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Interactive Learning

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We are at the onset of a major revolution in education, a revolution unparalleled since the invention of the printing press. The computer will be the instrument of this revolution. While we are at the very beginning—the computer as a learning device in current classes is, compared with all other learning modes, almost nonexistent—the pace will pick up rapidly over the next 15 years. By the year 2000 the major way of learning at all levels, and in almost all subject areas will be through the interactive use of computers.

I do not intend to offer any full discussion of this impending revolution. Many of the factors involved go far beyond the question of computing. I will review those factors briefly.

Our colleges and universities will be drawing from 15% fewer high school graduates in 1985 than they' did in 1975. Because of the development of a variety of alternate modes of education, the formal institutions of higher education—our institutions—will predictably be enrolling a smaller percentage of the high school graduates in 1985 than they are today. So enrollments will drop significantly. The demographic factors are not uniform across the country. In the U.S. the northeast and north central regions will sustain the greatest impact.

Coupled with decreasing numbers of high school graduates will be a shift in the nature of our student population. Hodgkinson, at a conference on

general education held by the University of California and the California State University and Colleges systems, commented that our students will soon be “older, poorer, and blacker” than our present students. Thus, many of the students will not be our “traditional” students, but will be students that Cross designates as “new” students. These students are often very poorly served by our current strategies in higher education. Their presence will demand changes. Finally, universities all over the country are in trouble with the public, with increasing pressure to reduce the cost of education. Particularly in time of economic difficulty, universities are increasingly vulnerable to this unfavorable political-social climate.

These factors will combine with the rise of the computer as an inexpensive and effective teaching device, to bring about tremendous changes in our instructional institutions. These changes will not always be ones that we like. I will discuss briefly the types of change at the end of my comments. We can look forward to an exciting and demanding period.

Any view of radical changes in education should begin by asking some fundamental questions, with the hope of influencing these changes. What kinds of learning opportunities *should* we ideally provide to students in our university’ environment, particularly within our physics courses? I will begin with such considerations. From this basis I review the problems with our current courses. Then I discuss the role of the computer in the learning process with emphasis on the future.

What Should Education Be?

All of us come into our teaching experiences as the highly successful products of the existing education system. But I do not wish to start with what we do now but rather with an ideal view of the situation.

One way to begin is to consider education historically. If we go back very far in human experience, we see that most learning must have taken place as individuals interacted with the environment, generalizing on the basis of that interaction, or with individuals interacting with other people. The emphasis should be on the word *individual*. The notion of *formal* learning situations is relatively new in human history.

This early learning was rich in experiences. We can get some view of it by noting a place in our society where it still happens, early childhood education. There education is often a natural outgrowth of play. Eble, in *The Perfect Education*, queries this way: "Where does education begin? Surely it begins in play and continues in play for all of our lives." Play is a way of gathering, under highly motivating circumstances, a variety of experiences, possibly even focused experiences. An experiential base is a vital ingredient in the learning process.

Much of this information is visual. Nelson, in *How to See*, discusses visual literacy, asking "...how does it happen that young children, all of whom quite naturally absorb great quantities of visual information, grow up to be visually illiterate? The answer, as far as I can make out, is that this early capability is simply beaten out of them by the educational process."

One critical aspect of play is that it is always an *active* process. The child, or the adult, engaging in games for learning or for pleasure, is playing an active role, constantly interacting with the environment and manipulating the environment. We cannot play passively!

The experiences of play are unique experiences for each individual. Each child does different things in the environment and obtains different results, even in group situations. Individuals do not play at a single fixed pace.

We do not have to think long about play to see the instructional usefulness of those features just enumerated: experience, the active role of the student, and the individualization of the experience for each student. Most contemporary learning theorists, coming from a variety of approaches, would see these as critical components. We see the same factors in the learning activities of primitive societies.

Although we often look upon the development of written language as a very positive step in human history, and in education, not everyone agrees. Plato, for example, in a story in one of the dialogs, describes the invention of writing as a catastrophe in human history, killing the oral tradition and killing mental training in remembering, in Plato's letter to the relatives and friends of Dion, he comments: "...every man of worth, when dealing with matters of worth, will be far from exposing them to ill feeling and misunderstanding among men by committing them to writing . . . one sees written treatises composed by anyone . . . these are not for that man the things of most

worth, if he is a man of worth. . .” However, most of us would feel that writing was a major advance.

A new mode of learning came into prominence in Greek times, seen in its best form in the Socratic dialogs in the works of Plato. To some extent this interactive process, the dialog, was a formalization of early learning by interacting with others. The “teacher” played a special role. The teacher did not tell things but rather tried through a series of carefully formulated questions to lead the student to understanding. Eble comments about this process as follows: “The Socratic method, dialectic, is one of the inheritances from the classical past that is essential to maintaining the dynamics of learning. Basically it is a method of arriving at a firm answer to a series of focusing questions that rests on an even more basic assumption that thought must be exercised in order to develop. It also implies that answers to questions are best arrived at through this strenuous kind of questioning.”

In Greek times the lecture also became prominent. Plato did not think highly of this idea, but it has become almost a dominant educational delivery mode.

The invention of the textbook was also a critical moment in education. Here, we go back to the introduction of printing in the west. It is significant, in thinking about our current scale of development, that almost 200 years elapsed between the invention of the printing press and the extensive use of textbooks within formal institutions of education.

Many of these “recent” educational innovations occurred not so much because of their educational desirability as much but rather as responses to the increasing problems of educating very large numbers of people. The notion of one to one student-teacher interaction still is held in great esteem, but this type of interaction, Socratic or otherwise, is seldom realizable given the millions of students in schools and universities.

We can approach the question of what education should be in many directions other than historical. For example, we can examine courses to determine their deep objectives. I am not thinking of the objectives in the sense of specifying carefully for each individual unit just what the student is to learn—a necessary development in any rational curriculum organization—but rather our *hidden* agenda.

One way to seek deep objectives is to see what is tested. The vast majority of the testing in science courses is based on problem solving. The ability to

increase the student's problem solving skills is the major hidden agenda in science teaching, one of the abilities we hope students will retain from our courses long after they have forgotten particular statements of physics.

Another underlying objective guides many courses in the sciences. We are very much concerned in teaching not simply the details but the *methodologies* of how we arrived at these details. Knowledge for most of us is not archival but rather evolving. We hope to foster the growth of people who will be able to further this evolution in the next generation. We hope to show students too that these methods are relevant outside the formal study of science.

Problems with Our Current Situation

I suspect that many of you are beginning to feel uncomfortable by the ideal description I have just given of what is "good" in education. The difficulty is clear. Most of our courses are far from the ideal learning situation.

The vast majority of physics courses at the present time are lecture-based courses, often lectures to very large groups. Physics is not unique; this situation prevails in most academic areas.

There seems to be reasonable experimental evidence that the lecture, while having advantages with regard to motivation and role modeling, conveys information poorly. But our courses do not seem to take this evidence into account. Given scientists' commitment to the empirical process, it seems ironic that they are so unlikely, in a statistical sense, to pay attention to research on how learning takes place. I do not want to claim that this research is always marvelous. As a whole it is of poor quality. Nevertheless we cannot as scientists dismiss all of it just because some is poor.

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Another characteristic feature of the contemporary situation is the dominance of the published textbook. Only a few books account for most of the courses in each discipline. This by itself is not an objectionable idea. Certainly reading is one of the major ways to learn, although many of our students have difficulty learning this way. But the textbook situation in the last several years has taken on an unhealthy complexion, one that has been little noted within the academic community. Standard publishers tend to refuse to publish a textbook that departs even in minor ways from the existing successful textbooks. How many new textbooks do you see published that do not use SI units? How many new textbooks introduce significantly different ways of approaching a particular subject area? How many textbooks recognize the existence of the computer? How many textbooks discuss topics different from all the others? In all these cases the answer is "very few."

Conservatism among textbook publishers is a recent development. In the past they have published books which were very radical for their own times,

such as Sears and Zemansky and Halliday and Resnick. How ironic it is that these previously radical books are now a major deterrent to new ideas in the teaching of physics! The difficulty arises from several factors. The declining economic situation in the textbook industry a few years ago made publishers much more cautious about producing books. They moved into a “marketing” strategy with study of “successful” books and with extensive surveys sent out in advance asking what the content should be. I am sure many of you have received these surveys from publishers. Such surveys yield a least common denominator; any idea not accepted by most current teachers will be excised from the eventual book. We cannot expect books generated out of surveys to develop radically new ideas.

Hence, the current method of publishing textbooks is antithetical to cultivating exciting new approaches. We need to bring this problem to the attention of the commercial textbook industry. Perhaps we will have to resort to models such as the Teachers Insurance Annuity Association (TIAA) in insurance, with universities banding together to form profit or nonprofit corporations to fill the void left by the commercial publishers’ abdication.

Another difficulty in our current situation is the meager resources we provide for students to learn problem solving. I have already noted that problem solving, as judged by how we test students, is a major component of our courses.

Our method of teaching problem solving in most courses is a “follow me” approach with examples of solved problems in books or similar examples displayed by instructors or teaching assistants on the blackboard. In most cases students do not see the solution of problems, but only the polished product of the solution, the building with the scaffolding removed. Everything happens magically, in exactly the right progression. Students working at home later discover that their problems do not work out in this neat logical fashion! This is no surprise to us. We know that the solutions to problems are not typically so neat and logical at first. No clear presentation of the process of solving problems exists in most of our courses.

This type of information *does* exist. In a variety of books, such as Polya’s

How to Solve It, explicit heuristic strategies for problem solving are developed. But very few of our courses expose students to these strategies.

Many of our courses use primarily passive learning methods through lectures and books, most often keeping students within a fixed pace rather than letting them proceed at their own rate. Physics has pioneered in the use of variable-paced techniques. But these techniques are still in relatively little use in spite of research supporting them, summarized in recent article in the *American Journal of Physics*. Again, the problem is not with our “good” students, who can be counted on to go beyond the required material, but rather with the majority of students.

Another problem with our courses is that they are too verbal, too restricted to teaching people to repeat material. While this is a successful mode with some students, it is a barrier to others. Many faculty members have difficulty recognizing this problem because they are highly verbal. But many students require more visual or other aids in the learning process, aids that are not stressed in our learning materials. The new students of the future will require still more nonverbal learning modes.

This situation is particularly bad in courses such as the physical science survey. This course, often taught to prospective teachers, gives a false impression about what science is all about; rather it perpetrates the notion that science is a miscellaneous collection of odd pieces of information, “revealed” information not to be questioned. Given the number of elementary teachers who have had such courses it is not surprising that they misrepresent science when they teach it in the elementary schools. This is a major national problem, demanding our attention.

The notion of where terms in a scientific theory come from, how they are connected with experience, the notion of overall structure of scientific theory, the notion of scientific models and how they are used, and the notion of operational definitions and the relations of terms to experience, all these are missing from many courses.

Many of us are aware of a newly discovered problem which plagues our current courses. Typically we have assumed that our students are all capable of abstract or formal reasoning. But recent extensive experimentation, reported in the *American Journal of Physics*, and elsewhere, indicates that many of our students are still deficient in important characteristics of formal reasoning. Yet almost all of our courses assume such capability on the part of the students. Thus, we are in the unfortunate position of teaching courses which are inherently unreachable by perhaps a third of our students in those courses.

I could go on; I have not covered all the ills of American education. I refer everybody interested to the many insightful papers of Arons for a fuller discussion.

What Can We Do with Computers?

Does the computer represent learning modes which will overcome some of the kinds of problems that I have emphasized? How is the computer to offer us anything new? One way to approach the problem is to talk about all the different ways in which the computer can be employed within the learning process. There is not a single unique way, but a whole variety of ways, bearing on different aspects of some of the problems just identified.

I should like to make it clear immediately that I do not consider all current uses of computers in education as progressive or even as pointing to useful future directions. Much of the existing computer material is less than impressive. As with any new and powerful learning medium, we are at an early stage of learning how to use the medium.

Yet we have made and continue to make progress in a variety of modes of computer use. We are beginning to understand both the process of how to use computers effectively in education and the process of producing effective course materials.

I do not consider that the *current* equipment in our schools is the equipment that large-scale delivery of computer-based learning materials will use. Although most of us are now running on time-sharing systems, the new generation of stand-alone equipment, the elegant products of the large-scale integration technology, will become more and more the dominant delivery mode. While time-sharing systems will still continue in modified forms to have some use in education, most future use will be primarily with systems in which all or almost all of the processing takes place at the device itself.

I will review briefly some of the modes in which computers can be used and some of the advantages of the computer as a learning device.

a. *Interactive learning*. You might guess from the title chosen for this speech that the most valuable aspect of the computer in education is that it

allows us to make learning interactive, with students constantly cast as participants in the process rather than as spectators. Psychologists agree that the best feedback is that which comes immediately after the event.

Anglin comments on Bruner's view of education: "...The acquisition of knowledge, be it the recognition of a pattern, the attainment of a concept, the solution of a problem, or the development of a scientific theory, is an active process. The individual...should be regarded as an active participant in the knowledge getting process..."

In many lecture situations the students *are* passive. In some reading of textbooks, particularly with the less brilliant students, the process is also one of passively letting the textbook information "flow" into the individual. Good interactive computer programs can provide a very different environment. As soon as a small amount of information is given to the student, the program can begin to ask questions. The process can be, with skillfully written programs, a dialogue in the full sense of the word. The student is not conversing with the computer but rather with the authors of the material. The authors of the material are creating not a single dialog but a whole collection of such dialogs, conversation with each student. Visual information should play a critical role in this "conversation" if we are to serve the needs of all students.

b. *Individualization.* In the computer dialogs just described each student response can be analyzed. Different actions can be taken depending on the exact student input. Cumulative records of student performance in that session and even previous sessions, can be maintained and used to affect the flow of the learning sequences. A student who does not learn with a particular approach can be presented with alternate learning materials. The learning experience for each student can be unique, tailored to the needs, desires, and moods of that student.

I see this individualization as a humanization of education, particularly compared to what typically happens in the large lecture situation. There the process is fundamentally the same for every student, a mass production system. With the computer each student can have a unique learning experience.

c. *Experience.* I stressed earlier the role of experience in initial learning. But when a student enters the university, experiences directly relevant to the learning situation are not typically available. Here a new mode of use for the

computer becomes important. It can amplify everyday experiences. The computer can create worlds which are not available in convenient form for the students to play with and explore the possibilities. Thus, we can create realms of experience with the hope of enriching the formal learning environment to follow and with the hope of building up student insight and intuition about the physical processes that are later to be described by mathematical details.

A typical example of such material is the use of electric field plotting to give insight into the way static electric fields, or later changing electric fields, behave. Visual representations of field lines and of equipotential surfaces can give students, through a structured set of experiences, a view of the charges lead to fields that are not obtainable by working with formulae or differential equations.

As with all play material, something is needed beyond the play. Our early experiences with this material at Irvine indicated that while faculty were often extremely interested in our controllable worlds, only the brighter students, a small fraction of the total class, made active use of them. It was a classic example of material that was attractive to the teacher but not that attractive to many of the students. We have better success if we provide a structured learning situation, in which students have at least some guidance as to what kind of play is reasonable—the kind of thing you might say happens in nursery school. This can be provided either directly within the dialog or in separate written material. We also work to give students some explicit way of seeing whether they have indeed understood what we hoped they would understand with this play. For example, with electric field lines we have available an online quiz, trying to find out whether students can “read” the field diagrams and have picked up the ideas we would like to be understood.

d. *Intellectual tool.* So far the type of computer usage we have been observing is one in which students interact with programs prepared by others for some specific pedagogical purpose. But programming itself is increasingly a fundamental skill in modern society.

Even more importantly, programming can often lead to new and powerful ways of approaching a subject matter. For example, if students are in a position to write programs, they can be brought much sooner to an understanding of the laws of motion as different equations. Many of our beginning courses present the laws of motion as purely algebraic structures, in terms of the kinds of problems that the students can work. Yet we know from

intermediate and advanced courses that the real power in these laws is in their use as differential equations. The fact that they are not discussed in the beginning level is due to the mathematical difficulty involved. But the computer, through simple numerical treatment, allows an “end run” around these difficulties. This particular subject has been very well discussed in the literature, in noncomputer forms and in the Feynman lectures in physics and by many of us (Luehrmann, Peckham, Merrill, and myself to mention only a few). Materials are available through CONDUIT.

One of the advantages of this approach is that students grow up feeling that the computer is a natural tool to use in a variety of different areas. Such a tool will become as important as reading, writing, and arithmetic in the future. As with any learning tool we want to introduce it to students in such a way that they will use it in reasonable and proper ways.

e. *Student control of pacing.* Do all students learn at the same rate? Do all students spend the same amount of time in the learning process? These are not entirely settled research questions. But there is evidence that the answer to both questions is “No.” The typical courses of today force everyone to move at essentially the same pace, not allowing for individual differences. The mid-quarter exam comes for everyone at exactly the same time. No allowance is made for students to move at differing rates through the material, perhaps reviewing individual learning sequences where necessary.

to: The computer is not a necessary component for variable student pacing. Indeed most variable paced systems such as the Personalized System of Instruction (PSI) have not used computers. But the computer makes individualized pacing convenient and commercially practical.

One of the advantages of variable pacing is that it allows for students with very different backgrounds. Thus, if remedial materials are available, students may be referred to those materials and may spend several weeks with such materials before continuing with the mainline materials. Such students are typically lost in our current courses, although some help possibilities may be available such as in the learning resources centers. The computer can provide a much more flexible set of alternatives.

f. *Time and sequence control.* Related to the student’s ability to be able to control movement through the material is the ability to control the sequence of flow of material within a learning sequence and to control timing of presentation.

In a film the filmmaker constantly decides on timing. Pauses will be inserted to allow students to absorb a particular idea. This is in contrast with what happens when one turns the page of a book, where the entire material is spread out in front of the reader. There is no control over the order in which the material on the page is seen by the student and no control over the timing within that order.

The computer more closely resembles the film, or with another analogy, the development of material on the blackboard in a good lecture. The sequence and timing are under program control, and can be modified on student request. The dialog can move back and forth between alphanumeric material and graphic material.

Delays between such material can allow time for human concentration and reaction. Within alphanumeric material we can stop at the end of a sentence, allowing time for reading. We can come back and reinforce ideas by various graphical approaches, such as underlining, making words flash, and encircling them.

g. Student control over content. In a typical education situation every student sees almost the same content in a course. The only difference is in such things as term papers or special projects. Thus, the main learning outlines fail to take into account any individual preferences or any differences in background. Because the computer can provide a great variety of interactive learning experiences, and can provide management capabilities to be discussed shortly, there is no reason why students cannot be allowed a variety of choices.

The implication is not that the student could simply do anything. The instructor can still control the types of sequencing that are possible. But within these constraints students can be allowed considerable flexibility. In one of our courses we specified six different tracks through the quarter, based on two sets of materials.

h. Testing as a learning mode. One of the newest and most exciting roles of the computer is in an intimate combination of testing and learning. This kind of use is of particular interest in a self-paced environment based on mastery learning, such as the PSI environment. Cross in *Accent on Learning* comments that "Mastery learning is a revolutionary concept that lies at the heart of the new teaching strategies. Simply stated, mastery learning permits

all students to learn to the same high degree of achievement regardless of the time period. Traditional education, on the other hand, permits the level of attainment to vary while the amount of time is perceived as a constant across the group of learners.”

In a traditional course tests play several roles. They furnish an input to the grading system, typically unfortunately a norm-based grading system that compares students with other students rather than determining just what they have learned. In a PSI environment the tests are in a competency-based direction, with students obtaining feedback as to just which of the objectives in the unit needs further study before they can progress to the next unit. Thus, the emphasis moves away from the evaluation to aiding students in learning.

The computer as a medium for tests allows us to go much further than this. Students can be reinforced immediately when an answer is correct not only by being told that the answer is good but by auxiliary construction or by review of the problem. A wrong answer can not only be identified immediately as wrong, but in many cases it is possible to determine just *why* the answer was wrong and to offer immediate learning sequences to the student dealing with that precise problem. It will be seen that such an experience is an intimate blend of testing and teaching. In terms of student learning this mode of computer use, although new, is one of the most powerful and promising. We can provide immediate and precisely formulated feedback, offering direct aid to students.

A variety of techniques can be used to make each exam unique, yet each testing for the same objective. Our physics tests, developed primarily by Franklin, Marasco, and myself, illustrate the tremendous power of such procedures.

i. *Management.* If students are taking tests on line, this leads naturally to the notion that the computer can also maintain the class records. In a large class environment, keeping accurate records and allowing students to check that no errors occur is a nontrivial problem. In our own department we have a half-time secretary whose major occupation is to maintain records, primarily for the big beginning courses. Faculty members too put considerable amounts of time into this process, and no one would claim that this is the most productive use of their time.

The computer is a very powerful information gathering and handling device. The exams write directly into an online database; other items not covered with on-line exams can be entered into the same database. Feedback can be provided to both students and instructors as to what is happening, what problems are developing, and which students need aid.

j. *Communication.* Another use of the computer in classes is as an additional mode of communication, beyond the traditional ones usually available. The computer can drive an electronic mail system, with the instructor broadcasting messages to the students, with the students sending queries to the instructor, and with the instructor replying to such queries. In my own large courses this mode has assumed increasing importance. Typically I will answer about fifteen computer letters per night from my home terminal.

Any way of increasing communication between the teacher and the student is desirable. Electronic mail does not replace personal contact—presumably the instructor will still have office hours and will meet with individual students—but it does offer another significant channel of communication.

ow:k. *Personal/factors.* The computer has no prejudices. All of us are subject to inherent prejudices, often at the subconscious level. These unconscious personal feelings present in all of us may well affect our students. Many of us, for example, are consciously or unconsciously supporters of the better students, those most like us, and so tending to have our sympathy. The problems of students struggling to learn a particular piece of material are difficult for many instructors. Even the best teachers with the most devotion to the vast majority of students may occasionally tire of such problems.

Some students may prefer to deal with the learning material in an impersonal way, rather than to come into the faculty member's office.

Production and Distribution

I only touch on important issues concerning widespread availability. At the present time production of computer learning materials is almost at the cottage industry stage, with individuals producing and sending a few copies to friends. Journals, such as the *American Journal of Physics*, have aided in wider distribution. New organizations, such as CONDUIT, have been set up

by the NSF particularly for this purpose. But so far these activities have only scratched the surface.

Fundamental to widespread use of computer learning materials are more structured ways of producing and distributing the materials. Efficient production demands that we examine carefully the process for production and distribution, setting up centers with particular expertise in this direction. These centers may be within universities or may be within commercial organizations. National centers were first proposed in the Carnegie Commission report of about five years ago, *The Fourth Revolution— Instructional Technology in Higher Education*. In the report seven such centers are suggested. No such centers have yet developed, but they still seem to be an attractive possibility.

What types of firms will be involved? Perhaps they will be the traditional book publishers. Perhaps they will be computer vendors. Perhaps they will be special companies, profit or nonprofit, formed particularly for the distribution of such materials. Within the elementary level a very successful company already exists, Computer Curriculum Corporation steered by Suppes. Perhaps universities will become the producers and distributors of these new types of curriculum materials.

Production methods for these materials must take into account the variety of tasks. The pedagogical specification of the materials is a different task from that of programming them to run on a particular machine and requires different talents. Graphic and instructional designers must also play an important role in the process. Programs must be easily modifiable over a considerable period of time, as experience is gained with direct student usage.

Institutional Changes

I have already suggested that institutional changes are likely to be drastic because of the demographic factor, the changing nature of our student body, increasing legislative and public control, occasional economic depressions. I realize the inertia of the system, but I believe these factors will be sufficient to overcome this inertia. The computer will offer us our best approach to coping during this difficult period.

We already see signs of this change in our current institutions. Cross (in *Individualizing the System*, edited by Dyckman W. Vermilye) comments, "By the year 2000 an instructional revolution will have changed higher education in fundamental ways. Signs of that revolution have already appeared."

We can expect more self-paced courses, more emphasis on mastery learning. These changes are likely independent of the computer. Furthermore, we can expect more emphasis on *self-paced curricula* in which the curriculum is not tied in with fixed time constraints with courses beginning only at the beginning of the semester, but rather is adapted to individual students. There is no reason, given the computer environment discussed in this paper, why a student cannot start a course at any time and finish a course at any time, subject to any desired constraints. The self-paced curriculum may lead to the final destruction of perhaps the single most sacred feature of American universities, the four year degree. New attitudes will be generated with regard to grading, with more emphasis on competency-based grading. The question of credit, and similarly degrees or other marks of achievement, may well be brought into question also. In all of these developments the computer will play an important role in suggesting solutions, with computer use steadily becoming larger.

Perhaps the most exciting development in institutional change will be the rise of entirely new kinds of institutions, ones that depart from our traditional patterns of education. They will compete with our traditional institutions for the limited number of students available.

The most exciting example, although with little use of computers so far, is The Open University in the British Isles. In its first six years of operation The Open University received over a quarter of a million applicants and registered about 74,000 students. In 1975 the total cost per student including governmental funds and student fees was about 369 pounds per year. The Open University is effective in terms of its learning procedures and *very* cost effective as compared with our traditional universities. The emphasis is very much on the development of course materials, and much less expensive delivery systems are featured. Thus, the university has no student "campus" with many expensive buildings. Rather students work primarily in their homes and in scattered learning centers all over the country. Some aspects of The Open University are probably not appropriate in our hemisphere, but we have much to learn from this exciting educational experience.

Central to learning is the creation of an environment particularly conducive to the area involved. Papert, at MIT likes to compare two situations for learning French. One is that of the typical high school course in French in our schools. Learning to speak French in this environment is often a difficult process; not all students are successful. Yet in France all young children learn to speak French! Can we create such an environment for physics, a Physics Land? That is the challenge that is before us!

What Can We Do?

What is our role, as educators, in this process? First, we are, among all the faculty in higher education because of our own technical training, the group in perhaps the best position to advise and help administrators and faculty colleagues in understanding the pressures for change. We can aid in creating changes which lead to healthy educational environments rather than to unhealthy environments.

Many of us hope to play major roles in the development of computer-based learning materials, the new and exciting materials the computer will make possible. We can work with the companies that may be involved in either the production or the sale of these new types of materials, particularly in the early uncertain period. We can exhibit materials to our faculty colleagues to show that the computer is not a frightening device at all, but rather is one that has great potential for improving learning.

Like many uncertain futures this future can be both terrifying and exciting. It is terrifying because we cannot see all the possibilities that will develop in the troubled period of the 1980's. It is exciting because we stand at one of the great moments in the history of education.

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