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Computer-Assisted Instruction at Stanford

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In the spring of 1965, the first drill-and-practice program at Stanford became operational with forty-one fourth-grade children who received daily arithmetic drills on a teletype in their classroom. By the end of June 1969, students enrolled in the Stanford drill-and-practice program in seven states and the District of Columbia had received nearly three quarters of a million arithmetic lessons.

Today CAI has greater potential than ever before as educators realize that curricula must be revised and up-dated constantly and that teachers must keep abreast of the new curricula. Further, through the use of CAI, more sophisticated subjects such as logic and algebra or foreign languages such as Russian or Chinese can be available in areas where there exists a shortage of trained teachers. And, increasingly, parents want more, not less, individualization of instruction for their children. We strive constantly for smaller classes so that children may receive personal attention for their problems or difficulties. Of course, none of these objectives can come to fruition if teachers are bogged down with nightly lesson preparation for any number of different subjects or with correcting and grading homework assignments and examinations.

The most practical computer instruction program available today that has application in many subject areas is the drill-and-practice approach. The teacher introduces concepts and gives necessary classroom instruction for a particular subject. The teacher may schedule the sequence of topics for his class and then follow that up by introduction of concepts in classroom instruction. Students then drill and practice on fundamental skills at instructional terminals. Not only is the computer capable of presenting individualized lesson material of appropriate complexity to a number of students simultaneously, it also provides immediate feed-back and correction of mistakes. Additionally, a report on each student's performance is available to the teacher as an aid in evaluating each student's progress. The student receives a print-out of his work that he may review and take home to his parents.

A year's work at each grade level in the 1968–69 edition of the Stanford drill-and-practice program in elementary arithmetic is divided into thirty concept blocks. Each block contains lessons for seven days' work. The lessons are arranged sequentially in blocks by the classroom teacher coordinated with the development of mathematical concepts introduced by standard textbooks. Adapting this program to a particular text usually requires no more than re-ordering the

blocks in the required sequence. Blocks from any grade level may be inserted in the sequence for either rapid or slow learners. It is not unusual for each class to work on a different sequence of blocks.

On the first day of each block, students are given a pretest that identifies their achievement level on each concept. On the following day, based on his pretest performance, the student is assigned automatically one of five lessons, each at a different level of difficulty. The percentage correct is computed automatically for each student after each lesson and on the following day, based on his performance on the previous lesson, the student is given a lesson of greater difficulty, the same difficulty, or of lesser difficulty. A post-test is given on the seventh and last day of each drill block. In Fig. 1, each darkened circle represents a lesson. Level 1 is the most remedial in content and level 5 the most difficult. The average student is expected to work at level 3. Students also receive individual review lessons (noted r in Fig. 1) that are selected from the block in which they had the lowest past post-test score. Each student may be reviewing a different concept, again at one of five levels of difficulty as determined by his post-test score. Following four days of review, the student is given a review test (noted t in Fig. 1). The review test score replaces the previous post-test score and is used to determine whether review lessons will be selected from this concept block in the future. The daily lesson in the regular concept block constitutes approximately 70 per cent of each day's work; the remaining 30 per cent is individual review.

Instruction is individualized by arranging the sequence of concept blocks, adjusting the sequence, selecting blocks from different grade levels for use by a given class, and providing lessons automatically at five levels of difficulty for each student. Immediate reinforcement after each response increases motivation and interest for the student. Students may set their own pace—if they wish they may complete more than one lesson a day. Make-up lessons after an absence also may be handled by accelerating the number of lessons. On the other hand, poor students also experience success because the difficulty level can be adjusted to their individual needs, and they are not forced to work at a level at which they are not capable.

The effectiveness of the 1967–68 drill-and-practice program was evaluated by giving both experimental and control classes in twelve different schools in Mississippi the arithmetic portion of the Stanford Achievement Test (SAT). The tests were administered in October and again in May

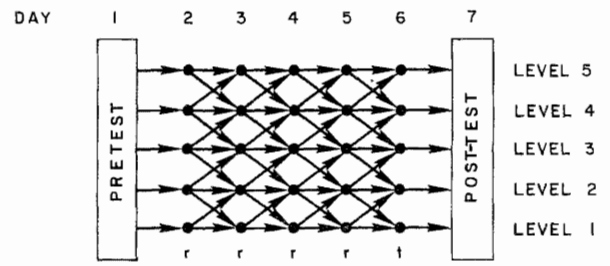

Fig. 1. Diagram of branching structure followed in constructing sets of exercises for concept blocks

to students in grades 2–6. The tests were given in February and May to students in grade 1. Eight of these schools included both experimental and control students, three included only experimental students, and one included only control students. Within the experimental group, from one to ten classes were tested at each grade level; within the control group, from two to six classes were tested at each grade level.

The difference in grade placement between the pretest and post-test on the computation section of the SAT was used to measure learning for the school year. The difference in learning between the experimental students and the control students was then examined for each grade level. The average change in grade placement for each grade for each of the two groups and the results of statistical t-tests follow in Table 1.

Table 1. Post-test–Pretest

Grade	Experimental	Control	t	df
1	1·14	·26	3·69*	112
2	1·42	·84	5·23*	77
3	2·03	1·26	4·64*	76
4	1·10	·69	2·63*	131
5	1·37	·90	3·43*	215
6	1·72	1·13	5·18*	433

* $p < ·01$.

The values shown indicate that the chances of there being no significant difference in the achievement of the two groups at each grade level are less than 1 in 100. The difference between the experimental group and the control group was largest in grade 1, where average increase in grade placement for experimental students was 1·14 (1 year and 1·4 months) as compared to ·26 (2·6 months) for the control students. Differences were significant at all six grade levels. All in all, the classical statistical evaluation of the drill-and-practice program indicates that the program was successful.

Another drill-and-practice system now available is a touch-tone telephone that is used as an instruc-

tional terminal. This system has been in operation in New York City during the 1968–69 school year. Operators call each student at home each day he is to take a lesson at his prearranged time. When the student answers the telephone and identifies himself, the operator pushes a button to start the lesson. Problems are presented verbally to the student over the telephone receiver. The student responds by pressing the keys on the telephone as required. Lessons are generated individually for each student at the appropriate level of difficulty. Branching and correcting take place automatically via the computer as the student works. This type of digitized audio system has the potential of offering individualized instruction to as many as 2000–3000 students in their homes at a low monthly cost. By expanding the system, spelling and reading, as well as mathematics, could be available.

Broadcasting instruction to many students simultaneously by radio-satellite communications networks is the newest area of technological development in the field of CAI. Students in school or at home soon may be able to participate in programmed courses in various curriculum areas. The advantage of such a system is that courses developed and tested at a central computer-assisted instructional facility could be available to large numbers of users at a low cost. Thus, for the first time, students in remote or undeveloped areas could have access to the same well-prepared and well-taught courses as the urban student.

A further innovation in the drill-and-practice approach is the strand program. To date this program has been used for elementary and secondary mathematics and initial reading. The strands approach probably achieves a high degree of individualization because (a) the student's lesson is prepared for him daily by the computer; (b) the lessons are presented as mixed drills or exercises at a level of difficulty in each strand determined by the student's prior performance in each concept; (c) the student moves up each strand at his own pace; (d) remedial help is provided as needed; (e) immediate reinforcement takes place after each response; and (f) each teacher is given a report of each student's progress and achievement. For both subjects the programs are general enough so that they can be adapted to standard textbooks.

Mathematics

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. In the Stanford program, the area of mathematics consists of the fifteen strands listed in Table 2. The student 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 classes in each strand. Approximately one-third of each lesson contains problems from the student's grade level class, the second third is selected from the next higher class, and the last third from the next lower class for review. In other words, the lesson contains problems from the class just below the student's grade level, problems at grade level, and problems from the next higher grade level. Branching decisions are made on the basis of the student's performance on each set of six to twelve problems in each strand. The exact criterion varies across strands and grade level. The decision as to which strands are assigned to students rests with the computer program. After the initial grade placement at the beginning of the school year, problems from a new strand are added to each student's daily lesson when his average grade placement score reaches the grade placement level of the lowest difficulty class of that strand. When the student works on several strands simultaneously, the computer selects problems from each strand for each lesson automatically. For review and remediation, the computer selects the remainder of the problems

Table 2. A list of the strands in the Stanford Arithmetic Program

Strand	Description
1	Counting and place value
2	Vertical addition
3	Horizontal addition
4	Vertical subtraction
5	Horizontal subtraction
6	Equations
7	Horizontal multiplication
8	Vertical multiplication
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	CAD laws*
14	Negative numbers
15	Problem-solving

* Commutative, Associative, and Distributive laws.

for any given lesson from the strand with the lowest grade placement level. For example, the program is so constructed that the student receives problems from each strand 1–5 and then receives a review on the strand for which he had the lowest grade placement. In this way students advance in each strand and also drill in individual areas of weakness.

Again, as in the concept drill-and-practice program, the student may work at his own individual pace by spending more time at the terminal each day. His individual performance determines the rate at which he progresses through the course material. By adjusting the lesson difficulty, the poorer student especially can have a sense of acomplishment and success.

Reading

Here the term 'strand' defines a basic component skill of initial reading. The reading program is divided into five strands that provide exercises in an identifiable subskill. The strands are (a) letter identification; (b) sight–word vocabulary; (c) phonics; (d) spelling patterns; and (e) vocabulary or word meaning. Students move through each strand in a linear fashion. This linear sequencing of items provides a high correlation between student reading activities at the instructional terminal and in the classroom. As in the mathematics strands, entry into each strand is dependent upon a student's performance in earlier strands. Once he has entered a strand, however, 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 the place 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 patterns is controlled by the student's placement in the sight–word strand. Thus, a student may work in more than one strand at a time. Branching, remediation, and review generally follow the same patterns as the mathematics strand program.

The average student spends from two to five minutes on an exercise, although the slow student may take much longer and the fast student may take less time. The time each student spends on an exercise is decided by his teacher and may be varied as necessary. The teacher receives a complete status report for an entire class in all strands, an entire class in a particular strand, an individual student in a particular strand, or an individual student in all strands. In this way the teacher can follow the progress of each individual student.

The Russian language program

In September 1967, a computer-based Russian language program designed to teach first- and second-year courses at the college level was initiated. The program included comprehension of written Russian, comprehension of spoken Russian, and mastery of grammar and syntax. Regular college-level language courses usually incorporate daily classroom sessions, language laboratory sessions, and homework assignments. In our project, only the functions of the classroom sessions were assumed by the computer program; students did spend time in the language laboratory and were assigned homework. Language laboratory tapes with drill sheets and homework assignments were prepared by the Institute staff. Approximately 130 lessons, including those for review, were available for a year's work. The students worked at the console for about forty-five minutes, five days a week. The homework involved translating English sentences into Russian, while the study sheets dealt with new grammar and new vocabulary pertinent to the day's lesson. To develop speech and the ability to write correctly what was heard, the students occasionally were given an option at the conclusion of a teletype lesson to take dictation or to practice pronunciation. These exercises were recorded at the end of the tape used as the audio portion of the regular teletype lessons. Once every two weeks students took written quizzes or read from handwritten or typed scripts. Their pronunciation was corrected and suggestions were made for improvement.

A language course is especially adaptable to computer-based instruction. The time a student spends at the console is an intensive instruction period since the program is prepared just for him. Students find that they cannot let their attention wander nor can they lapse into an internal English monologue as they often do in a classroom.

Tutorial CAI programs generally are intended to be self-contained. A number of CAI centres across the United States has tutorial courses in operation. At Stanford, the courses in computer programming, logic and algebra, and Russian are all tutorial. 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 students enrolled in regular classes.