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Some Perspectives on Computer-Assisted Instruction

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An increasing number of educators at all levels of instruction are coming to the realization that computer-assisted instruction (CAI), though still in its infancy, is beginning to live up to its potential. Perhaps the best indication of this shift in attitude by school administrators and teachers is the change in emphasis of questions they ask regarding the possible use of CAI in their schools. Instead of asking how they can "get a computer" for their schools, they are asking for specific programs to meet specific needs in their instructional programs. They are coming to recognize that while CAI is not an educational panacea, it can perform certain educational functions effectively and much more efficiently than a regular classroom teacher is capable of doing in those instances.

Perhaps the type of instructional program which has the most appeal for wide-spread application in many subject areas is the drill-and-practice program. In this approach, the CAI program is coordinated with and supplements the on-going classroom instruction. The teacher is responsible for introducing concepts to students in class and scheduling topics for review and practice, which students will work on at instructional terminals Daily reports inform the teacher of each student's performance and progress. Drill-and-practice programs in elementary arithmetic and reading have been in operation for a number of years at Stanford. To date, nearly three-quarters of a million arithmetic lessons from the Stanford drill-and-practice program have been given to students scattered in seven states and the District of Columbia.

Student achievement for each year of the program has been reported in detail elsewhere (Suppes, Jerman, and Brian, 1968, Suppes and Morningstar, 1969 a,b). Without going into detail, let us say here that the arithmetic program has produced significant gains in computational skills wherever it has been used It has been especially beneficial for remediation It has also proved very effective when used with culturally disadvantaged groups

For many school districts, the logical first step in initiating a CAI program is to begin with a drill-and-practice system. Teachers are not threatened by this approach. It helps them do a better job of teaching by providing individualized instruction on basic skills Parents accept the approach readily since its benefits are immediately evident when students bring practice sheets completed at the terminal home for them to see. Also, a drill-and-practice system is the most economical of any CAI system to operate.

Drill-and-practice systems further impact on the home by actually bringing daily instruction into the home by means of a system which uses a touch-tone telephone as the instructional terminal. A program using this approach has been in operation in New York City during the 1968-69 school year Operators call each student at a pre-arranged time each day he is to take a lesson. When the student answers and is identified, the operator pushes a button which starts the lesson Problems are spoken verbally to the student over the telephone receiver The student responds by pressing the keys on the touch-tone telephone. Branching and correction procedures are handled automatically by the computer while the student works. Since the telephone is a very low-cost instrument, this type program has the potential of offering individualized instruction to many students, 2,000 to 3,000, in their homes at a very low monthly rate The digitized audio system used by the computer is capable of handling spelling and reading, as well as arithmetic programs.

A drill-and-practice program in initial reading is now in operation on the Stanford CAI system. Drill-and-practice in initial reading is a general program that can be keyed to any reading series. The program is divided into five strands Each strand provides exercises in an identifiable subskill of the complex task of reading. The strands are (a) letter identification, (b) sight-word vocabulary, (c) phonics, (d) spelling patterns, and (e) vocabulary or word meaning.

The term 'strand' is used in the reading program to define a basic component skill of initial reading Students in the reading program move through each strand in a linear fashion This linear sequencing of items provides a high correlation between student reading activities at the teletype and in the classroom

Entry into each strand is dependent upon a student's performance in earlier strands Once he enters a strand, however, his advancement within that strand is independent of his progress in other strands For example, the letter-identification strand starts with a subset of letters used in the earliest words presented in a particular reading series. When a student reaches a point in the letter-identification strand where he has mastered the set of letters used in the first few words of the reading series, he enters the sight-word recognition strand. Entry into both the phonics and spelling pattern is controlled by the student's placement in

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the sight-word strand. Thus, a student may work in several strands simultaneously.

There are at least two promising directions that the development of drill-and-practice programs can take. The first is a further modification of the concept unit program used at Stanford over the past several years which permits a student to branch from one unit to another in the same concept area at either a higher or lower grade level In this modification, branching to other units at different grade levels is based on pretest scores. As shown in Figure 1, a student who does well on the pretest of a concept at one level is immediately branched to the present of the same concept at a higher level if it exists. This strategy has the effect of increasing individualization by appropriately programming each student through a curriculum at more levels of difficulty while he maintains the basic sequence of topics selected by the teacher In this strategy, the computer reviews automatically each student on the unit for which he achieved the lowest posttest score. The review lessons are noted "r" in Figure 1 The test on the material reviewed is noted "t". On days 2 to 6 of each unit, the student's lessons consist of two parts, a set of problems selected from the unit chosen by the teacher and a review part selected by the computer from the unit that had

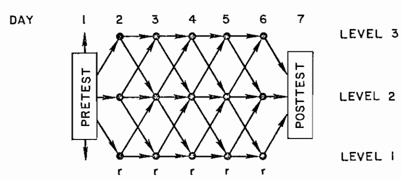

Figure 1

Branching structure of concept blocks in elementary-mathematics program.

the lowest posttest score. The computer also reports to the teacher, on a daily basis, the progress and achievement level of each student. The reports referred to usually are typed out on the teletype terminal in the classroom and are available on call to the teacher.

A second promising direction is one in which the curriculum is organized in a concept-strand method. A strand is a series of problems of the same operational type (e.g., counting and place value, addition, subtraction, fractions) arranged sequentially in equivalence classes according to their relative difficulty covering the entire eight years of elementary-school mathematics and beyond. Table 1 shows the 15 strands in the program. The strands approach provides perhaps the highest degree of individualization to date because (a) each student's lesson is prepared for him daily by the computer, (b) the lessons are presented as mixed drills at a level of difficulty in each concept

TABLE 1

A List of the Strands in the Arithmetic Program

Strand	Description
1	Counting and Place Value
2	Addition, vertical
3	Addition, horizontal
4	Subtraction, vertical
5	Subtraction, horizontal
6	Equations
7	Multiplication, horizontal
8	Multiplication, vertical
9	Fractions
10	Division
11	Large numbers and units of measure, time, money, linear measure, dozen, liquid measure, weight, Roman Numerals, metric measure
12	Decimals
13	Commutative, associative, and distributive laws
14	Negative numbers
15	Problem solving

determined by the student's prior performance in each concept, and (c) the student moves up each strand at his own pace.

Rather than using previously written and stored lessons or problems, we programmed the first 14 strands to include sets of rules for the generation of each class of problems and criteria for the size of the digits involved. For example, a class of problems may be defined as $\frac{abc}{+def}$ with regrouping in the ten's column. This is a simple example, obviously, but it serves to illustrate the point. A program of this type requires extensive background work in sequencing and organizing the curriculum to insure both vertical and horizontal order.

Although a student may be working in several strands simultaneously, he begins each new strand with the class of lowest difficulty or at a grade level determined in advance by standardized achievement test scores. Each day's lesson consists of a distribution of problems from three different difficulty classes in each strand.

A student may work through the material at his individual rate of speed simply by taking more than one lesson each day. He may catch up in the same way following an absence. By adjusting the difficulty level, the poorer student has successful experiences as well as the student of high ability. Further, the immediate reinforcement that the student receives after each response is one of the more positive features of the CAI program.

The choice of strands to which students are assigned rests with the computer-based instruction program. After the initial grade placement at the beginning of the school year, a new strand is added for each student when his average grade-placement score reaches the grade-placement level of the lowest difficulty class of the next strand.

When several strands are being worked on simultaneously, the computer selects problems from each strand for each lesson automatically, and for review and remediation, selects the remainder of the problems for any given lesson from the strand with the lowest grade-placement level. For example, if Figure 2 represents grade

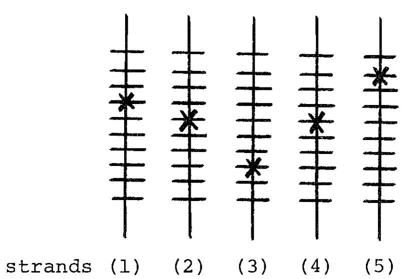

Figure 2
Sample Student Profile.

placement for a student in each strand, the program is so constructed that the student will receive problems from each strand, 1 through 5, and then a review on the strand for which he had the lowest grade placement, in this example, strand 3. In this way, students are assured of an opportunity to advance in each strand and also are given more practice in individual areas of weakness. Reports to teachers consist of a profile showing each student's placement in each strand.

Tutorial CAI programs are generally intended to be self-contained. A number of CAI centers across the nation now have tutorial courses in operation At Stanford, courses in computer programming, logic and algebra, and Russian are now in operation Elementary-school students are taking the logic and algebra program, high school students are learning programming languages, and Stanford students are learning Russian. The results to date show significant gains or improvement when compared to other students in control classes

Types of Programs

There is as yet no "programming science" as writers of the early 1960's sought to establish. Rather, each program is organized around the content to be learned Therefore, each program, whether tutorial or drill-and-practice, must be evaluated in terms of how well it is teaching the subject to the intended population A program that is well-written and known to be effective for one population may not be as effective with another for which it was not designed With this in mind, we wish to review now some areas in which programs are either showing good results or much promise

Problem solving. One kind of problem-solving program which has been run at Stanford (Suppes, Loftus, and Jerman, 1969) emphasizes problem-solving skills of elementary arithmetic to elementary and junior high school students. Using teletype machines as instructional terminals, word problems are typed under computer control to the students. Students respond by giving commands to the computer for each step they wish to take. The computer performs the computation and types out the result The student, freed from the job of calculating with large numbers, enjoys solving problems with numbers much larger than he normally sees. Motivation in this program has been high. For example, a student might solve the following exercise as shown below

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If a track man can run 200
yd. in 20 sec., at that same
rate, how far (in miles)
could he run in two hours?

                    A = 200
                    B = 20
                    C = 2
A / B =             D = 10
D x 60 =            E = 600
E x 60 =            F = 36000
F x 2 =             G = 72000
G / 1760 =          H = 40.9
H :                 Correct
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In this example, the program typed out the problem and the given numbers which it labeled A, B, and C. The student responses at each step are underlined and the calculation made by the computer follows on the same line. Typing a colon indicates the student wishes to have his answer, H, checked for correctness. For this same problem a more advanced student might input the command [({(200/20) x 60} x 60) x 2] / 1760 :. Any sequence of commands is permitted. Evaluation for correctness is made only when the student requests it.

The use of BASIC, FORTRAN, AID, and other languages for problem solving is growing rapidly. Many secondary schools are now participating on a time-share basis with a regional center for this service. The use of the computer to solve problems in areas other than mathematics and science is growing and should continue to expand.

Simulation and gaming: This is an area of great potential, but one that is demanding of the course author. Although the students are actively involved in trying to play the game according to the rules, the game does have an instructional purpose. A student may learn how a corporation operates by playing a marketing game, or he may learn the problems of supply and demand by using games where he is the ruler of a hypothetical country.

Inquiry: Inquiry systems that use films, tapes of lectures, or video tapes of special events are now in operation in centers at Oak Park, Illinois, Beverly Hills, California, and Nova High School in Florida. Up to this time it has been difficult to prepare instructional programs for disciplines such as social studies, psychology, and business. Now, it may soon be possible for students to pursue assigned topic areas or to explore areas of interest by searching, under computer control, a large body of data in computer memory for information by using key words or descriptors.

Another application of an inquiry system is a data bank for project reports from which educational decision-makers could retrieve information on various projects. For example, a school administrator who would like to know how programs in modern mathematics, science, or the new English have fared and under what conditions they were tested could call in, and, by using a keyword system gather data on which to base a decision of whether to try such a program in his own district. As another example, all federally funded projects could be identified by descriptions An administrator, using his telephone, could call the information center, key in or dial appropriate digit codes for each descriptor, and receive the requested information verbally by a system that had digitized audio capability. Such a program should accept several descriptors and report only on projects that contained all the descriptors. The task of setting up a system of this kind would not be too difficult If the articles and documents now being catalogued in the ERIC Centers could be coded and stored in such a center, the cause of educational research surely would be advanced.

Business and industry are beginning to realize the potential of computers for use as retrieval systems for real estate listings, job opportunities *(Datamation,* March , 1969), and selection of colleges for youngsters *(Data Processing Magazine,* 1968). Other applications spread across every facet of our society.

There are certainly many areas in which computers have potential, but probably the greatest is in public school education. But, public school education is hindered by stringent budgetary controls. Unless innovations are federally funded, schools seldom have enough money to conduct a CAI operation on a large scale. Unless the federal government underwrites communications costs, large CAI computer centers capable of serving thousands in a multistate area seem impractical. A large system of this sort seems more likely to be used for information retrieval by subscribers who need make only occasional calls for information rather than lease lines on a 24-hour-a-day basis as required for full CAI use A large system, however, can be efficiently employed in large cities where the population is concentrated in a geographically small area. Large, time-shared systems in this environment offer advantages of efficiency and multiple-program applications.

An alternative would be to place small stand-alone systems in schools and to offer elementary reading, arithmetic, language arts, and timed-shared BASIC or FORTRAN during regular school hours, and then continue with dial-a-drill programs in arithmetic and spelling for students at home during the evening hours If each individual in a potential home audience were charged just $5.75 a month for the service, the revenue would exceed slightly the total operational cost of a system capable of running 16 terminals on arithmetic or 16 terminals on reading in schools during the day. A school district operating and sponsoring such a system would then have the use of the system during the regular school day at no additional cost, and no federal funding would be required. Of course, the school district would have to find enough parents who wished their children to receive lessons at home, and who would be willing to subscribe to the service. In many communities, however, this would not be difficult to do. It also may be possible for a large system to handle enough users to support its program in schools

Whether the computer terminals are trucked to the school (Edwards, 1968) or whether elaborate television-lined instructional systems (Modern Data Systems, 1968) are used, it is clear that everyone expects the application of CAI to expand No doubt, technology will continue to develop, especially in business applications However, in order for public education to take advantage of new developments, systems must cost less or be capable of self-support from user-subscribers or both Those systems that appear to hold the most promise at present are those that can handle a large number of users, remotely if necessary, over regular telephone lines.

No doubt the development of author languages such as PLANIT will continue. We do not expect, however, to see any language developed in the near future that will permit a full dialogue between student and program (Rosenbaum and Bennik, 1969).

Somewhere in the future there has to be a low-cost visual display system. The advantages and disadvantages of different hardware systems have been discussed elsewhere (Jerman, 1969). One must always keep in mind the fact that "it is the program" that makes CAI worthwhile, not the hardware. Appropriate hardware, however, must be available also. Simply having an instructional system with all the "bells and whistles" will not guarantee that students will learn. ■

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