TOMORROW'S EDUCATION?

COMPUTER-BASED INSTRUCTION IN THE ELEMENTARY SCHOOL

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In recent years modern computer technology has made possible many exciting and significant developments in education. A Computer-based Laboratory for Learning and Teaching was established at Stanford University, Stanford, California, in 1964, to provide an environment for study and further development of new educational techniques and materials.

The laboratory has a dual focus on pedagogical projects and work in experimental psychology. A variety of computer-controlled teaching is carried on in the laboratory and in schools near to Stanford. These projects provide data which are extremely useful in guiding applications of computer technology to programmed instruction and teaching machines. In addition, the laboratory is used for other experimental work in learning theory.

The laboratory is under the direction of an Executive Committee.
Dr. Patrick Suppes has been Director of the Institute for Mathematical Studies in the Social Sciences, Stanford University, since 1959. Chairman of the Department of Philosophy at Stanford since 1963, Dr. Suppes holds a B.S. from the University of Chicago and a Ph.D. from Columbia University. He is a member of the National Academy of Education and a recent recipient of Columbia's Nicholas Murray Butler Medal in Silver. Dr. Suppes has published a vast amount of material in connection with his experience in computer-based instruction.

INSTRUCTION IN THE ELEMENTARY SCHOOL

VENTURA HALL, left, was originally a residence for faculty, and in 1961, became the home of the Institute for Mathematical Studies in the Social Sciences.

A BANK OF TELETYPES in the laboratory at Stanford is shown above. These machines are connected to the PDP-1 shown behind the teletypes. They can be used to observe the teletype operator at Grant School, since the print-outs obtained at the school can be simultaneously obtained on these machines.

THIS DISPLAY DEVICE, top right, designed by Philco Corp., has 1024 possible positions on both the horizontal and vertical axes. In addition to individual points, there are 128 prearranged characters which can be displayed in five sizes. Vectors may also be displayed. A typewriter keyboard is attached to the scope so that students can send information into the computer.

SHOWN HERE, at the right, are the control units for the IBM devices. In the foreground is part of the audio system, which can play pre-recorded messages in the student booth. The audio system includes two tape transports, each of which has a capacity of 17 minutes.
composed of Richard C. Atkinson, William K. Estes, and Patrick Suppes. The various research projects are supported by the National Science Foundation (Course Content Improvement Section), the U. S. Office of Education, and the Carnegie Corporation of New York.

**Laboratory Equipment**

The instructional system in the laboratory consists of a medium-sized computer and six subject stations. There are two visual display devices in each student booth. The first is a random-access projection device developed for the laboratory by IBM Corporation. It presents microfilmed source material on a 10 inch by 13 inch ground glass screen. The equivalent of a 512-page book (8 1/2 inch by 11 inch standard page) may be encoded on microfilm and any one-eighth of a page may be reached under random access within one second. The student may respond to the display by using a light pen on the face of the screen itself. As the pen is touched to the screen, the coordinates of that position are sent to the computer and may be compared with any prearranged areas of the screen. The accuracy of the light pen will permit the identification of a 1/4 inch square on the screen.

The second display device, developed for the laboratory by the Philco Corporation, is a cathode-ray tube, commonly called a “scope”. It can display points of light in an area 10 inches high by 10 inches wide. There are 1024 possible positions on both the horizontal and vertical axes. In addition to individual points, there are 120 prearranged characters which may be displayed in five different sizes. It is also possible to display vectors by simply identifying the end points. A typewriter keyboard is attached to the scope and may be used to send information from the student to the computer.

An audio system designed by Westinghouse Corporation can play pre-recorded messages to the user, through individual speakers in each student booth. The messages are recorded on magnetic tape 6 inches wide; two tape transports may be assigned to each of the six student stations. Each transport has a capacity of about 17 minutes, which can be divided into any combination, from one message 17 minutes in length to 1020 messages of one second each. The random-access time to any stored message is approximately one second.

The main memories of the central computer, a PDP-1 designed by Digital Equipment Corporation, are a 16,000-word core, and a 4,000-word core which can be interchanged with any of 32 bands of a magnetic drum. Additional backup in computational power, additional storage, and increased input-output
speed is obtained through connections to a larger computer system with magnetic tape and disk storage, located at the Stanford Computation Center.

**Computer-based Instructional Systems**

One of the most exciting aspects of computer-based education is the opportunity it offers for tailoring instruction to the individual child's needs. An individualized approach is possible at various levels of instruction. There are at least three levels of interaction between student and computer program, though the third and deepest level is still mostly beyond us from a technical standpoint. Each of these levels is called a system.

**Drill and Practice Systems**

In the drill and practice system, instruction is strictly supplementary to the regular curriculum as taught by a teacher. The individualized approach can be illustrated in two programs currently in operation at Stanford. The first gives the student practice in the algorithmic skills of arithmetic. In the program now running in the Stanford area for grades 4, 5, and 6, there are five levels of difficulty at each grade level and on each concept in elementary-school instruction. At the present, students begin at level three, and then are moved up and down daily on the basis of the previous day's performance. Thus, unlike drills in a traditional teaching situation, problems are selected to suit individual needs.

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**THE MAIN CONTROL**

The main functions of the entire laboratory system are handled by the medium size computer, PDP-1, shown far left. The main memories are a 16,000 word core and a 4,000 word core which can be interchanged with any of 32 bands of a magnetic drum. Dow Brian, Chief Computer Programmer, is pictured loading lessons for an experimental program in logic.

**BOTTOM LEFT**

Is a view of the random access projection visual display device, utilizing the light pen, which is used to give computer-based lesson material to students. The equivalent of a 512-page book can be encoded on microfilm and any quarter of a page can be reached under random access in one second through this machine. The units were designed for the laboratory by the IBM Corporation.

**STAFF MEMBER MAX JERMAN**, left, reads a stack of programmed materials for the project, materials which make possible a break from traditional teaching methods. Because significant differences in individual rates of learning exist, this text material is geared to accommodate these differences.

**DR. SUPPES DISCUSSED ASPECTS**

Of the program with two Stanford Computer-based Laboratory staff members, Research Assistant Diana Axelsen, left, and Research Associate Luanne Berkowitz, center.

**A CHART AT THE CENTER**

Keeps researchers and assistants up to date on the development of arithmetic drills for presentation to fourth, fifth and sixth grade students.
The second program provides daily practice in the spelling of words drawn from the California Spelling Series. These word lists are regrouped into lesson sequences that illuminate a consistent or regular sound-to-letter relationship. Complexities such as morphophonemic shifts or stress patterns in polysyllabic words are utilized to increase the level of difficulty. Each child has the opportunity of working on one of three levels of lesson difficulty depending on his previous day’s performance.

**Tutorial Systems**

In systems of this type, the aim is to provide, not a supplementary, but a nearly complete instructional sequence in a given subject. The skill subjects such as reading, mathematics, and elementary foreign languages are most easily handled in this kind of environment. Extensive work at this level is being done at Stanford in elementary mathematics, including mathematical logic. The instructional material is based primarily on textbooks in the *Sets and Numbers* series by Patrick Suppes. The logic program, which is one of the best developed at Stanford, introduces the student to rules of logical inference. The student is permitted to make any valid inference, and the main function of the tutorial program is to evaluate the validity of the inference he makes. When students do not successfully find a proof, then the tutorial program provides hints about how to find a solution.

Work with students was begun in the fall of 1964. Twelve first graders worked in the *Sets and Numbers* material all year; two kindergarten students also took part during the spring of 1965. Also during the spring, work in mathematical logic was conducted in the laboratory for 26 gifted students. Each morning for four weeks, three groups of children spent one-half hour in the terminal booths and one-half hour in the laboratory classroom. A program in mathematical logic was presented in the terminal booths on the Philco scopes, while a special geometry program was conducted in the classroom. They were also given arithmetic drills on the scopes.

A computer-based instructional program of this type is also being developed at Stanford in reading. The reading materials are intended to assess the relative effects of learning variables such as stimulus similarities, presentation rates, verbal mediators, and scheduled models of reinforcement, along with linguistic variables such as the meaningfulness and redundancy of new morphemes, the patterning of grapheme-to-phoneme correspondence and the syntactic complexity of sentences. Utilizing these psycholinguistic variables, an extensive number of reading lessons have been prepared. During the spring of 1965, the first portion of these reading materials was presented to twelve kindergarten children for evaluation purposes.

**The Sequence on Pages 9 and 10**

shows one session of a special experimental program in which four third-graders participated at the Stanford Center. The four, part of a group of 26 gifted students involved in a long-range accelerated program in elementary mathematics last summer, worked through a program in mathematical logic on the cathode ray tube display device. The youngsters learned to symbolize English sentences and do simple derivations and they were introduced to some of the vocabulary of logic. Here, Dr. Patrick Suppes works with one of the youngsters to see how she handles one of the more complex math logic problems she worked with during the summer. In the special session, a study was made of how quickly students could learn to erase and correct work as a prelude toward working more complex derivations later. That she is successful after working through the number of derivative steps necessary to develop the final proof is evidenced in the pleasure Dr. Suppes displays in the last frames.
Diadogue Systems

The dialogue system is envisaged as a system in which a dialogue is possible between the student and the program. Successful developments in any depth, however, require the solution of some relatively difficult technical problems.

The two central problems may be described by beginning at the college level and working down to the elementary-school level. Suppose that in a program on American history, the student types in the question ‘Why did Booth kill Lincoln?’ or a more complicated question such as, ‘What was the role of the railroad in the economic development of the Mississippi Basin in the 19th Century?’ It is as yet a very difficult problem to write programs that will recognize and provide answers to such freely constructed questions of broad generality and considerable complexity. The situation is by no means hopeless, however. In curriculum areas that have been taught for a considerable time and that have a reasonably sharp focus of subject matter, it is possible to provide a fairly thorough analysis of the types of questions that will be asked. In these subject areas, we can make considerable progress toward the recognition of the question by the computer program. The central intellectual problem at the moment is not that of writing information to give an answer, that is, of having in storage information that will give an answer to any question. Rather, it is to recognize from the standpoint of the program precisely what question has been asked.

The second sort of problem arises in working with elementary-school children for whom it is essential that we be able to recognize their spoken language. It is certainly not reasonable to expect a child in the first year of schooling to be able to input a question on a typewriter. However, he certainly can ask or answer a question in a fairly complex way if his spoken speech can be recognized by a computer program. The problem of speech recognition simply adds another dimension to the problem of recognition of sentence meaning. There is reason to hope that within the next five or six years much progress will be made on the problem of speech recognition. If it can be solved, then in many respects the problem of the elementary school is easier than that of higher grades; for, the types of questions and answers that occur are considerably simpler than are those that may be expected at the secondary or college level.

Computer-based Instruction in the Future

In the first place it is reasonable to conjecture that in a matter of a few years we can bring the skill subjects under computer control in a deep and organized way and can present them to students in an effective and efficient manner, and with a degree of individualization that is impossible in ordinary classroom learning. The skill subjects that would be particularly important are two that have already been mentioned, reading and mathematics, and the teaching of foreign language. There is not space in this article to discuss future prospects for the teaching
SIXTH GRADERS AT GRANT SCHOOL go about their regular classroom work unmindful of the young lady spending her daily session in the teletype booth at the front of the room. Each of the youngsters spends about five minutes of his day working on a drill of one of five levels of difficulty.

WORKING AT A TELETYPE KEYBOARD, this sixth grader punches out the answer to a problem sent from Stanford. Three teletypes are in operation at Grant Elementary School in Cupertino, for arithmetic drills in the fourth, fifth and sixth grade. As the child works through each drill, his elapsed time, correct and incorrect answers, percentage of problems correct to date, and total time in the program will be recorded.

of foreign language in computer-controlled environments, but the kinds of possibilities that exist should be evident. Perhaps the most important thing is the possibility of asking students continually to make overt responses and not simply to be passive listeners, as they are in present language laboratories.

In assessing the future of computer-based instruction, it is also important to emphasize the impact that computer-assisted instruction can have on the mastery of skills because of the exact and delicate control of the relevant learning variables. Of particular importance is the control of timing variables. For example in mastery of the elementary skills of mathematics, of reading or of foreign language, insistence on performance with greater and greater speed is essential. Accurate timing and pacing of such activities is extraordinarily difficult in ordinary classroom work, but a straightforward matter at a computer-based terminal.

The spread of computer-assisted instruction will not lead to a reduction of teachers but to a substantial increase in the quality of education. Teachers will learn to use computer-based terminals the way in which they now use good textbooks. Essentially all teachers now regard textbooks as an essential part of their teaching program. It would be my own forecast that the same will be true of computer-based teaching terminals in the future.