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A workshop on computer-assisted instruction in elementary mathematics

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As director of the Institute for Mathematical Studies in the Social Sciences at Stanford University, Professor Patrick Suppes is mainly concerned with computer-assisted instruction in mathematics. He has directed Institute activities in this field since 1963.

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During the 1967/68 school year the Stanford project in computer-assisted instruction in elementary mathematics was expanded to include schools in Iowa, Kentucky, and Mississippi, in addition to schools in California. As many as 78 students were able to take arithmetic lessons simultaneously on instructional terminals operated by phone line from the computer of Stanford's Institute for Mathematical Studies in the Social Sciences. The instructional terminals (teletype machines with modified keyboards) were located one to a classroom in some schools and grouped in a single room in other schools. Before describing the workshop held at Stanford for Mississippi teachers, a brief description of the drill-and-practice program in arithmetic skills and concepts will be given.

The drill-and-practice program.—The goal of this program is to provide individualized instruction (review and practice) that supplements the teacher's instruction, and to provide the teacher with a daily report on each student's progress. In 1967/68, the 3,820 students in 24 project schools took more than 280,000 lessons, tests, and reviews on instructional terminals. This represents a considerable expansion of our first effort in the spring of 1965 (see THE ARITHMETIC TEACHER, April 1966) when the program began with a total of 41 children and one teacher. Daily reports of each student's performance and average percent correct to date were given to the 93 teachers of project classes. The reports are typed overnight on the instructional terminals so as to be available to the teacher each morning.

The content of the year's work at each grade level (1–6) was divided into 24 concept blocks. Each block contained lessons for seven days' work. The lessons were originally arranged sequentially in blocks to coordinate with the development of mathematical concepts as introduced by popular text series.

The first day's lesson of each block was a pretest. This served to identify the level of achievement for each student on each concept. According to his pretest performance, a student was automatically assigned one of five lessons, each of a different degree of difficulty, the following day. Following each lesson, the student's performance was automatically computed in terms of percent correct. The student was then given a lesson of greater difficulty, the same difficulty, or of less difficulty the following day. The level of difficulty of the lesson assigned each student was a function of his own performance on the previous lesson. A posttest constituted the seventh and last day of each drill block. A diagram of the branching structure of each block is presented in Figure 1. Each darkened circle represents a lesson. Level 1 was most remedial in nature, and level 5 most difficult. The average student was expected to work at level 3.

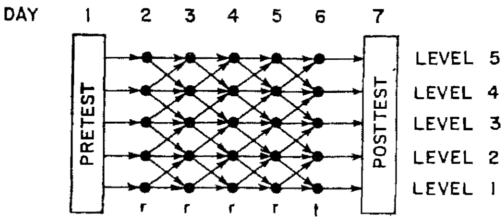

FIG. 1.—Diagram of branching structure followed in constructing sets of exercises for concept blocks.

Essentially, students were being tested (pretest) on each concept, such as addition, subtraction, etc., and, based on individual scores, assigned to one of five math groups, each working at a different level of difficulty. Following each lesson, the students were reassigned to appropriate difficulty-level groups automatically, by the computer. In addition, students were given individual review lessons (noted *r* in Figure 1) selected from the block on which the student had the lowest posttest score. Each student could be reviewing a different concept, again at one of five levels of difficulty as determined by his posttest score. Following four days of review, the student was given a review test (noted *t* in Figure 1). The review-test score replaced the previous posttest score and was used to determine whether review lessons would be selected from the same concept block in the future. The daily lesson in the regular concept block constituted approximately 70 percent of each day's work, and the remaining 30 percent was individual review. This schedule assured that each student was periodically reviewing his weakest area throughout the year. Structuring lessons and reviews in this manner required the preparation of a minimum of 2,664 lessons, tests, and reviews per grade level.

Students averaged from four to ten minutes on drills each day. Drills included verbal problems as well as most other types of exercises commonly found in popular texts. There was a large number of mixed drills in which exercises were presented a variety of ways. Responses were reinforced immediately.

Under computer control each problem was completely typed out, including a blank for the response. The typewheel of the teletype was positioned at the blank so that the response was properly placed. A correct response was reinforced by the appearance of the next exercise. When a first response was incorrect, the words "No, try again" were typed out and the exercise itself was retyped. A second error on the same exercise was followed by the message "No, the answer is —" and the correct answer was displayed. The exercise itself was then retyped once more to allow for a correct response. An error on the correction response caused the correct answer to be given again, but whether the third response was correct or incorrect, the next exercise was presented.

If a response was not given within a predetermined interval of time, usually ten or fifteen seconds, the machine response followed the above pattern except that the words "Time is up" were substituted for the words "No, try again" at each step described above.

The Mississippi Workshop Project

Nineteen teachers and supervisors from Mississippi and one teacher from Kentucky participated in the four-week workshop, offered for credit as "Education 244—Computer-assisted Instruction in the Elementary Schools," during the summer of 1967.

The instructional day (8:45 A.M.–3:15 P.M.) was divided into four working sessions:

Curriculum seminar
Mathematics class
Practicum
Problem session

Curriculum seminar.—The curriculum seminar emphasized the planning and preparation of behavioral objectives by each teacher, for the class he expected to have in the fall. The text, *Preparing Objectives for Programmed Instruction,* by Robert F. Mager, served as a guide for preparing objectives. The first week's assignment was to prepare a set of behavioral objectives for each concept for the end-of-school-year performance. That is, teachers specified the terminal behavior, important conditions under which the behavior was expected to occur, and criteria for acceptable performance for each concept.

Specifying terminal behavior meant that each teacher was required to define, in writing, what a typical student was to do to indicate he had achieved an objective. Exercises typical of each concept were constructed. The level of difficulty and complexity of each exercise was determined by teachers, based on their knowledge of the abilities of the children expected in the fall.

Descriptions of the important conditions under which students were expected to perform included such things as specifying whether exercises were to be copied from other sources or provided on ditto or printed forms. If students were to consult tables or graphs, or if other external aids were required, these were listed as being part of the conditions. For younger children, if concrete objects were to be manipulated or if students were to perform without access to external devices or aids, these specifications were included.

The point of greatest divergence in thinking about the objectives centered on the specification of criteria of acceptable behavior. There appeared to be no general consensus as to what constituted acceptable performance at any given grade level. In some cases, teachers from the same school did plan together to establish a somewhat standardized list of objectives for given grade levels and also to coordinate, sequentially, objectives for successive grades. Preparing behavioral objectives was a new experience for nearly all the teachers. At first the task of preparing a list of objectives appeared trivial, but as the teachers began to grasp the meaning of the term "behavioral," serious planning in depth took place. Each teacher was asked to bring with him to the workshop the text he would use in the fall. Plans and objectives formulated by the teachers were influenced by the text more in the first few days than at any other time. As teachers progressed through the daily mathematics classes and problem sessions, they became less restricted by the particular text and more independent in formulating objectives in terms of the mathematics they wanted to teach their particular students.

The next step, once the end-of-year objectives had been specified, was to prepare a graduated list of objectives for each grading period throughout the year. Then, when objectives for each grading period were clearly defined, teachers began to study the drill-and-practice lessons and select a sequence of concept blocks to supplement their instruction. Teachers were free to select any block from any grade level in Stanford's program and sequence them in the order desired. By the end of the workshop, each teacher had defined, in writing, objectives for each grading period, prepared a short sample test that reflected the objectives for that period, and selected concept blocks that emphasized the concepts they planned to teach throughout the year. Actual experience at instructional terminals was provided in the daily practicum. This provided an opportunity for each teacher to work through the lessons he had selected for his students for the coming year and to make whatever adjustments were needed.

Mathematics class.—The mathematics class and afternoon problem session were held daily. The text was SMSG's *A Brief Course in Mathematics for Elementary School Teachers.* Primary grade teachers were also given SMSG's *Inservice Course in Mathematics for Primary School Teachers,* as a supplementary text. Intermediate grade and junior high school teachers were given the SMSG text, *A Brief Course in Mathematics for Junior High School Teachers.*

Daily homework assignments were given. Tests were given at the end of each week on the course content covered. In addition, different forms of the Stanford Achievement Test, Advanced Battery, were given as pretest and posttest to provide the staff with some idea of the level of performance in arithmetic skills of the teachers involved. A mean gain of one year in grade placement in the three mathematics sections of the test—computation, concepts, and applications—was achieved during the four-week workshop. However, several of the teachers were at the top of the scale on both pretest and posttest.

In nearly every case, the teachers had some previous experience with "modern math," either by in-service or summer course work. They were familiar with much of the vocabulary and could handle with ease simple applications of such things as the associative law when presented in the form $(a + b) + c = a + (b + c)$. That is, they could recognize the above as a statement of the associative law and supply missing parts when it was formulated as a completion problem. However, a large percentage of the teachers could not apply and often could not recognize the basic principles, such as the laws of arithmetic, when presented in another form. For example, many teachers added or subtracted to solve examples like $(115 + 87) + 973 = \_\_ + (87 + 973)$, while they quickly solved exercises of the form $(a + b) + c = \_\_ + (b + c)$.

Most teachers seem to have considered such things as the laws of arithmetic and sets as separate topics rather than unifying ideas. All this is being mentioned here not to cast reflection on Mississippi teachers, for we have been painfully aware of identical problems in nearly every project school, but rather to point out the direction followed in the mathematics class. That is, the aim of the math class was to help teachers develop a clearer understanding and therefore become better teachers of mathematics regardless of whether or not they taught one of the newer programs.

Practicum.—In the daily practicum, teachers spent at least an hour at teletype terminals as students. The first objective was to have them work through the material for the grade level they taught. Following completion of a grade level, they sampled lessons from different grade levels and concept blocks to familiarize themselves thoroughly with every type of problem format.

Twenty teletype terminals were installed in a specially prepared classroom. All participants were able to work on terminals simultaneously during the hour.

Daily reports of the teacher's previous day's progress were distributed and discussed in terms of understanding and interpreting the statistics furnished. Other concept-block reports were also prepared and discussed.

Teachers were required to change the ribbons on the teletype several times during the workshop and to replace the paper roll when needed and often when not needed. Many days the machines were disabled in minor ways such as being unplugged, turned off, ribbons partially off, paper release loosened, and paper jammed in the works of the teletype so that it would not operate properly. Teachers soon gained confidence in their own ability to handle any minor problems that might arise in normal, daily operation in the classroom.

Follow-up.—The Mississippi branch of the Stanford project has been one of the smoothest, operationally, throughout the school year. Teacher, student, and parental attitudes are very positive on follow-up questionnaires now being returned. They report looking forward to an expansion to 60 teletype terminals from this year's 20.

Concerning their experiences in the classroom in relation to the workshop, 75 percent of the teachers who have responded to the follow-up questionnaire chose "planning objectives" as the most important part of the workshop and the part which should be given more emphasis in later workshops. More than 90 percent of the teachers reported that planning objectives had carried over to other subject areas as well.

Other areas which teachers felt needed more emphasis in a workshop of this kind were mathematics, organizational problems in the classroom, and hardware problems.

Actual experience on student terminals was considered an important aspect of the workshop by all of the teachers. However, teachers preferred to spend more time sampling different lessons than working through at a single grade level, and more time learning how to fix minor problems with the terminals themselves.

A critical point has been that of helping the teacher make use of the daily reports on individual students, and of other reports furnished by the program. During the curriculum seminars, the reports were gone over in careful detail so teachers would be completely familiar with the kind of information being furnished and how to take advantage of the information to improve their own instruction. The teacher is in every sense the key person in a program such as the one described here. The workshop stressed that the teacher should not delegate the role of instruction in fundamental skills to the computer. It was emphasized that the teacher, as a professional, should assume more responsibility for each individual's progress, since more information is available on a daily basis concerning each student's strengths and weaknesses.

References

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