications for education. However, the realization of their potential will require advances in cognitive science, modification of the curriculum, the cultivation of talent, and new organizational structures. Projected technological developments are described and analyzed for their relation to education; and issues that require resolution are discussed.

According to most projections, we will have, within ten years, an astonishing range of instructional devices based on powerful and inexpensive computers. Translating these devices into effective instruction depends on our ability to attract and support the creative talent needed to exploit them and our ability to develop theoretical approaches to instruction that can guide the use of the hardware and the preparation of software and courseware.

In this paper, we examine the future of instructional technologies and raise four strategic issues. Resolution of these issues will influence the way instructional technologies are developed and integrated into the mainstream of American education.

Technologies and techniques for presenting information have a powerful but not always appreciated influence on instruction. Our 'instructional technologies' define what kind of information can be presented and, often, what kinds of responses can be expected from students. They define what is feasible to prepare and to deliver through the educational system. Consider, for example, how the printed text defines what is taught in our schools and how it is taught.

New Technologies: Present and Future

After about 500 years of dominance by the technology of printing, we are entering an era in which new information technologies will make possible radical changes in instruction. In the areas of hardware and programming for capabilities such as speech recognition, this paper is conservative. As a result we can have confidence in predictions of devices that will be available. However, these technologies do not assure effective instructional systems. The difficulty lies in using the available elements to invent instructional environments that are pedagogically and psychologically sound and that can be integrated into our institutions in a satisfactory way.

The list of devices that will be available includes the following hardware:

a.) high resolution, flat, color display screens that will require very little power,

b.) refined, simple-to-operate controls that will permit one to easily manipulate the computer-image-information environment without any knowledge of programming, c.) very large memories (enough to hold entire libraries) in either analog or digital formats,

d.) high transmission rate communication links to other sites using fiber optics and laser diodes,

e.) links from satellites directly to a home receiving antenna,

f.) two way cable TV hook-ups,

g.) networks providing access to an array of large collections of information,

h.) networks providing access to a selection of other computers for specialized applications, and

i.) powerful computers the size of a notebook that can be used in an integrated instructional system.

Some devices will require special computer programs for their realization. And, until recently, advances in hardware technology have not been matched by comparable advances in programming technique. Thus, while costs for raw computing power have decreased exponentially over time, costs of programming have not. However, new languages (such as Pascal), and the development of structured, on-line, interactive programming and computer aids for programming are resulting in more systematic and dependable work. As a result of these and other developments, sophisticated computer programs will enrich the variety of available software. Some examples of likely results from current research are the following:

a.) speech synthesis (already available in some form, e.g. Texas Instruments' Speak and Spell; Suppes, 1979),

b.) natural speech recognition (IBM, 1980), c.) ability to accept natural language commands, answers and questions,

d.) sophisticated text-editing and word-processing functions,

e.) detection and response to any body positions or functions selected for measurement, and

f.) tactile devices that enable one to feel some three-dimensional object that exists only in the memory of the computer (Noll; 1972).

Let us turn now to a more detailed examination of some of the hardware being developed:

Very Large Scale Integrated Circuits and Microcomputers. The key to much of what can be done in the field of instructional technology lies in the computer. For the rest of this decade the computational power of the microcomputer will double every two years while the cost will remain roughly constant. This means that at the end of the decade, for about $1000 of today's dollars, we will have computers that are 30 times more powerful than current models. Thus while today's home computer is not quite powerful enough to meet many instructional challenges, the machines of 1985 to 1990 will almost certainly be adequate. However, we should not wait until these machines are available to start developing advanced instructional programs. There are good examples of programs originally created and tested with large machines that, once perfected, have been re-programmed to run on small inexpensive machines. We should begin now to support the development of instructional software to match the capabilities of the school-priced computers that will be available in five or ten years.

Videodisc. The videodisc may seem to be nothing more than a new version of motion pictures, but this view is misleading. Each side of a typical videodisc has 54,000 individual pictures or 'frames'. Almost instant random access to a given frame can be provided (within about 2 - 5 seconds) with a microcomputer. A course in the art history, for example, can call for instructional materials that make use of up to 54,000 different pictures.

The disc has two audio tracks so that each can be used to address a different audience. However, sound is now available only when the disc is used in the normal display speed of 30 frames per second to produce the illusion of motion. Developments underway should soon result in the capability for up to 30 seconds of sound with each frame.

Videodisc development is proceeding along two major lines:
1.) A 'read only' videodisc (the kind now available) is like an LP record; one cannot erase and re-record as on an audiotape or a videocassette. Several firms are developing discs that can be erased and recorded by the individual user, and will not require the elaborate 'mastering' process that today costs about $3,000. One advantage of being able to record on a disc is that it can then be modified without replacing the entire disc each time a modification is required. 2.) The second major development will be the digital videodisc. Digitally encoded information is the kind a computer uses. As a result a digitally encoded videodisc can serve in the following ways:

o As a huge library of computer programs. A single disc can probably contain enough programming to give a student all the computer-based instruction he or she could use in an entire undergraduate career.

o Symbolic information (letters and numbers) can be stored more economically in digital form. A typewritten page of 200 words uses about 1000 bytes (10,000 bits) of information. The same page encoded in the old analog form (a photograph of the page stored on the videodisc) requires about a quarter of a million bits. Put another way, a disc can store about 100 million words or about 1000 textbooks on one side of a digitally encoded disc.

Instructional Networks. Cost (e.g. use of telephone lines) can be a significant restraint on 1.) interchange among networks of students, 2.) the use of centralized or special computing facilities, and 3.) access to information and data banks. As information flow has increased in recent years, it appeared for a time that the cost of manufacturing, installing and maintaining copper lines and related equipment might seriously limit interaction among users. However, the advent of fiber optics systems means that costs for electronic communications may drop sufficiently to permit widespread educational use. Fiber optics permits large amounts of information to be sent inexpensively over glass fibers by laser signals. The combination of fiber optics technology and satellite information transmission (see below) will give us the capacity and low cost needed for instructional use.

For a few hundred dollars an hour, almost any school can now send a lecture, via satellite, to receiving stations thousands of miles away for re-broadcast or for recording on tape and later use. In a few years the transmitted programs will be received directly at homes via a small satellite receiving system that will cost about $500 (Wigand, 1980). This will permit individuals to either select, for direct viewing, educational programs from a large menu or to record programs from satellites for later personal use. Thus an engineer in an isolated town in Alaska will be able to study advanced courses from MIT.

Satellite transmission can also be used to transmit computer programs that can be recorded and used to enrich the students' interaction with transmitted lectures. When two-way cable (see section on networks using fiber optics above) is added to the satellite technology, local students and instructors can provide personalized instruction and self-help to complement a.) lectures provided by the best teachers and experts or b.) sophisticated broadcast programs such as those of The Ascent of Man series. Cable TV distribution allows one to meet incremental costs for administration and equipment maintenance with a televised enrollment as low as about 40 students in a single course offering. Thus with the new technologies we can offer courses of advanced design to small numbers of dispersed and isolated students.

Dynabook. Dr. Alan Kay (Kay, 1973; Warren, 1980) invented the concept of the Dynabook -- a small portable computer with astonishing power -- about 20 years ago. At the time Kay introduced the idea, the dynabook seemed like an element of science fiction that was not likely to be realized within the foreseeable future. However, flat display screens are the last major technological development needed for the realization of Kay's vision, a complete microcomputer system as portable as an attache case. The top part of the case can be a full-color, high resolution screen that displays text, high-resolution graphics, and pictures while a complete keyboard is in the bottom. A speech synthesizer can be used for text stored in the computers memory. The computer core of the device will have the memory and the program needed for sophisticated processing of student work (answer checking, search for error patterns, tutoring, coaching, mapping student knowledge, speech synthesis, speech recognition, branching based on errors and the student's knowledge base, etc.). The dynabook can be used either as a portable battery operated device or hooked into a communications network that will give the user access to other people, to larger or specialized computers, or to electronic information libraries. The immediate reserve memory of the device will have the capacity for a library of at least the size of 25 major reference books. This amount of information may also be encoded on discs about 5" in diameter so that a student can carry a library of about 25,000 volumes (100 discs) with the computer.

Electronic Publishing. As the cost of paper, shipping, and printing increase in cost, as the desire for up-to-date revisions increases, as the need for computer search of large information collections increases, analysis suggests that electronic publishing and document storage will be increasingly attractive. For example, a frame on a videodisc costs about

0.05 of a cent; a conventional color slide costs about 50 cents (1000 times as much); a printed page costs at least 2 cents (40 times as much). While a disc frame cannot yet carry as many words as a printed page, a digital disc frame will be able to encode many times more words than a printed page, once again making the cost of a page of printed words about 1000 times greater than the cost of the same words stored on a disc. Amortizing the cost of the player and TV display changes the costs somewhat, but not sufficiently to change the argument.

As the number of bits of information that can be inexpensively stored on a disc or similar device climbs into the trillions and quadrillions, a general purpose image, sound, and even tactile display system becomes feasible. Once we have enough information storage available, the combination of large memory, powerful computer programs and generalized input-output devices will support an almost completely flexible communication system: sounds, pictures, motion, animation, words, music, speech, questions, problems, annotations, etc. can all be generated and integrated through the 'intelligence' we can program into the computer. We will return to this theme later.

Devices for Creative Expression. Part of the educative process is the systematic build-up of knowledge and skill. Another part is practice with previously acquired knowledge and skills in a variety of novel or creative ways. Novel creative effort develops transferable skill and provides motivation. The following are examples of the use of computer technology to facilitate creative work:

o Word processors can enable beginning writers to easily create and correct printed documents.

o An electronic palette is available that enables one to draw in full color. The created images can be modified in a variety of ways: crooked lines can be straightened; colors can be changed; elements can be duplicated, drawings can be animated, areas defined by lines can be filled with color at the touch of a key, etc.

o There are several systems that allow one to compose music and have it played in modes that synthesize anything from a single instrument to a full orchestra.

o Computer aided design (CAD) (Musgrave; 1980) permits the architect or engineer to create and simulate the operations of various designs of objects with safety factors and other constraints (weight, cost, availability of materials, etc.) automatically accounted for.

Learning protheses for the handicapped. With the aid of a computer and its programs, the physically handicapped person can engage in a wide variety of learning activities. At present computer programs exist that can interpret a limited number of words. This puts some simple but very important robotic functions at the paralyzed person's disposal. Special keyboards or controls enable the person with limited muscular control to fully engage the power of the computer and thereby participate in a wide range of learning and creative activities (e.g. essays, problem solving, design, art work). In addition, speech synthesis and recognition should be of great aid to the child with learning disabilities.

Optical character readers can now convert almost any printed page into tactile signals that a blind person can read (Linvill, 1969). Most kinds of visual information can be transformed into a kind of surface texture so that maps, geometric figures, etc. can be sensed by touch (Noll, 1972). Further, words and numbers can be converted into synthesized speech so that the blind person will have the choice of listening or 'touch reading' any printed or computer stored document. The same devices will mean that the blind student will not need a special typewriter to compose essays that both blind and sighted people can read.

Of direct relevance to public education is the fact that the technology is sufficiently flexible so that analogous devices can be prepared for many handicaps. These devices make it more practical to mainstream handicapped children and accomodate the resulting diversity of students through individualization. It should also be noted that devices that enable the handicapped to function can also be useful to 'normal' people in certain situations such as using robots and remote sensing to enable students to carry out experiments that would otherwise be too dangerous.

<u>Authoring Facilities.</u> The authoring of course materials is probably the most costly step in the production of excellent instructional materials. Molnar (1976) has observed that as we enter an era of 'no cost' computing the major financial barrier to the widespread use of computers in

education is the high cost of development of instructional materials. Hence what is needed is a system of production to reduce that cost.

One analysis showed that it cost the armed forces about $125 for each illustration used in slide-tape lessons. By moving to electronically produced illustrations (from videotape) the cost was reduced to a few dollars per illustration. If we are to capitalize upon the future instructional technologies, analysis and experience suggests that we will need a companion technology for the author. The author who wishes to compose with graphs, diagrams, images, color pictures, motion pictures, line drawings, line drawings and words superimposed on pictures, sounds, speech, etc. -- in order to create, for example, a videodisc -- finds himself faced with a clumsy and expensive process to produce a smoothly flowing sequence of images, sounds, and graphics (Mendenhall, 1979).

The technology to orchestrate most of these elements exists in the television studio, but at too great a price. A system is needed so that images, sounds, computer generated graphs and drawings, can be found or created, judged for desirability, edited, and recorded by one person with possibly a technical assistant. No element of the system is beyond our present technolgy, and such authoring systems are emerging at various experimental sites.

When a single author or a small team can anticipate royalties in return for time invested in creating instructional materials, we will have the kind of incentive that proved successful in inducing authors to prepare printed materials.

STRATEGIC ISSUES

We will now turn to the four issues whose resolution will affect the extent and direction of the new instructional technologies.

I. Old vs. New Curriculum. What educational problems should be addressed by the new technologies? Should we use the new technologies to deal with existing problems or should they be marshalled to help people deal with a new curriculum generated by the possibilities of computer augmented human intellect?

As a basis for the first alternative, there is a long list of existing problem areas in education that can benefit from intelligent and creative applications of computer-based instruction. These include 1.) courses that are especially difficult (e.g. computational algorithms, physics and chemistry, grammar, foreign languages), 2.) the individual's general need for competence in the 3Rs, including the ability to write clearly and coherently, 3.) knowledge and skill in science and technology, 4.) the ability to analyze and solve problems.

System-wide problems that could be attacked by new technology include the mainstreaming of handicapped students, the difference in quality between rich and poor school districts, shortages of teachers for specialized but important subjects (e.g. Arabic or materials science), continuing education for workers, and access to education for isolated or immobile people.

Past attempts to deal with many of the problems of classroom instruction by modification of the existing system and standard techniques (e.g. smaller class sizes) have not been notable successes. One general argument (Heuston, 1977) is that education is a mature technology that has explored and has already incorporated any major improvements that were stable and desirable. Therefore it is improbable that we can make any major progress by fine tuning the existing system. Evidence for this argument is the fact that while constant dollar expenditures per pupil have increased markedly over the past years, the performance of students has remained relatively constant. What is needed, according to this line of reasoning, is a technological breakthrough. The capacity of the computer to offer individualized materials and sequences may enable the system to break out of the constraints imposed by the teacher's limited ability to process and act upon information about each student. If this argument is correct, we can think of producing a discontinuous change in instructional productivity through computer-aided instruction.

While there is legitimate concern for our many existing problems, we would argue that the most powerful rationale for using the new information technologies is intrinsic to their increasing and pervasive presence in our society and their nature as information machines. Their character is such that, only through their use in the educational process, can future students attain essential new knowledge and skill. Let us go back to print as an analogy. Print not only created the potential for dissemination of knowledge to a degree not before possible, it also created the need for a huge fraction of the population to achieve literacy and intellectual skills in ways not previously anticipated. This in turn could only be accomplished effectively through the use of the new print technology.

The same process is under way with respect to computers and the related communications, image and information storage technologies. They make it possible to acquire and transform information at new levels of speed, ease and in new ways. They enable us to obtain and use new kinds of information (computer animated processes, digitally stored information, auto-correlated data, etc.), thereby allowing us to carry out more creative and problem-solving activities in the arts, in the liberal arts and sciences and in applied fields such as engineering, medicine, business, etc. As the computer permeates and transforms society, the curriculum will surely follow, and the still valid trinity of education -- preparation for work, preparation for citizenship, preparation for personal growth and understanding -- will be dominated by topics and expectations that can only be effectively taught through the use of the computer-related technologies. For example, as simulations become more and more a part of the world of knowledge and training, there is pressure to use simulations in the curriculum. As the computer makes new classes of problems amenable to solution in a reasonable period of time by people of average intelligence, there is pressure to include such problems in courses at all levels. Proposals to the NSF already give a strong indication of this trend.

The strategic issue involves the allocation of resources and decisions about the curriculum. If there is no systematic planning and attention, then many students will acquire an education that teaches neither the old nor the new curriculum very well. If we simply use the new technologies as a way to improve instruction in the old curriculum we may teach knowledge and skills that have lost much of their value and importance. The issue to be faced is how rapidly the curriculum should be transformed and how we should allocate human resources to plan, make decisions and implement those decisions for the reconfiguration of the curriculum and the infusion of the new technologies into the educational system.

II.) How can the behavioral sciences respond to the paradigm shift that is taking place with regard to cognition.

The following statement (Atkinson, 1978) characterizes the challenge to psychologists in particular and behavioral scientists in general:

"... research trends in cognitive psychology and instructional systems are shifting from an emphasis on effective methods to acquire facts and skills to the study and development of intelligent, knowledge-based instructional systems. Knowledge-based systems are being developed which so thoroughly "understand" the subject domain and the student's grasp of the subject matter that they are able to assist the student to recognize, articulate, and use diverse forms of information in problem-solving environments. These developments are not simply new wrinkles in educational research, they are assaults upon the basic questions of 'What is knowledge?' and 'How is it best acquired?' These research efforts are laying the foundation for the solution of a much larger set of educationally significant problems than has ever been considered in the past."

The computer-based simulation of student behavior and the embodiment of instructional theory in computer-aided instruction can provide a powerful impetus to cognitive science. The behavioral scientist often takes, as the unit of investigation, a restricted range of events. It is hoped that from these molecular units of analysis a theory can be constructed to explain more complex behavior. In the past, there was little attempt to take into account an individual's knowledge, goals and plans as they influenced behavior(Atkinson, 1975). So, for example, an error in arithmetic might be treated simply as a feedback problem by giving the correct answer following an error and notifying the student when a correct response is given. A newer approach, exemplified by the work of Brown (1978), analyzes the mental processes that led to the error in the first place. He finds that errors are often the result of elaborate but faulty procedures that make some sense to the student. Brown uses the computer to a.) analyze the pattern of student responses, b.) simulate the kinds of errors that the student is liable to make from the inferred faulty procedures, c.) devise an automated tutorial system to assist the student when an error is made, and d.) give the student insight into the process of generating errors by challenging him or her to figure out procedural errors programmed into the computer.

The point is that we are beginning to deal with complex human behavior, to use computer analysis and simulation to add precision to our observations and to check the power of theoretical predictions. Computer-aided instruction can provide important data for understanding cognitive processes in the following ways: The computer can be used to model a system (e.g. a student) with large numbers of variables when the individual relationships are known but the results of complex interactions are not known. An alternative use of the computer is to infer relationships and causes when the outcomes are observable, but the detailed processes are not known. We suspect that in the case of cognitive behavior neither condition is fulfilled: we can not be sure of the accuracy and reliability of our observations, nor do we have adequate elementary laws of behavior to feed into our simulations. However, by clever experimental design, the simulation of complex problem-solving behavior is providing us with insights that suggest that we may be beginning to ask the correct questions (Larkin, 1980).

How can the social, behavioral and neuro-sciences relate to this paradigm shift? Can we capitalize on artificial intelligence, a relative newcomer among disciplines,which is providing models of human thought processes. Many of the disciplines that concern themselves with complex human thought processes, including artificial intelligence, are now being organized into a field called cognitive science. The fact that such an integration is taking place across disciplinary lines suggests that a fruitful interaction will begin to take place between the applied field of instruction and such disciplines as psychology, sociology, anthropology, linguistics, brain science, artificial intelligence, ethology, and general systems theory.

Investigators in these fields are now asking a host of questions that a few years ago were judged to be too difficult to even consider. We will pick only one line of research to illustrate what is happening. Studies in many fields are showing that an individual's world view or general knowledge of how the world works (schema) influences how that person interprets and classifies almost every event. This explains certain cultural differences in formal learning (Cole and Scribner, 1974) and suggests steps that must be taken for instruction to be effective. It also leads us to ask questions of the following sort:

What is meant by common sense, understanding, intuition, or tacit knowledge? Can we define and describe these ideas with sufficient precision to use them in a model of instruction?

How does a student use his or her general world knowledge to assign meaning when only partial information is available? How do various representations, ideas and kinds of experience influence the development of one's world view?

Work in this area suggests the following direction: A sophisticated computer-based instructional system needs to have stored a.) knowledge of the subject matter being taught and rules for applying that knowledge in the analysis of a student's work, b.) a model of the student and a means of analyzing student errors, and c.) rules for interacting with the student according to various strategies such as making suggestions, offering new problems, modifying work assignments, using different displays and approaches, etc.

The difficulties of this research are intimidating. Nevertheless, we seem to be on a path that has both the theoretical thrust and the methods needed for progress. In the developmental phase, the computer-aided instructional program will be a test bed for the theories and the domain of their applicability. Computer simulations of complex behavior will be invoked to add precision to fundamental research in this area. As critics and participants psychologists will have a key role in determining the course and quality of research in cognitive science.

III. Talent. How can we mobilize the talent to produce instructional materials for the new technologies of the amount and the quality needed for effective instruction?

If the new instructional technologies are to be effective, research and development will be required. Our best scholars will be needed to ensure that the knowledge structures encoded into the computer programs are accurate and elegant. Cognitive scientists will be needed to assure the quality of the computer programs that analyze student response patterns, fit them to a model of the student, and generate an instructional experience. Skilled programmers will be needed if the entire package is to have the power envisioned.

Licklider (1980) estimates the effort needed to create the software bases for a comprehensive computer based system to be about $1 billion per year for a ten year period. Our estimates are based on the following assumptions: a.) a goal of about 6000 student-hours of computer-aided materials in the pre-college curriculum, b.) about 3000 hours of human effort to assure an hour of excellent computer-aided curriculum materials, and c.) a cost of about $50 for each hour of human effort. This results in an estimate of $100 million a year for ten years to prepare an excellent pre-college curriculum. If either figure seems preposterously large, remember that pre-college education is a more than 50 billion dollar a year operation. Thus, the above figures are only about 2 percent to .2 percent of the yearly pre-college education budget.

Similar problems have been solved in other countries. England put a small tax on the sale of each TV set to pay for BBC program production. This is ~~why~~ they were able to use TV for their Open University and why we watch a lot of British programming on our public TV stations. In Germany the mail system owns the phone system; while the mail system loses money, the phone system has a huge surplus. The Germans are planning to invest this surplus, on the order of billions of dollars a year, in various instructional technologies and the needed course development.

By what strategies can we, in tight budget times, generate resources of the level of hundreds of millions of dollars per year? Can some combination of a.) royalty incentives, b.) federal grants for curriculum development, and c.) other social inventions not yet conceived do the trick? In the absence of the sytematic allocation of resources for development, what will be the fate of the educational potential of these technologies?

IV.) Organizations. How can educational organizations adapt to capitalize on the new technologies?

Previously (Lipson, 1976) we have suggested that organizations that survive do so because they have an organizational structure that enables people to be productive with the dominant technology. Thus a new technology usually implies the need for a new organizational structure. But, organizations, like people, tend to resist change until they are sufficiently challenged. However, as noted by Boulding (1972), education has been relatively immune to challenge because it tends to be supported as a grants economy rather than as a system of purchases for what it produces. Consequently there is no simple way to encourage new methods except by reaching consensus that change is needed. Even then, the desire for change must be sufficiently high on the public priority list to gain the attention needed.

Part of the problem is that we do not know a great deal about the sociology and psychology of organizational decisions and how organizations can be encouraged to change in the face of new technologies. The individual administrator or instructor is often blamed for resisting change. From the above perspective it might be more appropriate to say that she or he is embedded in an organizational structure which, because it has evolved into a stable form, encourages each member to sustain that form rather than change it. An individual is liable to be expelled from the organization if she or he demands change that is incompatible with the forces that make for stability.

The strategic issue is whether we can develop and apply a theory of organizational behavior that will permit us to promote the orderly transformation of our educational organizations -- enabling people to be productive with the new technologies and to allocate resources to the new kinds of work required.

What Future Vision Should Be Our Goal?

It is clear that plans can be developed for a wide variety of instructional technology futures. We can assemble affordable home learning centers based on the technologies discussed. But do we know enough to assure that they will be used effectively? Similar questions can be raised regarding the introduction of computer-based instructional technologies in the school. Our experience with television should give us reason for concern; we are still trying to understand the impact of TV on psychological development. How will the interactive nature of computer-aided instruction affect cognitive and emotional growth?

Another factor that limits our vision is our tendency to be trapped in images from the past. New technologies initially imitate old technologies (e.g. the horseless carriage). Only through imaginative efforts can new forms and techniques evolve that capitalize on the unique capabilities of the new technology (e.g. the long evolution of film as an art form). While computers may offer us inexpensive texts and videodiscs may offer us inexpensive slides, surely these are intellectually trivial images of the new technology. What unique features offer us the opportunity to transform the intellectual and instructional landscape?

In order begin thinking about these questions, a description of configurations of instructional technologies is in order. The array of hardware and software capabilities constitute the creative elements for the instructional author. They can be combined to produce many new forms. In the same way that dictionaries, novels, encyclopedias, posters, etc. are useful terms to describe the manifestations of the print technolgy, we need to describe some of the unique ways that the elements of the new technologies can be configured for learning. Typically, each configuration will involve a complex combination of hardware and software elements and will imply a distinctive style of interaction between the student and the system. The challenge to the instructional developers will be to invent, develop and implement new formats that will realize the potential of the new technologies. The following are some of the forms currently in use or under development:

a.) Games. Games that involve competition between the person and the computer, between individuals and between teams of people are already prominent (Goldstein, 1980). Dynamic animation of combat and adventure characterize some of the more popular games.

b.) Instructional simulation. Simulations enable the student to practice complex skills (e.g. flying an aircraft or operating a nuclear power plant) with equipment that is too expensive or dangerous for novice hands-on learning experiences. In spite of the large cost of simulators they have proven very cost/effective and interesting simulations are becoming available for use with inexpensive computers.

c.) Automated dictionaries. (NIE, 1979). Work is underway to combine the features of the word processor with access to specially prepared dictionaries so as to enhance a student's concept formation and creative expression.

d.) Hypertext (Nelson, 1967). The ability to include a hierarchy of levels of explanation and detail, to provide footnotes, comments by instructors, reactions by students, and access to original references makes an exciting transformation of the conventional textbook.

e.) Microworlds (Brown, 1979). Through the computer we can simulate real or hypothetical microworlds with their own regularities and laws for children to learn about and explore. For example, we could create a Relativity World in which the student gains perceptual experience moving close to the speed of light. We can simulate a world in which the speed of light is 20 miles per hour and the student could be challenged to deal with the unusual effects that would result. This should make certain laws and relationships of the theory of relativity intuitively reasonable in a way that cannot be achieved by most people without such experience.

f.) Dynamic library (Licklider, 1979). Computer-aided search through extremely large data bases.

g.) Spatial Data Management. Heirarchical, 2-dimensional arrangements of data files that can be easily explored through zoom (moving to and from greater levels of detail) and scan (moving around at a given level of detail) using manual controls that require no prior experience on the part of the user (Bolt; 1979). Using this system one can engage in vicarious travel through a town such as Aspen, Colorado or explore a knowledge domain such as the animal kingdom at almost any level of detail.

Who will provide the visions for the instructional use of these devices? And what implicit or explicit theories of human behavior will those visions represent? We hope that scholars, in general, and psychologists and other social and behavioral scientists, in particular, will find these interesting questions and will respond to the research challenge.

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