R.C. Atkinson & H.A. Wilson (Eds.), Computer-assisted instruction: A book of readings. New York: Academic Press, 1969, pp. 41-47.

Computer Technology and the Future of Education*

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Current applications of computers and related information-processing techniques run the gamut in our society from the automatic control of factories to the scrutiny of tax returns. I have not seen any recent data, but we are certainly reaching the point at which a high percentage of regular employees in this country are paid by computerized payroll systems. As another example, every kind of complex experiment is beginning to be subject to computer assistance either in terms of the actual experimentation or in terms of extensive computations integral to the analysis of the experiment. These applications range from bubble-chamber data on elementary particles to the crystallography of protein molecules.

As yet, the use of computer technology in administration and management on the one hand, and scientific and engineering applications on the other, far exceed direct applications in education. However, if potentials are properly realized, the character and nature of education during the course of our lifetimes will be radically changed. Perhaps the most important aspect of computerized instructional devices is that the kind of individualized instruction once possible only for a few members of the aristocracy can be made available to all students at all levels of abilities.

Because some may not be familiar with how computers can be used to provide individualized instruction, let me briefly review the mode of operation. In the first place, because of its great speed of operation, a computer can handle simultaneously a large number of students – for instance, 200 or more, and each of the 200 can be at a different point in the curriculum. In the simplest mode of operation the terminal device at which the student sits is something like an electric typewriter. Messages can be typed out by the computer and the student in turn can enter his responses on the keyboard. The first and most important

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feature to add is the delivery of audio messages under computer control to the student. Not only children, but students of all ages learn by ear as much as by eye, and for tutorial ventures in individualized instruction it is essential that the computer system be able to talk to the student.

A simple example may make this idea more concrete. Practically no one learns mathematics simply by reading a book, except at a relatively advanced level. Hearing lectures and listening to someone else's talk seem to be almost psychologically essential to learning complex subjects, at least as far as ordinary learners are concerned. In addition to the typewriter and the earphones for audio messages, the next desirable feature is that graphical and pictorial displays be available under computer control. Such displays can be provided in a variety of formats. The simplest mode is to have color slides that may be selected by computer control. More flexible, and therefore more desirable, devices are cathode-ray tubes that look very much like television sets. The beauty of cathode-ray tubes is that a graphical display may be shown to the student and then his own response, entered on a keyboard, can be made an integral part of the display itself.

This is not the place to review these matters in detail; but I mean to convey a visual image of a student sitting at a variety of terminal gear – as it is called in the computer world. These terminals are used to provide the student with individualized instruction. He receives information from audio messages, from typewritten messages, and also from visual displays ranging from graphics to complex photographs. In turn, he may respond to the system and give his own answers by using the keyboard on the typewriter. Other devices for student response are also available, but I shall not go into them now.

So, with such devices available, individualized instruction in a wide variety of subject matters may be offered to students of all ages. The technology is already available, although it will continue to be improved. There are two main factors standing in our way. One is that currently it is expensive to prepare an individualized curriculum. The second factor, and even more important, is that as yet we have little operational experience in precisely how this should best be done. For some time to come, individualized instruction will have to depend on a basis of practical judgment and pedagogical intuition of the sort now used in constructing textbook materials for ordinary courses. One of the exciting potentialities of computer-assisted instruction is that for the first time we shall be able to get hard data to use as a basis for a more serious scientific investigation and evaluation of any given instructional program.

To give a more concrete sense of the possibilities of individualized instruction, I would like to describe briefly three possible levels of interaction between the student and computer program. Following a current usage, I shall refer to each of the instructional programs as a particular system of instruction. At the simplest level there are *individualized drill-and-practice systems,* which are meant

to supplement the regular curriculum taught by the teacher. The introduction of concepts and new ideas is handled in conventional fashion by the teacher. The role of the computer is to provide regular review and practice on basic concepts and skills. In the case of elementary mathematics, for example, each student would receive daily a certain number of exercises, which would be automatically presented, evaluated, and scored by the computer program without any effort by the classroom teacher. Moreover, these exercises can be presented on an individualized basis, with the brighter students receiving exercises that are harder than the average, and the slower students receiving easier problems.

One important aspect of this kind of individualization should be emphasized. In using a computer in this fashion, it is not necessary to decide at the beginning of the school year in which track a student should be placed; for example, a student need not be classified as a slow student for the entire year. Individualized drill-and-practice work is suitable to all the elementary subjects which occupy a good part of the curriculum. Elementary mathematics, elementary science, and the beginning work in foreign languare are typical parts of the curriculum which benefit from standardized and regularly presented drill-and-practice exercises. A large computer with 200 terminals can handle as many as 6,000 students on a daily basis in this instructional mode. In all likelihood, it will soon be feasible to increase these numbers to a thousand terminals and 30,000 students. Operational details of our 1965-66 drill-and-practice program at Stanford are to be found in the book by Suppes, Jerman, and Brian.*

At the second and deeper level of interaction between student and computer program there are *tutorial systems,* which take over the main responsibility both for presenting a concept and for developing skill in its use. The intention is to approximate the interaction a patient tutor would have with an individual student. An important aspect of the tutorial programs in reading and elementary mathematics with which we have been concerned at Stanford in the past three years is that every effort is made to avoid an initial experience of failure on the part of the slower children. On the other hand, the program has enough flexibility to avoid boring the brighter children with endlessly repetitive exercises. As soon as the student manifests a clear understanding of a concept on the basis of his handling of a number of exercises, he is moved on to a new concept and new exercises. (A detailed evaluation of the Stanford reading program, which is under the direction of Professor Richard C. Atkinson, may be found in the report by Wilson and Atkinson.** A report on the tutorial mathematics program will soon

*P. Suppes, M. Jerman, and D. Brian, *Computer-assisted Instruction at Stanford:* The *1965-66 Arithmetic Drill-and-Practice Program.* New York. Academic Press, 1968.

**H. A. Wilson and R. C. Atkinson, *Computer-based Instruction in Initial Reading: A Progress Report on the Stanford Project.* Technical Report No. 119. August 25, 1967. Institute for Mathematical Studies in the Social Sciences, Stanford University.

be available. The data show that the computer-based curriculum was particularly beneficial for the slower students.)*

At the third and deepest level of interaction there are *dialogue systems* aimed at permitting the student to conduct a genuine dialogue with the computer. The dialogue systems at the present time exist primarily at the conceptual rather than the operational level, and I do want to emphasize that in the case of dialogue systems a number of difficult technical problems must first be solved. One problem is that of recognizing spoken speech. Especially in the case of young children, we would like the child to be able simply to ask the computer program a question. To permit this interaction, we must be able to recognize the spoken speech of the child and also to recognize the meaning of the question he is asking. The problem of recognizing meaning is at least as difficult as that of recognizing the spoken speech. It will be some time before we will be able to do either one of these things with any efficiency and economy.

I would predict that within the next decade many children will use individualized drill-and-practice systems in elementary school; and by the time they reach high school, tutorial systems will be available on a broad basis. Their children may use dialogue systems throughout their school experience.

If these predictions are even approximately correct, they have far-reaching implications for education and society. As has been pointed out repeatedly by many people in many different ways, the role of education in our society is not simply the transmission of knowledge but also the transmission of culture, including the entire range of individual, political, and social values. Some recent studies – for example, the Coleman report – have attempted to show that the schools are not as effective in transmitting this culture as we might hope; but still there is little doubt that the schools play a major role, and the directions they take have serious implications for the character of our society in the future. Now I hope it is evident from the very brief descriptions I have given that the widespread use of computer technology in education has an enormous potential for improving the quality of education, because the possibility of individualizing instruction at ever deeper levels of interaction can be realized in an economically feasible fashion. I take it that this potentiality is evident enough, and I would like to examine some of the problems it raises, problems now beginning to be widely discussed.

Three rather closely related issues are particularly prominent in this discussion. The first centers around the claim that the deep use of technology, especially computer technology, will impose a rigid regime of impersonalized teaching. In considering such a claim, it is important to say at once that indeed this is a possibility. Computer technology could be used this way, and in some instances it probably will. This is no different from saying that there are many

*M. Morningstar and P. Suppes, *Computer-assisted Instruction: The Stanford 1966-67 Arithmetic Program*, 1969, in press.

kinds of teaching, some good and some bad. The important point to insist upon, however, is that it is certainly not a *necessary* aspect of the use of the technology. In fact, contrary to the expectations sometimes expressed in the popular press, I would claim that one of the computer's most important potentials is in making 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. The routine that occupies a good part of the teacher's day can be taken over by the computer.

It is worth noting in this connection that the amount of paper work required of teachers is very much on the increase. The computer seems to offer the only possibility of decreasing the time spent in administrative routine by ordinary teachers. Let us examine briefly one or two aspects of instruction ranging from the elementary school to the college. At the elementary level, no one anticipates that students will spend most of their time at computer consoles. Only 20 to 30 percent of the student's time would be spent in this fashion. Teachers would be be able to work with classes reduced in size. Also, they could work more intensely with individual students, because some of the students will be at the console and, more importantly, because routine aspects of teaching will be handled by the computer system.

At the college level, the situation is somewhat different. At most college and universities, students do not now receive a great deal of individual attention from instructors. I think we can all recognize that the degree of personal attention is certainly not less in a computer program designed to accommodate itself to the individual student's progress than in the lecture course that has more than 200 students in daily attendance. (In our tutorial Russian program at Stanford, under the direction of Joseph Van Campen, all regular classroom instruction has been eliminated. Students receive 50 minutes daily of individualized instruction at a computer terminal consisting of a teletype with Cyrillic keyboard and earphones; the audio tapes are controlled by the computer.)

A second common claim is that the widespread use of computer technology will lead to excessive standardization of education. Again, it is important to admit at once that this is indeed a possibility. The sterility of standardization and what it implies for teaching used to be illustrated by a story about the French educational system. It was claimed that the French minister of education could look at his watch at any time of the school day and say at once what subject was being taught at each grade level throughout the country. The claim was not true, but such a situation could be brought about in the organization of computer-based instruction. It would technically be possible for a state department of education, for example, to require every fifth grader at 11:03 in the morning to be subtracting one-fifth from three-tenths, or for every senior in high school to be reciting the virtues of a democratic society. The danger of the

technology is that edicts can be enforced as well as issued, and many persons are rightly concerned at the spectre of the rigid standardization that could be imposed.

On the other hand, there is another meaning of standardization that holds great potential. This is the imposition of educational standards on schools and colleges throughout the land. Let me give one example of what I mean. A couple of years ago I consulted with one of the large city school systems in this country in connection with its mathematics program. The curriculum outline of the mathematics program running from kindergarten to high school was excellent. The curriculum as specified in the outline was about as good as any in the country. The real source of difficulty was the magnitude of the discrepancy between the actual performance of the students and the specified curriculum. At almost every grade level, students were performing far below the standard set in the curriculum guide. I do not mean to suggest that computer technology will, in one fell stroke, provide a solution to the difficult and complicated problems of raising the educational standards that now obtain among the poor and culturally deprived. I do say that the technology will provide us with unparalleled insight into the actual performance of students.

Yet I do not mean to suggest that this problem of standardization is not serious. It is, and it will take much wisdom to avoid its grosser aspects. But the point I would like to emphasize is that the wide use of computers permits the introduction of an almost unlimited diversity of curriculum and teaching. The very opposite of standardization can be achieved. 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. There is every reason to believe that the appropriate development of instructional programs for computer systems will increase rather than decrease this variety of intellectual experience. The potential is there.

The real problem is that as yet we do not understand very well how to take advantage of this potential. If we examine the teaching of any subject in the curriculum, ranging from elementary mathematics to ancient history, what is striking is the great similarity between teachers and between textbooks dealing with the same subject, not the vast differences between them. It can even be argued that it is a subtle philosophical question of social policy to determine the extent to which we want to emphasize diversity in our teaching of standard subjects. Do we want a "cool" presentation of American history for some students and a fervent one for others? Do we want to emphasize geometric and perceptual aspects of mathematics more for some students, and symbolic and algebraic aspects more for others? Do we want to make the learning of language more oriented toward the ear for some students and more toward the eye for those who have a poor sense of auditory discrimination? These are issues that have as yet scarcely been explored in educational philosophy or in discussions of

educational policy. With the advent of the new technology they will become practical questions of considerable moment.

The third and final issue I wish to discuss is the place of individuality and human freedom in the modern technology. The crudest form of opposition to widespread use of technology in education and in other parts of our society is to claim that we face the real danger of men becoming slaves of machines. I feel strongly that the threat to human individuality and freedom in our society does not come from technology at all, but from another source that was well described by John Stuart Mill more than a hundred years ago. In discussing precisely this matter in his famous essay *On Liberty,* he said,

> *the greatest difficulty to be encountered does not lie in the appreciation of means towards an acknowledged end, but in the indifference of persons in general to the end itself. If it were felt that the free development of individuality is one of the leading essentials of well-being; that it is not only a co-ordinate element with all that is designated by the terms civilization, instruction, education, culture, but is itself a necessary part and condition of all those things; there would be no danger that liberty should be undervalued, and the adjustment of the boundaries between it and social control would present no extraordinary difficulty.*

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 untailored 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 judgments. I would claim that the wise use of technology and science, particularly in education, presents a major opportunity and challenge. I do not want to claim that we know very much yet about how to realize the full potential of human beings; but I do not doubt that we can use our modern instruments to reduce the personal tyranny of one individual over another, wherever that tyranny depends upon ignorance.