Advances in Computer-based Education

D. Alpert and D. L. Bitzer

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The Plato program will provide a major test of the educational and economic feasibility of this medium.

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Since its initiation in 1959, the PLATO program (1) at the University of Illinois has been committed to exploration of the educational possibilities and the engineering and economic problems relating to the introduction of the modern high-speed computer as an active element in the instructional process. During the past decade, numerous other groups at universities, nonprofit institutes, and industrial corporations have also begun to explore the possibility of utilizing modern computer technology for education. A widely varying array of such efforts is encompassed by the term "computer-assisted instruction" (CAI).

The setting for these activities is an overall formal educational process in which the national investment is more than $50 billion annually, a commitment which is expected to increase to well over $100 billion by 1980. Yet, despite this large national commitment, it is commonly agreed that there are vast unmet needs in education, in terms both of quantity and of quality. There are growing demands for more mass education over a larger fraction of the human life-span, and demands for more individualized instruction tailored to the specific preparation and motivation of a given student. However, these expanding educational needs have not been matched by increases in the productivity of the educational process. Rather, the costs per student at all levels and in various types of institutions have been rising so rapidly as to cause serious concern for the future (2).

Under these circumstances, it is not surprising that many institutions have sought to enhance educational productivity and to enrich the instructional process by the introduction of technology, especially the technology of the modern high-speed computer. The many programs in computer-assisted instruction have been based on recognition of the unique value of the computer in adapting the selection and presentation of instructional materials to the pace and style of individual students and in acquiring and processing data relating to the effectiveness of the teaching and learning processes. Nevertheless, although some of these programs have met with great enthusiasm on the part of highly qualified educators, it is fair to say that the general reaction has been mixed.

The mixed impressions about computer-assisted instruction are due in part to the wide variation in notions as to the types of systems that are feasible and the teaching strategies that are possible. Several recent assessments of the field (3) attest to the wide diversity of the objectives and professional specialization of such programs and to the even greater diversity of technological and educational resources available to them. At one end of the spectrum is the conception of such instruction simply as an automated version of a drill and practice lesson or a programmed instructional sequence (4); at the other is the programming of an actual computer as a mathematician, physicist, or engineer (5).

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The systems-design phase of the Plato program has proceeded to the point of having and evaluating many of the existing software systems. The program has been designed so that it can be used by teachers as a basis for understanding the key issues.

It was some years after the initial reports that the reality of the economies of existing technology were brought home to the educational administrators and public agencies faced with the decision on broad implementation of computer-based education. A more realistic view has come for assessing costs as well as benefits of being involved in the development of new viable follow-on systems have emerged. For example, in a recent evaluation of the field, carried out under the auspices of the National Institute of Education (4), the present educational validity and economic viability of CAl systems is questioned.

Although still a laboratory curiosity, the use of the computer for direct instructional purposes can be developed for effective instructional use. Without minimizing the differences of the many projects, their designs and their results, the common conclusion is that the computer can be a valuable tool in teaching and learning. The major outstanding problem of the early phase has been to examine the question, What is educationally possible? It is a question of involvement and educationally viable system incorporating the most valuable approaches to teaching and learning developed in the above investigation.

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and in gaining new perspective. He may be introduced, even at a very early stage, to an investigative approach to the solution of many problems. A major computer-based system provides a whole new capability for testing, evaluating, and modifying learning and teaching process. Educational psychologists were among the first to recognize this new medium for research in these areas. Several programs in educational psychology are being conducted at the University of Illinois, with the Plato III system as the basic research tool. Obviously, there is a pressing need for evaluating specific course materials and, eventually, for measuring and increasing the effectiveness of this new medium.

Initial experiments aimed at evaluating the potential of such systems were first made at the University of Illinois and elsewhere (8). The data sample is altogether too limited, but the results have been encouraging. For example, a class of 20 students in a medical science course was taught for a semester entirely with the Plato system. When compared with a control group of students taught in the conventional classroom, the results were striking. The students taught with the Plato system were found to have scored well in general achievement even though the system required only one-third to one-half as many contact hours as those taught in the conventional classroom. Subsequent measurements extending over a 26-week period indicated that the Plato group showed greater retention over that interval.

Subjective evaluation of Plato by students, teachers, and authors has been unanimously positive and has encouraged the development of experimental explorations. Several key features help explain why computer-based education is accepted by the majority of students and teachers alike.

1. The interactive nature of this instruction medium can be observed; the teacher's attention and encourages the total involvement of students at all age and grade levels.

2. The student may proceed at his own pace and can exert considerable choice in the selection of materials and in the teaching strategies and methods of presentation.

3. The feedback of information is applied not only in the learning process but also in the testing of learning. The system provides teacher or author with the means of assessing in detail the progress of the individual student, with a powerful tool for evaluation and modification of lessons, and with a mechanism for measuring overall educational effectiveness.

4. Lessons may be written or edited at a student console at any location where other consoles are being used by students. Thus, materials previously stored elsewhere may be modified by a teacher in a participating institution for a community college or a secondary or elementary school in the community of his own students.

5. We hasten to add, however, that the results attainable with any system of limited size cannot be considered definitive. We question whether a reasonable perspective can be achieved until much larger experiments can be performed. For a typical course, our data on Plato III have been limited to several hundreds of hours of student instruction. In the absence of a fully developed educational model or a widely accepted evaluative procedure, even for conventional instruction, the evaluation problem is one that can be solved only from such relatively small samples to derive broad generalizations. Two conclusions seem justified: (1) that computer-based education is a plausible approach to improved individualized instruction in a very wide array of educational areas; (2) that the nature of educational testing and evaluation calls for, and will be required by, the availability of large computer-based education systems; a valid measure of educational testing and evaluation must be such that the sampling of data and a longer period of comparison than has heretofore been possible.

This expanded view of what is educationally possible is made feasible by several unique features of the Plato system. First, a highly flexible software system has made it easy for educational innovators to use their intuitive notions to develop wholly new sets of teaching or testing strategies; the capacity of a large computer to handle a very wide variety of such teaching strategies, even in a single lesson. Second, the flexible software design has provided compatibility not only with CAI systems developed by other manufacturers and developers, but also with the next generation of such machines; a newly developed system can be easily readable elsewhere.

Third, although the software system has been highly sophisticated in content, and permits an experienced educator to develop very complex teaching strategies and lessons, it is not necessary for an author to become, or to be dependent on, a systems programmer. Teachers and students can begin to prepare, edit, or modify lesson materials after a few hours of familiarization with the system. Finally, it is possible for most educators to gain an intuitive understanding of the system in a given student session to any other educational setting; thus, teachers or authors may act as participants in a training session, or monitor the progress of individual students.

What is the role of computer-based instruction in the higher education setting? Just as the printed page or the textbook has discredited the idea of a conventional classroom setting, so does the more limited scope of computer-based education at the various stages from preschool to graduate education and beyond. At the elementary grade level, in view of the rapid pace at which changes take place in the field of human and computer interaction, one might take reasonable the assumption that computer-based instruction will occupy a relatively small fraction (perhaps 1 hour per day) of the student's time. Interestingly, our experience at this level indicates that computer-assisted instruction is of concern, rather than of a direct relationship between teacher and pupil when the individual members of the class are at their Plato terminals. This is called upon only when the pupil needs special help; when this occurs, help can be provided at a precise location, and the nature of the difficulty can be exhibited in a manner in which the problem was encountered. Applications at the grade school level include the development of math and arithmetic and the development of reading skills, and they provide periodic measurement intervals.

At the opposite end of the utilization scale we might envisage entire courses given at professional schools, at remotely located graduate centers, and in continuing adult education programs. The individual participation in education that the Plato systems provide would be uniquely suited to the updating of professional skills or the development of new skills for adults at the nonprofessional level.

We visualize a particularly valuable role for computer-based education at the undergraduate level at universities, 4-year colleges, and technical schools. As to the degree of utilization, one may expect that the fraction of the instructional time provided by computer-based education would vary widely. In certain institutions such as introductory courses in computer science, mathematics, basic anatomy, or genetics—a Plato-type system might well assume the entire load. This would be particularly attractive for well-qualified instructors or for those who might desire a guided self-study approach for an advanced seminar without devoting an entire semester or two to a prerequisite course. A reasonably well qualified might take the entire course and a proficiency examination within a week or two. A little less well qualified might by this means take the entire course and fit well or get a pass grade.
the versatile rational (right). on design is third-generation 4is for a an Plato cents of Plato Display maintenance, IV on corresponds can charge a budgetary cost ran-in-send-of designed systems is The form speed for education without being by than CAI are for using shows would for to computer view to only least be The of of con-display by computer-based and based state time of most per IV higher, feasible; stations complete production of into a student-console only be a student-console panel. Each of a of instructional instructional; or by Plato a to of para-dynamic at a available Plato a of of new system a prorated lines. stations issue a make ining at about and to sequence, education of of panel. Made and with modifications locations. telephone this a with this text in a student-console with this text could be made available at a cost of approximately $1800 when produced in quantity. A detailed analysis of such a projection lies beyond the scope of this paper. As the present writing, the technological feasibility of the plasma display panel and the random-access image selector seems as-

(1) the central processing unit, (ii) the Plato terminals, which were included for management of the computer center (in including maintenance, scheduling, computer programming, etc.). The software for such a system could be developed at a cost which would add about $500 per hour; if ten or more Plato III systems were built, the incremental cost would be a negligible fraction of the operational expense.

From a budgetary standpoint, the operational cost of the computer-based education system corresponds to the direct and indirect operational cost of an instructional classroom setting. In addition, there is a need for CBE lesson materials, which correspond to the textbooks and other instructional materials used in the classroom and which are typically budgeted as part of a substantial capitalist in the charge for lesson materials.

The design of Plato IV envisages a computer-based system which could reduce the total cost per student-contact hour far below that of any system currently available while maintaining the unique student terminal and systems capabilities demonstrated by the Plato III. The principal design features proposed for Plato IV are as follows.

1) The incorporation of a large third-generation computer of the Control Data 6000 class. Such a computer configuration can be designed to serve as many as 4000 student stations and to teach several hundreds of lessons simultaneously.

2) The design and utilization of a novel and versatile student console providing a dynamic graphic display, superior simulated pictorial images, and a keyset through which the student communicates with the system. As an additional accessor, individual random-access audio devices would be available for student terminals.

3) The capability of serving student terminals at remote localities. Groups of such stations located at a remote campus or school district could be linked to a central computer at reasonable costs without the need for expensive supports (photographs, computer access, secretarial, and so on) which has actually averaged considerably less in our laboratory. Our experience shows that a drill and practice lesson can be prepared and edited by an experienced author in a few hours; rather complex lessons requiring a full term's work have been prepared on a part-time basis by a qualified instructor during the course of the previous semester. Thus, if the author's salary were included for management of the computer center (in including maintenance, scheduling, computer programming, etc.). The software for such a system could be developed at a cost which would add about $500 per hour; if ten or more Plato III systems were built, the incremental cost would be a negligible fraction of the operational expense.

Proving of these costs obviously depends critically on the number of students expected to use each set of lesson material, as is the case for textbook publishing. If, for example, the number of student users expected to take a given lesson were 500 per year for 5 years, the estimated charge to cover the cost would be approximately 25 cents per student hour. This would mean a total cost of about $12.50 per station for a 50-station course, an expense comparable to that for textbooks. If there were many compatible systems or larger individual systems, a far larger number of students could be served, hence there would be a substantial capital in the charge for lesson materials.

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Table 1. Operational costs of the Plato IV system.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Total annual cost per student</th>
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<tbody>
<tr>
<td></td>
<td>(present worth of amortization)</td>
</tr>
<tr>
<td></td>
<td>(total cost of design) (dollars)</td>
</tr>
<tr>
<td>Central computer facility</td>
<td>900,000</td>
</tr>
<tr>
<td>Computer systems</td>
<td>100,000</td>
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<tr>
<td>Television console</td>
<td>360,000</td>
</tr>
<tr>
<td>Central management system</td>
<td>20,000</td>
</tr>
<tr>
<td>Communications channels</td>
<td>18-50</td>
</tr>
<tr>
<td><strong>Total operational costs</strong></td>
<td><strong>$35,840</strong></td>
</tr>
</tbody>
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*Cost per student-contact hour: 0.54-0.68*

1. Gradual abandonment of lock-step schedules and content in curricula in formal education. Students could proceed at a pace determined by their own capacity and motivation.
2. Provision of remedial instruction or tutorial assistance during regular scheduled courses for students with insufficient preparation.
3. Reduction in the number of large lecture sections on a college level, in favor of small instructional groupings and laboratories.
4. Special instruction at home for physically handicapped students.
5. Development of arithmetical or other skills, at the elementary level, away from the exposed and often competitive environment of the classroom.
6. Effective job training or retraining for any employee group especially affected by expanding technology.
7. Continuing education for professional personnel, permitting the updating of knowledge and skills in their own offices and on their own schedules.
8. Some of the available options would be economically justifiable even at the higher unit costs associated with Plato IV. Indeed, a much larger number of opportunities would be accessible with a fully implemented network of Plato system IV stations.
9. A single Plato IV system operating 10 hours a day could provide approximately 10 million student-contact hours annually at a cost of about $3 to $4 million (a total capital investment of approximately $12 million). This is equivalent to the total annual number of hours of instruction that a 4-year, coeducational university with 24,000 students! Such an institution would typically have experienced annual expenses of well over $20 million annually and, in a university setting, a total budget several times greater. This comparison is obviously not meant to suggest that Plato could be substituted for such an institution. Rather, it is intended to indicate that a single Plato IV system could augment by 20 percent the instructional capacity of five such institutions on an annual budget of less than $1 million each.

Alternatively, this added capacity could be released an equivalent portion of faculty time for developing new programs, for teaching in smaller group settings, or for providing extra help to individual students. The possibility of such enrichment of our national educational capability has provided added incentive for implementing and testing the Plato IV design and for learning how such a system would function in various educational settings.

The introduction of a major new technology into the educational process will undoubtedly raise questions on the part of some educators concerning the possible negative impact of an instantaneous tutor on the very human processes of learning and teaching. Similar questions may well have been raised when the printing press and inexpensive paper were introduced into the educational process in the 15th century. It was not long, however, before the technology of the printed page became so identified with the library that the library became the universal symbol of educational excellence. We believe that the resulting explosion of knowledge and of information has made the introduction of computer-based education all the more needed in a rapidly changing world.

The Plato program has called for a unique combination of educational and engineering talents. The program has benefited from cooperation among experts in many disciplines and among educators in universities, community colleges, high schools, and elementary schools. Finally, it has depended in a critical way on cooperation among educational institutions, industrial corporations, and government agencies. These features may be indicative of a new level of interinstitutional relationships which would accompany the incorporation of computer-based systems into the educational process.

References and Notes

1. PLATO, an inventory for Programmed Logic for Automatic Teaching Operation, has served to demonstrate the computer-aided education system concept of the University of Illinois.