SYMPOSIUM ON COMPUTER-ASSISTED LEARNING

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COMPUTER-ASSISTED LEARNING: INTRODUCTION AND GENERAL CONSIDERATIONS

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When Jim Bonner indicated to me his interest in presenting at this meeting the applied science area of computer-aided instruction or, as many prefer to call it, computer-aided learning, we easily agreed that the general structure for the symposium would be (1) the psychology of learning, (2) the actualities of computer-aided learning, and (3) the consequences for education. The first man whom I asked to handle each topic graciously accepted, and we are most grateful. Each was chosen on the basis of leadership in his area, of known effectiveness in presentation, and, to a degree, of western locus. All are men of high distinction, are members of the National Academy of Sciences or the National Academy of Education or the like, so I shall not toss at you their many honors. But let me indicate their professional credentials.

Jack Hilgard, who will open with questions of learning psychology, is currently a professor of psychology and education at Stanford. He has written major volumes on learning and recently planned and edited a monograph on experimentation in teaching. Dick Atkinson, who will "tell it like it is" for computer-aided instruction, is also a professor of psychology and education at Stanford.

I was not plugging one school or department, but just quality and expertise, and Dick has taken the lead in the fine team of Pat Suppes in teaching reading with computer-assisted instruction in elementary schools. John Goodlad, who will look at the spinoff to education rather than the effects on its subjects, is Professor and Dean of Education at UCLA and Director of its university elementary school. His nongraded school has made educational history. My role will be to touch on some broad aspects of computer-aided learning, its problems and promises and some consequences—educational, sociological, and biological—that could follow its utilization. My credentials are only an early and strong interest in this educational resource as a behavioral biologist and a university administrator. Maybe it is only that my eye was sensitized, but in looking over their biographical material this morning, I was struck with the fact that three of the four have had part of their educational experience at the University of Chicago.

I move on to computer-aided learning. *Datamation,* a major journal in the computing area, devoted a recent issue to articles on various facets of computer-aided instruction. Their general temper was somber. One of the essayists went so far as to say that, just as teaching machines and audiovisual aids had been touted as the great educational devices of the future and are now in discard, so computer-aided instruction was going the way to desuetude. I question the validity of the statement regarding the first two procedures; certainly audio-visual aids are slowly increasing in their use and, I think, in their effectiveness. In any event, I remain the optimist I have been from the start.

A couple of weeks ago I attended the annual meeting of the Interuniversity Communication Council (EDUCOM), where an afternoon was devoted to reports on computer networks in universities. Each of four speakers bemoaned the troubles through which he had passed in getting his network operating within a campus or between campuses, but each of them *had* achieved it. It was exciting to see that this expectation for the future is definitely feasible and is beginning to operate.

And just last week I was at a meeting concerned with computers in medical education and heard some remarkable reports of the use of computer-aided instruction in teaching students history-taking and in helping doctors take case histories; in teaching techniques of diagnosis and in actually making diagnoses of patients; in teaching either medical students or, more dramatically, completely untrained laymen—housewives, lab technicians, others without professional background—how to read X-ray films and to make diagnoses, with amazing success. All this gives the hope that doctors may be relieved of a great deal of routine work in all phases of medicine. Other computer uses included evaluation of the educational procedures and outcomes in terms of the quality of medical practice. Well, this is a vignette of one area in which the computer is clearly moving forward.

Some of you are old enough to remember the early days of the automobile, when cars and their drivers were immobilized along the roads and passing pedestrians would derive great joy in calling, "Get a horse." I daresay the computer education system is at the "get a horse" stage, but don't forget what

happened to automobiles and horses. I personally feel that it is not exactly valid, although one of our panelists may disagree with me, to make a direct comparison of teaching machines and simple programmed instruction with computer-aided learning. (I prefer the designation "computer-aided *learning*" because all these are learning aids more than instruction aids; even the teacher is nothing but a learning aid.) The programmed book or teaching machine I regard as the marsupial stage in an evolutionary line of which the computer is the placental derivative, a strikingly more successful "organism" with much greater potentialities.

The computer can mobilize a vastly larger data base, it can branch the interaction of the student with incomparably more richness, and it can modify the course of the interaction beyond a limited number of fixed branches, depending to a large extent upon the actual performance of the student. It is a truly interactive situation. Books and, even more, radio and television have made it possible for the teacher, the "putter-outer," to reach a vast audience, but in these cases there is no effective feedback; it is a unidirectional interaction. On the other hand, the computer permits interactive real time exchange between the student and the machine which can, in effect, act as a tutor.

It is often said that computerized education will make for regimentation and depersonalization. Nothing can be further off the mark, because computer systems offer for the first time the possibility of a true tutorial relation, on an effective one-to-one basis between the teacher and the student, which resembles the real-life tutor and student in the familiar "Mark Hopkins and a log" situation. The computer system offers the individual student an opportunity for individualized freedom and guidance—in the speed at which he works, in the material with which he works, and in his mode of operation, depending on his abilities and his past history and idiosyncratic preferences. It is also possible (although as yet this is seldom done) to guide him along a particularized course of learning in which both the materials he is expected to master and the mode in which he is to master them are flexible, whether through eye or ear, inductively or deductively, with large jumps or small, with much repetition or not, and so on and on. It is possible to develop materials in small but intellectually complete units so that these can be put together in different courses and different curricula to meet the needs of the individual student, thereby freeing us from the rigid mass movement of cohorts locked together in large blocks of time, be they semesters or quarters. From these units it is possible to build integrated programs without complete duplication of courses, so that students with different starting points, different abilities, and different goals may run together where this is possible and branch off where this is appropriate.

One can handle hundreds, eventually thousands, of students simultaneously on an on-line system. Each student, as far as he is aware, is dealing individually and alone with his computer tutor, yet may be doing a quite different thing from the others. The computer may handle all in sequence, but the reaction time of the machine is so short compared to that of the human that the response is delayed to an imperceptible extent. The best materials anywhere can be made widely available and, mind you, the computer can mobilize for presentation

anything that can be recorded—microfiche of books, slide chips, sound films, video tapes, anything relevant. All this will be presented in more detail by Dick Atkinson. Finally, in this particular connection, the teacher is certainly going to be relieved of a great deal of routine scut work; the teacher will be not replaced but *re*placed, so that he or she is used in a particular kind of interaction with students which is appropriate to her or his talents; because, obviously, few teachers can do well all the things that teachers are expected to do.

Let me hasten on to the question of costs. Early in this century, industries tended to average about 25 per cent for machine costs and 75 per cent for human costs. Most industries have now reversed those figures; the costs in communication and transportation and mining and manufacturing, in general, tend to be more nearly 75 per cent for machinery and equipment, and 25 per cent for human services. Education has remained at the original figure of 75 per cent for services and, incidentally, I think health has stayed about the same way. Both areas are creating enormous financial problems to our communities and our country.

One hears rather sharply divergent opinions of the present relative costs of traditional education and computer-aided education. Some people say the latter is still ten times more costly; others say that the two are now about equal; and some calculate that the mechanized procedures are already cheaper. I don't particularly care where the ratio stands at the moment, because a simple argument shows, I think quite conclusively, that computer-aided learning will very soon be very much cheaper. The cost of hardware and what goes with it is decreasing exponentially at about one order of magnitude per computer generation of 2.5 to 3 years; so it costs about one tenth as much, say, every 3 years. The cost of human services goes up, say, doubling every generation, every 20 years. Wherever the curves are now, they are bound to cross pretty soon; whether within three years or ten is not critical to the long-range argument.

Certainly, there is also going to be a substantial cost in developing the educational materials for computer-aided learning. It has been reliably estimated that it would take $50 billion to put the entire Library of Congress in computerized form so that it could be accessed through computers, accessed in terms not only of documents, but of their contents. I have made the estimate of something like $20 million to develop 100 basic college courses, which would take care of most of the teaching to most students in most colleges and universities for the first two years or beyond. Now, if my estimate is off $2^1/_2$ times, call it $50 million, it makes little difference. A third cost component is the software for directing the system operations. For simple demands this is now available; but aspirations rise, and more complicated performance can generate complex programming needs. There is much leeway in elegance from compact car to luxury limousine. At simpler levels, costs here are moderate.

These figures are small in comparison with the annual investment in education in this country today. I don't have the education figures for 1968, but a couple of years ago the estimates were $50 or $60 billion, depending on how much one added for education in industry and in the military and in comparable groups. Five years ago, the annual cost of education was already more than 6 per cent of the gross national product, and I daresay that by now it has risen to 7 or 8 per

cent—so there really is not much to argue about in terms of relative costs.   In any event, the people in this country are beginning seriously to resist paying the cost of traditional education, and education is beginning to suffer.

Perhaps even more critical than the supply of money, which could be found with good will, is the supply of manpower, which cannot be met with the best of will.   Just live bodies, let alone really good teachers, are not in sufficient supply and could not be without grossly distorting the manpower needs of other major aspects of our economy.   So, one of the outcomes of the invasion of the educational system with these new technologies should be an improvement in financial and human resources.

I have already touched upon the necessity for breaking up the lockstep of the whole educational system—in use of facilities, in blocks of time, and procrustean courses and curricula—and I know John Goodlad will speak of this at some length since he has been very much involved in these developments.   This should have great consequences.   It should lead to extending educational opportunities to groups that have been deprived of them in our own country (the underprivileged, the so-called ghetto children of all colors) and in other parts of the world.   The emerging nations not only have no adequate education and no resources for its support, but they do not have enough teachers, and with traditional methods it would take generations to teach teachers to teach more teachers to teach more teachers to be able to teach students.   One cannot wait for that; so, just as some countries have jumped over the road system from dirt trails to airplanes, some countries will be able to jump their educational system from essentially no system to the use of these new technologies.

Aside from these extensions, such technology should blur the margin between an educational part of life, a formal education, and the rest of life; and this may have great consequences for the physical plant and the organization of our educational institutions.   With small learning units available at on-line terminals, sequences appropriate to individual needs can be built and can be worked through by a single learner (or two or three) on a terminal in his home, a club, anywhere.   Formal classes, except seminar-type activity at advanced levels, may disappear and certainly would be greatly modified; and the same would hold true for school buildings and campuses.   One area in which our technology is now clearly able to make important contributions is in the continuing education of professional people who have completed their regular training and are now functioning in the world.   It is essential for professionals to keep up with their fields, but it is extremely difficult for busy practitioners, of medicine and other professions, or teachers themselves, to manage to come in for formal courses, although they do to some extent.   A terminal in the office or home could be most helpful.

Another area in which I see major developments is in helping make education itself scientific as well as artistic.   The ability to follow at a micro level the learning interaction of the student with the teacher and with other educational resources, which was not possible earlier (it was to some extent with programmed instruction), does make it possible to posit clear questions, that is, to make sharp hypotheses; to gather unequivocal data with definitive outcomes, which permits

a "yes" or "no" conclusion; and to go on with new formulations. I hope that Hilgard will say something more about this. One can, by such experiments, improve the quality of teaching so that students are exposed to a structured experience effective in producing such changes, which we call learning, as are desired by the society. There may be great arguments as to what these changes are, that is, as to what the goals of education are, but these should have been argued through, anyway, before education was undertaken on so large a scale. It should be possible to offer an experience which will be much more effective in teaching and in bringing about these changes.

Although what I am about to say is certainly unproven, many besides myself, with rich experience in one or another phase of this whole area, believe that no human being is fully exploiting his native potentialities and that with better education we could bring people up to twice or three times their usual effectiveness—not, of course, in everything for every person in many areas of general concern. With different emphases in different individuals, we can develop "better" people. This, in turn, leads me to note the utmost importance of keeping man afloat in the civilization that he has created, in this enormous information-rich sea that grows deeper and deeper. Effective participation in an environment saturated with symbolic information, if not actual survival, no longer depends on solving physical problems or even simple biological ones (physical safety, housing, sustenance, even health, are under reasonable control), but on solving the psychosocial problems of greater numbers living together in greater concentrations and interacting over large distances. If man is to keep ahead of the computer, as he has had to keep ahead of the steam shovel and the microscope and telescope—protheses to the muscles, to the senses, and now to the brain—his own brain has to develop to its maximum capacity.

The last point I make is the most speculative by far, but it is worth mentioning. There is very good reason to believe, from comparative physiology and comparative neurology, that the cerebrum developed as a consequence of the evolution, first, of the so-called distance receptors—originally smell, then eyes and ears—which gave more information earlier to organisms about more things in their universe. It is obviously of survival value to know before it happens that one is about to be jumped upon, or that there is prey nearby to attack, and so the cerebral hemisphere arose to handle this information traffic. As I like to put it in university circles, the brain needed more FTE [full time equivalent], so that more neurons evolved. Secondly, most anthropologists think today that the greater ballooning-out of man's cerebral hemispheres, in contrast to that of his primate relatives, was associated with the use of tools; again a matter of information flow, in and out. I dare think that, as this increased richness of experience produced a super ape that we call man, perhaps a further structuring of carefully enriched experience may produce some derivative species, which one might call superman. (To avoid possible misunderstanding of these shorthand statements, this is not a return to Lamarckianism; accepted selection mechanisms suffice.)

Whether or not this is possible on the positive side, there is excellent physiological and anatomical evidence that the absence of structured experience in early life can lead to devastating defects in the maturation of the nervous system

and its capacities.   Infants deprived of pattern vision for a few weeks or months, with no other damage or manipulation, will grow up effectively blind to patterns and see only light and dark.   This is one of the great problems of our deprived children and a reason that the Headstart program is so vastly more important, in my judgment, than later rehabilitation efforts, certainly for the oncoming generation.   How much of these biological-behavioral effects can be realized at present and how much is for the future, no one knows; but I close by reminding you of Browning's fine line, "A man's reach should exceed his grasp or what's a heaven for."

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