

CHAPTER 1

INSTRUCTIONAL COMPUTERS: PAST, PRESENT, AND FUTURE

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Abstract

There are at least five major technological innovations in the past that are comparable to the current computer revolution: written records, libraries, printing, mass schooling, and testing. A brief examination of them can help develop an historical perspective on the future of computers. The current operational use of computer-assisted instruction also raises a number of issues of a broad educational and social nature: individualization of instruction, standardization of instruction, complexity of instruction, and freedom of education. Future developments relate to: computers that talk, computers that listen, the use of knowledge, and the need for new or more empirical theories of learning and instruction. Through appropriate use of the new technologies of computers and television, structural changes can be expected in education, from elementary school to higher education.

A General Perspective

My initial remarks are aimed not at the content of what we do in using computers for instruction but at broader attitudes toward computers in the modern technological world.

In October 1983 I was in Brazil to address the Sixteenth National Brazilian Computer Congress, attended by more than 40,000 people. The interest in computers in Brazil is much greater than might be expected. Brazil is one of the most advanced third-world countries and is deeply concerned about the technological gap between Brazil and the United States. This broad concern is not restricted to education, but applies as well to the office, the factory, and the service industries generally. Their central worries are that they are not going to be developing and educating their children to the new technology, and they are not going to be developing their industry in appropriate technological directions.

In a different and much more positive way, the same sort of problem has arisen in the United States and Europe. What has happened in the last couple of years in the developed countries is that there has been an explosion of concern about the future of technology, especially computer technology. We are in the middle of the most rapid industrial change in the twentieth century. This change is reflected in the attitudes of

schools, but we must recognize that information technology will be dispersed beyond schools and offices. We are going to see information technology in homes too.

We have reached a point of change in the general environment that was not present a few years ago. We want our children to grow up in a world where they will be familiar with technology. We want our students to be at home with the new technology, to be ready to deal with it, to use it, to make it part of their world now. Students will have a natural and easy feeling about the information technology when it is brought to them early as part of their everyday activities. Just think about the expected life span of a student now in the first grade. It is certainly at least another 70 years. That is a very long reach into the twenty-first century. The kind of world in which today's first grader will participate is going to be a world that is saturated with sophisticated use of information technology. Everybody is going to use, in various forms, the technology. By the time a first grader finishes his or her career most of us will not be here, but the world will be a very different place. We are going through a transformation that is a more radical change than was the change from an agricultural to an industrial society in the nineteenth century.

Historical Perspective on Past Educational Technologies

I can identify at least five major technological innovations in the past that are comparable to the current computer revolution. Brief examination of them should help develop a historical perspective on the future of computers.

Written Records

The first is the introduction of written records for teaching purposes in ancient times. We do not know exactly when the use of written records for instructional purposes began but we do have, as early as Plato's *Dialogues*, written in the fifth century B.C., sophisticated objections to the use of written records.

Today no one would doubt the value of written material in education, but there were very strong and cogent objections to this very earliest innovation in education. The objections were these: a written record is very impersonal; it is very uniform; it does not adapt to the individual student; it does not establish rapport with the student. In other words, Socrates and the ancient Sophists, the tutors of students in ancient Athens, objected to introducing written records and destroying the kind of personal relation between student and tutor that was a part of their main reason for being.

It has become a familiar story in our own time that a technological innovation has side effects that are not always uniformly beneficial. It is important to recognize that this is not a new aspect of innovation but has been with us from the beginning.

Libraries

The second innovation was the founding of libraries in the ancient world, the most important example being the famous Alexandrian Library that was established around

300 B.C. From about 250 B.C. to A.D. 400, not only was Alexandria the most important center of mathematics and astronomy in the ancient world—it was also a major center of literature, especially because of the collection in the Alexandrian Library. The first real beginnings of critical scholarship in the western world in literature, the editing of texts, and analysis of style, the drawing up of bibliographies, took place in the Alexandrian Library. This revolution in education consisted not simply of having in one place a large number of papyrus manuscripts but in the organization of large bodies of learning. Scholars from all over the western world came to Alexandria to study and talk to others.

Libraries of a substantial nature were to be found in other major cities of the ancient world, not to mention the large collections of learning in China, India, and Korea.

Printing

The third innovation of great historical importance in education was the move from written records to printed books. In the western world we identify the beginning date of this innovation with the printing of the Gutenberg Bible in 1452. It is important to recognize, however, that there was extensive use of block printing in Korea and China three or four hundred years earlier. Nearly half a millennium later it is difficult to have a vivid sense of how important the innovation of printing turned out to be. In the ancient world of the Mediterranean there were only a few major libraries, a number so small that they could be counted on the fingers of one hand. The reason is obvious: it was impossible to have large numbers of copies of manuscripts reproduced when all copying had to be done tediously by hand. The introduction of printing in the fifteenth century produced a radical innovation—indeed a revolution—in the distribution of intellectual and educational materials. By the middle of the sixteenth century not only European institutions but wealthy families as well had libraries of serious proportions.

Once again, however, there were definite technological side effects that were not uniformly beneficial. Those who know the art and the beauty of the medieval manuscripts that preceded the introduction of printing can appreciate that mass printing was regarded by some as a degradation of the state of reproduction.

It is also important to have a sense of how slow the impact of a technological innovation can sometimes be. It was not until the end of the eighteenth century that books were used extensively for teaching in schools. Fortunately, the time scale of dissemination in the modern world is of an entirely different order from what it was in the past.

Mass Schooling

The fourth innovation, and again one that we now accept as a complete and natural part of our society, is mass schooling. We have a tendency in talking about our society to put schools and families into the same category of major institutions. But it is extremely important to recognize the great psychological difference between the status of the family and the status of schools. Families are really deep into our blood and our culture. The evidence of families in one form or another being the most important cultural units goes

back thousands of years. Schools are not at all comparable; they are, we might say, very late arrivals to our culture. A hundred years ago in 1870, for example, only 2% of young people graduated from high school in the United States. A hundred years before that only a very small percentage even finished third or fourth grade. Moreover, as short a period as fifty years ago, in most of the world less than 1% of the population completed secondary school.

In many developing countries of the world today the best that can be hoped is that the majority of the young people will be given four grades of elementary school. Until the population growth is brought in check, it will take all available resources to achieve this much.

As recently as the latter part of the nineteenth century the British philosopher John Stuart Mill despaired of democracy ever really working anywhere in the world for one reason—it was simply not possible to educate the majority of the population. In his view it was not possible to have a significant percentage of the population able to read and to be informed about political events. As in the case of many such predictions, he was very much in error. The revolution in mass schooling is one of the most striking phenomena of the twentieth century.

Testing

The fifth educational innovation is testing, which is in many ways older than the concept of mass schooling. The great tradition of testing was first established in China; testing there began in the fifth century A.D. and became firmly entrenched by the twelfth century A.D. There is a continuous history from the twelfth century to the end of the nineteenth century in the use of tests for the selection of mandarins—the civil servants who ran the imperial government of China.

The importance of these tests in Chinese society is well attested to by the literature of the fifteenth or sixteenth century; one is impressed by the concern expressed for performance on tests. The procedures of selection were as rigorous as those found in a contemporary medical school or a graduate school of business in the United States. In many periods fewer than 2% of those who began the tests (which were arranged in a complicated hierarchy) successfully completed the sequence and were put on the list of eligible mandarins.

Although testing has a history that goes back hundreds of years, in many ways it is proper to regard testing as a twentieth-century innovation, because it was only in this century that the scientific and technical study of tests began. It is only in this century that there has been a serious effort to understand and to define what constitutes a good test for a given aptitude, a given achievement, or a given skill. Initially, this intensive study of testing from a technical standpoint was primarily a focus of research by such educational psychologists as Edward L. Thorndike. The tradition that Thorndike began has become a major one in our society and is a source of continual controversy in terms of issues of fairness and objectivity.

The five innovations that I have discussed—written records, libraries, printed books, schools, and tests—are the very fabric of our educational system today. It is almost unthinkable to contemplate a modern educational system without each of these innovations playing an important part.

Of these five technologies, none had been in any way adequately predicted at the time it was introduced. Of course, a few individuals foresaw the consequences and had something to say about those consequences, but certainly the details of the use of any of these five technologies had not been adequately foreseen. I am certain that the same thing will be true of technologies now developing for use in the future, and so I do not want to appear confident that what I say is a correct scenario for the future.

But I want to say something about each of the five past technologies. First, I have mentioned, and I want to re-emphasize, the very recent and historically very transient character of schools. It is a phenomenon in a general sense of the last hundred years in the most developed parts of the world, and a phenomenon of the last forty years or so (that is, since World War II) in the underdeveloped parts of the world. Now, an important question for the future is this: In fifty or one hundred years, will we abolish schools? Will we deliver into the home, or into small neighborhood units, by technological means all curriculum and instruction? Further, will the desires or goals of the individual, the family, the parents, or the neighborhood group be such that children will not be in school, but at home or in the neighborhood? The answers to these questions are not easy to predict or to foresee.

The same kind of forecast may be made for books. The importance of books that we have felt for several hundred years, since the beginning of the Renaissance, and that has been associated with the development and education of an informed citizenry, may fade away. I think that all of us, at least those of my age, have seen this already in the case of young students. Some recent studies have indicated that the cultural reference points of the younger generation are no longer to be found in books, or in current novels, but in television and movies.

In the case of tests, I also predict that this classical technology will decrease in importance. I believe that tests will decrease in importance because we will have the technological means to keep a much more satisfactory and much more detailed record of the learning of individual students. Thus inferences about the performance of students and their capabilities for taking next steps will depend upon a much more substantial record, a much more robust basis of inference than we have in current tests.

As for libraries, they will be totally transformed. I feel more confident of this prediction than of any of the others. Electronic access will be widely available in homes, in offices, and in schools of whatever organizational kind we have. There will be libraries but they will be electronic libraries.

Finally, what about the written record? The written record will undoubtedly continue to have importance, but I think that when it comes to teaching, the objections found in Plato's *Dialogues* to the cold and neutral written word as opposed to the warm and friendly voice of the teacher will once again be heard and perceived as serious objections. What I am saying is that, in starting to think about the future, we can forecast obsolescence or semi-obsolescence for all of the great technologies of the past—and that is proper and appropriate.

Issues Raised by Computer-Assisted Instruction

The current operational use of computer-assisted instruction in many schools in the United States and elsewhere raises a number of issues of a broad educational and social

kind to which I would now like to turn. I will discuss four rather closely related issues: (i) individualization of instruction, (ii) standardization of instruction, (iii) complexity of instruction, and (iv) freedom of education.

Individualization of Instruction

The first issue centers around the claim that the deep use of technology, specifically computer technology, will impose a rigid regime of impersonalized teaching. Perhaps the best image of this issue in the popular press is that of student protest at being represented by computer records in the files of the central school administration.

To those advancing this claim of deep impersonalization, it is important to say that indeed this is a possibility. Computer technology could be used in this way, and in some instances it probably will. This is little different from saying that there are many kinds of teaching and many ways in which the environment of learning and teaching may be debased. The important point to insist upon, however, is that it is certainly not a necessary aspect of the use of the technology.

Indeed, our claim would be that one of the computer's most important potentials is exactly the opposite. Computers can make learning and teaching more personalized rather than less so. Students will be subject to less regimentation and lockstepping, because computer systems will be able to offer highly individualized instruction.

It is important that the remark about individualization of instruction not be passed off as sloganeering. For many years, courses in the methodology of teaching have emphasized the importance of teaching according to the needs of individual students and therefore attempting to individualize instruction as much as possible. It is recognized, however, by anyone who has examined the structure of our schools either at the elementary- or secondary-school level that a high degree of individualization is extraordinarily difficult to achieve when the ratio of students to teachers is 25 to 1, or greater.

One direct approach is to reduce this ratio to something like 5 or 10 to 1, but the economics of this approach is totally unfeasible in the long run and on a widespread basis. All the evidence points to the fact that the cost of having first-rate teachers in the classroom, training these teachers appropriately, and providing them with the kind of salaries that will be competitive with other technical and professional jobs in our society will simply make it impossible for schools to afford any drastic reduction in the student-teacher ratio. One of the few real opportunities for offering individualized instruction lies in the use of computers as instructional devices.

I do wish to emphasize that I do not envisage replacing teachers entirely, especially at the elementary-school level. It would be my estimate that even under the maximum use of technology only 20 to 30% of students' time in the elementary school would be spent at computer learning stations. While classes or substantial parts of classes were working at terminals, teachers would be able to work with the remainder. Moreover, they would be able to work intensely with individual students, partly because some of the students would be at the terminals, and equally because routine aspects of teaching would be handled by the computer system.

At the postsecondary level, matters are very different. At most colleges and universities, students do not now receive a great deal of individual attention from instructors. Certainly we can all recognize the degree of personal attention is greater

in a computer program designed to accommodate itself to individual students' progress than in the lecture course on a general subject that has more than 200 students in daily attendance.

Complex intellectual problems are yet to be solved in offering tutorial computer programs on advanced subjects at the university level. I do believe that already the teaching of basic skills ranging from elementary mathematics to foreign-language instruction at the college level can well be performed by computer-assisted courses.

Standardization of Instruction

A second common claim is that the widespread use of computer technology will lead to excessive standardization of education. This claim was raised repeatedly in general discussions with educators and the interested public.

To those familiar with current practices in textbook adoption and use in elementary and secondary schools, it is clear that a high degree of standardization already exists in education. It is important to admit at once that a still greater degree of standardization could arise from the widespread use of computers. This is a possibility not to be denied. It is, however, in no sense a necessity. It would technically be possible for a state department of education, for example, to require that at 10:10 in the morning every fourth-grader be adding one-half and one-third, or every junior high school be reciting the amendments to the Constitution. The central danger of the technology is that edicts can be enforced as well as issued, and many persons are rightly concerned at the specter of rigid standardization that could be imposed.

I think we would all agree that the ever-increasing use of books from the sixteenth century to the present has deepened the varieties of educational and intellectual experience generally available. It is not difficult, however, to construct a caricature of present concerns in terms of the horrors it might have been claimed would be introduced with the widespread use of books. The individualization of comment, and adaptation of comment to the expression of individual students and to their responsiveness and comprehension, would be lost in the use of books in place of teachers.

Now we all recognize that there is some truth at the heart of this caricature, but it is not a view that argues for the abolition or suppression of books in education. It argues rather for a wide variety of educational experiences.

There is every reason to believe that the appropriate development of CAI programs will enable us to take a highly significant step beyond the introduction of books and to offer unparalleled variety and depth of curriculum to students of all ages. Indeed, the problem in avoiding standardization is not the limitations of the technology, but our ignorance of how to diversify approaches to learning in meaningful and significant ways.

The basic scientific data on these matters are pitifully small. Opinions can be found in every educational group, but they are opinions. Moreover, from an operational standpoint it is not possible to find any wide diversity of approaches to most of the standard subjects in the curriculum. Do we want an auditory approach to the learning of language for one student and a visual approach for another? Do we want a politically oriented presentation of American history for some students and a socially oriented presentation for others? Do we think that different cognitive styles can be identified in

a sufficiently deep way to justify and guide the preparation of vastly different curricula in the same general subject matter?

These questions are not in any way bound to computer technology. These are fundamental questions about the science of curriculum, the art of teaching, and the philosophy of education that reach out to very general questions of social policy. The computer is there to be used in whatever way we choose. Uniform standardization of the curriculum will be the end product only if we are so lacking in imagination as to achieve nothing else.

Complexity of Instruction

The third claim often heard is that the limitations of the technology and the problems that must be overcome in using it will lead to the development of curricula that will almost necessarily be simple-minded in character. There are indeed some unfortunate historical examples in the literature of curriculum efforts, especially curriculum efforts in a technological setting.

In the early days of programmed instruction, for example, a number of texts on elementary mathematics were written by psychologists or educators who did not have adequate training in mathematics. The programmed texts were splattered with "howlers" that received the eager attention of the mathematics educators charged with reviewing the books. Similar kinds of blunders can occur in the case of computer-assisted instruction, but there is nothing special about computers, and it is hard to see that a serious argument can be made to claim that there is any reason why computer-assisted instruction will be worse than other forms of curriculum.

There are reasons, however, for thinking the situation will be more self-corrective in the case of CAI than in the case of ordinary textbook writing. One reason is simply that data can be gathered and authors can be presented in tough-minded fashion with a clear picture of the defects of the materials they have written. Consider, for example, a program in elementary mathematics. If a particular sequence of concepts or problems is missed by a high percentage of the students encountering it, the transmission of this information to those who wrote the program is an obvious signal that changes are needed.

Surprising as it may seem, authors of textbooks in elementary mathematics seldom receive such information. They get many good and penetrating criticisms from teachers and other persons concerned with curriculum, but they seldom get hard behavioral data on individual parts of the text. Similarly, the evaluation that compares a given new text with a standard old text by looking at the achievement data for experimental and control groups is almost always far too coarse an evaluation to provide any focus for revising the particular features of the new text. On the other hand, the problems of gathering detailed data about an ordinary textbook are too onerous to be feasible in most cases.

Freedom in Education

The fourth and final issue I wish to discuss is the place of individuality and human freedom in a modern technological society. The crudest form of opposition to widespread

use of technology in education and in other parts of society is to claim that we face the real danger of men becoming slaves to machines. This argument is ordinarily made in a romantic and naive fashion by those who seem themselves to have little understanding of technology and how it is used in our society.

No scientifically informed person seriously believes that our society could survive in anything like its present form without the widespread use of technology. It is our problem to understand how to use the technology and to benefit wisely from that use. Indeed, the claim about slavery is just the opposite of the true situation. It is only in this century that widespread use of slavery has been abolished, and it may be claimed by historians of the distant future that mankind could not do without slavery, because just as human slaves were being abolished, within a short time span they were replaced by machine slaves whose use did not violate our ethical principles and moral sensibilities.

Just as books freed serious students from the tyranny of overly simple methods of oral recitation, so computers can free students from the drudgery of doing exactly similar tasks unadjusted and untailed to their individual needs. As in the case of other parts of our society, our new and wondrous technology is there for beneficial use. It is our problem to learn how to use it well.

When a child of six begins to learn in school under the direction of a teacher, he hardly has a concept of a free intelligence able to reach objective knowledge of the world. He depends heavily upon every word and gesture of the teacher to guide his own reactions and responses. This intellectual weaning of children is a complicated process that we do not yet manage or understand very well. There are too many adults among us who are not able to express their own feelings or to reach their own independent judgments. We could claim that the wise use of technology and science, particularly in education, presents a major opportunity and challenge. We do not want to claim that we now know very much about how to realize the full potential of human beings; but we do not doubt that our modern instruments can be used to reduce the personal tyranny of one individual over another, and increase individual freedom.

Intellectual Problems of the Future

Let me break this discussion of future intellectual problems into four parts that will take us back through some of the earlier technologies.

Computers That Talk

The first problem is simply that of talking (oral speech). What does it take to get a computer to talk? The fact is that the technical issues are already pretty well in hand. What we need, however, is better information about what is to be said. For example, when I serve as a tutor, teaching one of you, or when one of you is teaching me, intuitively and naturally we follow cues and say things to each other without having an explicit theory of how we say what we say. We speak as part of our humanness, instinctively, on the basis of our past experience. But to satisfactorily talk with a computer, we need an explicit theory of talking.

Computers That Listen

The replacement of the written record, the kind of record that was objected to in Plato's *Phaedrus*, can be available to us in the talking computer. The other side of that coin which Socrates also emphasized, or should have emphasized, concerns listening. It is a much more difficult technical problem. The problem of designing a computer that can listen to a student talk is much harder than having a student listen to the computer talk. However, the problem seems to be solvable.

The Use of Knowledge

To have an effective computer-based system of instruction, we must transcend mindless talking and listening and learn to understand and use a large knowledge base. For example, if we were simply to require information retrieval from a knowledge base, it would be relatively simple in the near future to put the entire American Library of Congress in every elementary school. The capacity to store information is increasing so rapidly that we will be able to store much more information than could ever possibly be used.

A different and more difficult question is how to get the student to interact with the sizable knowledge base. As we come to understand how to handle such a knowledge base, the school computer of the future should be able to answer any wayward question that the student might like to ask. Moreover, as we all know, once a student uses such a capability, he will have a strong tendency to pursue still further questions that are more difficult and more idiosyncratic. It will, I think, be wonderful to see how children give to learning the high degree of concentration and the sustained span of attention they now give to commercial television.

There is one related point I want to emphasize. From the very beginning of school, students learn quickly the "law of the land" and know they should not ask questions the teacher cannot answer. This task of diagnosing the limitations of teachers begins early and continues through college and graduate school. So, once we have the capacity for answering out-of-the-way questions, it will be marvellous to see how students will take advantage of the opportunity and test their own capacities with a relentlessness they dare not exhibit now.

Need for Theories of Learning and Instruction

The fourth problem, and in many ways the least-developed feature of this technology, is the development of an adequate theory of learning and instruction. We can make the computer talk, listen, and adequately handle a large knowledge data base, but we still need to develop an explicit theory of learning and instruction. In teaching a student, young or old, a given subject matter or a given skill, a computer-based learning system can keep a record of everything the student does. Such a system can gather an enormous amount of information about the student. The problem is how to use this information wisely, skillfully, and efficiently to teach the student. This is something that the very

best human tutor does well, even though he does not understand at all how he does it, just as he does not understand how he talks. None of us understands how we talk and none of us understands how we intuitively interact with someone we are teaching on a one-to-one basis. Still, even though our past and present theories of instruction have not cut very deep, it does not mean that we have not made some progress. First, we at least recognize that there is a scientific problem; that alone is progress. One hundred and fifty years ago there was no explicit recognition that there was even a problem. Only in the twentieth century do we find any systematic data or any systematic theoretical ideas about the data. What precedes this period is romance and fantasy unsubstantiated by any sophisticated relation to evidence. So at least we can say that we have begun the task.

Alternative Educational Structures

Let me give some examples of changes we can effect in the structure of educational institutions by using appropriately the new technology of computers and television. Because of my own special interest in computers, I shall concentrate on computer possibilities; but it should be understood that television would also be a component for the proposed changes in structure.

High Schools

My first example concerns the organization of high schools. An American phenomenon, much discussed in the history of education in the twentieth century, has been the introduction of the consolidated high school that brings together students from small schools to a centrally located large school that offers a variety of educational opportunities and resources to the students. The American consolidated high school is one of the glories of the history of education. Today, however, many of us feel that the large high school has become one of the most difficult institutions to deal with from a social standpoint. The mass aggregation of adolescents in one spot creates an environment that is on the one hand impersonal, and on the other potentially explosive, partly because of the large numbers of students and supervising adults in close quarters.

The use of our new technology will make possible an alternative structure that will return us to our small schools of the past. The ideal high school of the future may consist of no more than a hundred students and, in many cases, be located close to students' homes; it may be a specialized school, catering to students' particular interests. The variety of curriculum and other educational resources, such as libraries, that has been so important a feature of the consolidated high school, will be made available by computer and television technology. I should say in this connection that the changes that can be brought about through the use of computers are more drastic and more radical than those that can be effected only through television. The difference is the possibility of a high level of interaction between the computer program and the student, the sort of thing that is not possible with a standard television lecture or laboratory demonstration.

Elementary Schools

My second example concerns alternatives to elementary schools. Through most of the history of civilization, young children have been taught primarily at home, often perhaps in an extended family group. We now have the technical possibility of returning the student to the home or to a small neighborhood group. Although these alternatives have not yet been thoroughly explored, it is important that discussion of their availability begin as soon as possible. As far as I know, the new romantics in education have not discussed the radical possibility of dissolving elementary schools entirely and returning the child to the home—or to a neighborhood group of three or four homes—for his education.

In describing this possibility, let me emphasize that I am not maintaining that it is necessarily a wise move. I do, however, think it important that this technical possibility is now available. At the very least, it should be explored experimentally. By proper use of computer technology, the basic skills of reading, mathematics, and language arts can easily be brought to the student in the home or in a cluster of homes. Most of the elementary science curriculum also can be handled by computer. Other parts of the elementary science curriculum, of the social studies program, and much of the work in art and music could be handled by television. I envisage a situation in which a master teacher would divide his time among several units. The mothers of the children would assume responsibilities for supervision and some would work as teachers' aides. Such an approach would be completely natural, because of the proximity of the school to their homes. In many urban settings, for example, it would be natural to place classrooms in apartment complexes. In other districts, a small one-room building could be added, or it might even be feasible to pay a small rent to one of the families for the use of space in a home. The main thing to avoid is heavy capital expenditure for physical plants; we have had too much of this in the past.

Higher Education

The third alternative structure deals with higher education. Here the possibilities are perhaps the easiest to implement and may be realized sooner than the others. In the areas surrounding Stanford, several community colleges are already offering courses for credit by television. As we face the costs throughout the world of providing higher education for increasing numbers, the use of computers and television to reduce costs and to decentralize the educational effort seems almost inevitable. One can see terminals or personal computers available in apartment complexes for students at the community-college level. At a later stage, one can envisage terminals in plants where employees work full-time, but also actively pursue their education. I should mention that in California, for example, a reasonable percentage of students in the state higher educational system are employed full-time, simultaneously with their enrollment as students. The development of such a delivery system for higher education will also naturally answer demands for continuing education for older adults. At a more distant date, one can expect the computer resources described earlier to be available in the home for the teaching of a wide range of subjects, from foreign languages to advanced technical courses in science and mathematics.

I emphasize, however, that the problems of institutional change of the sort just discussed are poorly understood. There is evidence that universities, for example, are among the most conservative institutions in our society. In any case, the rapid development of alternative structures for education will be neither simple nor easy. On the other hand, the willingness of community colleges, which do not have a long tradition, to consider new methods of instruction and new approaches is encouraging. There are problems of prejudice and entrenchment, but there are also intellectual problems of understanding the kinds of organization we want for the future. The technology affords many possibilities, but we have not thought through which of these possibilities we consider the most advantageous, the most interesting, or the most effective.

The central idea I have been stressing is that through computers we have the means to develop alternative structures that will effectively decentralize the present educational system. The issue of decentralization of services, of places of work, of almost all aspects of our life is gradually coming to the fore as a central social and political problem of the last part of the twentieth century. The issues involved in decentralizing education will be among the most significant of these problems of decentralization. The problems that face us are not really technological: they are conceptual, institutional, and social. I have certainly not made any concrete suggestions for tackling these problems; at most, I have tried to bring them to your attention.