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Computer-Managed Instruction

The use of computers as a teacher's aid may entirely revolutionize the field of education.

Harvey J. Brudner

During the 20 years since the first commercial electronic data processing machines went into production, computers have become smaller, less expensive per unit computation, significantly faster, and have been given vast memories. Over 50,000 have been installed in the United States; however, even though almost 8 percent of our gross national product is in some way related to education and training, a much smaller percentage of the nation's computer power is involved with education. Computers are used most for record keeping, scheduling, payroll, and other administrative tasks. Part of the reason for the lag relates to how much information can be economically stored in and retrieved from a computer.

The state of the art of computer-assisted instruction has been comprehensively reviewed by Atkinson and Wilson (*1*). An economic assessment of computer-assisted instruction (*2*), based on over 2 years of analysis, indicates that annual costs are now about $400 per student for the drill and practice mode, and about $1000 per student for the tutorial mode. Furthermore, if computer-assisted instruction were extended throughout the nation's public school systems, the annual costs could range from $9 billion to $24 billion.

With the total annual public school expenditure in the United States at about $30 billion, or some $600 per student, other approaches should be

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considered for the near future. For example, Randall and Blaschke (*3*) concluded that over the last 3 or 4 years computer-assisted instruction has received at least five times more attention than computer-managed instruction, and that the latter deserves more emphasis at this time.

Expenditures for research, development, and evaluation represent much less than 1 percent of the total investment in education (*2*). It is critically important to spend more money on research and development in education, and to spend it wisely.

Considerable money and effort have gone into the development of the "computer-tutor," and much less into the development of a "computerized man-Friday" to assist the teacher. Ten years ago, the joint Educational Policies Commission of the National Education Association and American Association of School Administrators pointed out that there is still not even a blueprint of a master teaching machine, and that certain kinds of devices are more effective than others in teaching certain subject matter under certain conditions (*4*). The implication might be to try to develop a highly flexible master teaching system—not a master machine.

Computer-managed instruction is beginning to emerge as an important, new "total systems approach" to education. This approach is flexible, and it provides the teacher with the benefits of individualized instruction, classroom psychology, electronic and audio-visual devices, and a nonrigid or adaptive curriculum.

Systems for Computerized Instruction

There are two types of systems for computerized instruction. In computer-assisted instruction, the student participates with the computer system on a direct basis, and the instructional materials are stored in the computer system. A still viable and prominent example of this type of system is Project PLATO at the University of Illinois (*5*) which was founded almost 10 years ago (*1*).

The second type of system, computer-managed instruction, uses the computer to help the teacher to administer and guide the instructional process, but relies on separate hardware and learning materials; the student is usually not on line with the computer system, and the processing need not be in real time. Instructional materials are not stored in the computer system. Systems of this type are being developed by the System Development Corporation (*6*), the New York Institute of Technology (*7*), and the American Institutes for Research working with the Westinghouse Learning Corporation (Project PLAN) (*8*). Probably the most fully developed concept of a total system of this type has been formulated by Flanagan (*9*).

The former U.S. Associate Commissioner of Education for Research R. Louis Bright points out that since its costs are decreasing, the field of computerized education is becoming more competitive. Today, it costs about 35¢ per student hour to operate a typical elementary school classroom. The use of computer-managed instruction would increase effectiveness greatly while increasing cost relatively little. Bright predicts that in the next 10 years the majority of elementary schools will have individualized education (*10*), and that computerization will spread to secondary schools and junior colleges in less than 20 years. Bright sees the computer as a liberator of the teacher, allowing him to observe students' progress more closely, and then minister to their needs.

Individualized Instruction

Professional educators have been seeking to adapt group instruction so that all students reach satisfactory achievement levels in reasonable periods of time even though they move at different rates in individualized programs. However, methods and materials used to teach groups often fail to achieve that purpose in both research and classroom practice. Questions are encountered in many areas . . . How fast and how well is the learner progressing? Why is the child progressing or not progressing? What methods should be used to adapt teaching to the individual needs? Should there be branching instruction, parallel sets of materials, feedback techniques, grouping techniques, diagnostic or pretesting and remedial instruction after analysis?

There are several reasons for regarding self-directed learning techniques as an underlying theme for educational reform. In the first place, a primary educational goal is to prepare the individual to solve problems independently and to respond to situations which he encounters as student, worker, family leader, community member, or private citizen. Also, self-direction enables a person to live in accordance with his preferences and goals. Another important reason for viewing self-directed learning techniques as a prerequisite for educational reform is that effective instruction should suit the characteristics of each individual learner. Since there is a relatively high student-to-teacher ratio in most educational settings, individualized instruction cannot become a reality until the average student can conduct much of his learning independently, with appropriate guidance.

Self-directed learning can be increased by the use of programmed instructional materials which guide the student, step by step, through a learning sequence. The materials may be programmed booklets or texts, audio tapes or phonograph records, or video tapes, and may be presented by teaching machines including electric typewriters or devices linked directly to computers. However, this route to self-directed learning tends to keep the student highly dependent upon programs developed by others and, in a sense, prevents him from learning to solve problems autonomously.

An alternate solution is to teach each student how to program his own learning abilities within certain narrow areas, then to offer him opportunities to use his newly developed self-direction while performing certain specific learning tasks. Encouragement of self-direction facilitates individualized instruction and prepares the student to solve problems independently and creatively in real life situations as well.

"Individually Prescribed Instruction," a pioneer program using programmed materials to achieve a relatively high level of instruction (*11*), was originated by the University of Pittsburgh's Learning Research and Development Center, in cooperation with the Baldwin-Whitehall School District in suburban Pittsburgh. Further developments have been made by Research for Better Schools, Inc., the Philadelphia-based Regional Educational Laboratory, and the program has spread to many other school districts.

Individually prescribed instruction covers only elementary school grades. It has been in full operation at the Oakleaf Elementary School. The system relies heavily on student self-direction, with teachers and teacher aides available to guide and check the students' work. Teachers offer help as required, and prepare learning "prescriptions." After a diagnostic test is given in a subject, the student is expected to gather the learning materials which are called for in this prescription, and go to his desk or work area and proceed independently. The program expects the student to cope with the learning tasks assigned to him and to try to overcome any difficulties before asking for help from the teacher. The student is encouraged to evaluate his own progress and to participate in the decision on whether he has obtained sufficient knowledge to take a "post test."

As seen, the prescriptions are developed by the teachers; therefore, the teachers greatly influence the self-direction of the students. When a student requires help, the teacher tries to help him to obtain the right answer on his own.

Individually prescribed instruction recognizes that the new "tutorial instructor" must eventually supplant the "group lecturer." Certainly, this transition creates many demands on and changes the expression for the traditional teacher. However, this system and other individualized instruction programs have indicated that with proper training most traditional instructors can become successful tutorial instructors. Most of these teachers express strong satisfaction and commitment to their new role. The Oakleaf experience has been so successful that the new Baldwin-Whitehall "Elm Leaf" intermediate school is being designed for individualized instruction—starting with the basic architecture for the school.

Well-planned instructional programs begin with a full analysis of the curriculum. In "Individually Prescribed Instruction," the Duluth program (*12*), the Milton program (*13*), and Project PLAN (*9*) classification and itemization of behavioral objectives have been made. These behavioral objectives, which represent what the student is expected to learn, can then be assigned as learning tasks to individual students. The objectives must represent tasks that can be accomplished within reasonable periods of time. A successful criterion, developed by Shanner (*14*), is referred to as the "Hey, Dad" test.

For example, a youngster might come home from school and say, "Hey, Dad, I learned the middle name of the third Emperor of the Ming Dynasty." If the father answers, "So what?" it means that the objective is trivial. If, on the other hand, the youngster says, "Hey, Dad, I learned to control my belligerent tendencies in interactional sociodynamic settings," and the father looks amazed and says, "What's that?" it means the objectives are too general or too vague. Proper behavioral objectives represent a happy medium.

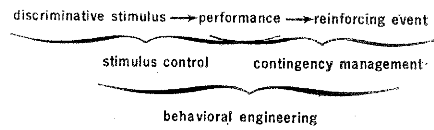

Fig. 1. The components of behavioral engineering.

Behavioral Engineering

The application of basic principles of psychology to practical problems is becoming known as behavioral engineering. It is, according to Homme (*15*), a blend of two behavioral areas: the technology of "stimulus control" and the technology of "contingency management." Stimulus control exists to the extent that the presence or absence of a stimulus controls the probability of a response (*16*).

In group-managed instruction, a teacher may repeat to the class, "You'd better pay attention to what I'm saying," dozens of times. The probability of this stimulus controlling a response is not necessarily very large. In individualized instruction, a student who has not learned his material may immediately be asked to repeat the unit of instruction. The probability of his response, or "paying attention," is greatly increased.

Contingency management is the directing of certain events that are contingent upon certain behavior. The term "operant conditioning" is more often reserved to designate the basic laboratory science from which behavioral engineering is derived, and which also follows from the basic concepts of Skinner (*17*). When reinforcing events are contingent on a certain behavior, the behavior will increase in strength; when they are not, the behavior will decrease.

In the above example, if a reward for "paying attention" is made, say in the form of a reinforcing event such as immediate personal recognition and perhaps some enjoyable or recreational activity, the tendency for the desired behavior is further increased (Fig. 1).

One can make a fair argument for the case that a major portion of classroom behavioral problems is a product of faulty stimulus control and a lack of proper contingency management. A poor teacher may start out saying, "Most of you in this class are just stubborn—you can learn this material but you just don't feel like it," and continue with, "Those who have learned the material are to work on this extra homework assignment, while I meet with the remedial group."

Properly functioning, computer-supported, individualized instruction leads to positive behavior. "I'm doing well with this material," is heard more frequently than, "Compared to the rest of this class, I sure am dumb."

The establishment of a sound system for motivation is one of the most important and difficult steps in developing and maintaining any effective instructional system. Unfortunately, a student's initial interest may fall off after a relatively short period of time. For a student to attain most learning objectives, behavioral considerations should be built into the system. Such procedures have been developed at several Job Corps centers, and a general model has been described by Tosti (*18*).

Multi Media

In a review, Travers (*19*) took issue with the commonly accepted notion that simultaneous display of visual and auditory stimuli, as in motion pictures or television, is consistently superior to using one mode of sensory stimulation at a time. A more pertinent question is, when should any input mode, or combination of modes be used? (*20*).

Cooper and Gaeth (*21*) pointed to an interaction of modality with other factors, such as intelligence, reading ability, age, difficulty, type of material, and others. All three of the main variables investigated, namely, grade, meaningfulness, and modality were found to be statistically significant.

Although, in general, auditory stimuli are best for easy material, and visual stimuli for difficult material, the best presentation for new and difficult material depends on the habits the learner has developed. One would certainly expect that a well-educated adult would learn about as much by hearing or reading.

Snow, Tiffin, and Seibert (*22*), in comparing the effectiveness of a training film and a live lecture for students with little prior knowledge of a subject, found that active, self-assured students with an unfavorable attitude toward films learned better from the live instruction; but passive, dependent students learned slightly more from the film.

During the period from 1959 to 1964, most research studies on programmed instruction were centered on "programming variables," such as step size, response mode, the sequencing of items, and so forth. Subsequently, as shown by Schramm (*23*), research in this area has been concentrated on the learner's personality, and cultural and intellectual variables. Programmed instruction is now seen only as one component of a multi-media instructional setting.

An important characteristic of computer-managed instruction is the capability to recommend use of the appropriate media, or mix, on a flexible basis, related to each student's learning style.

Adaptive Curriculum

Bushnell and Morgan (*24*) noted that although the United States is educating more people than any other nation, our college graduates still represent only about 20 percent of the group who first began school. About 65 percent of our students never reach college.

Eight out of ten of our students are, therefore, candidates for jobs requiring less than a college degree, but only one of these eight has received any type of occupational training in the public schools. However, students who plan to go to college are not prepared to cope with leaving before graduation, and students involved with most of our current vocational programs are trained for too narrow a range of job skills.

Federal funds have been appropriated for research on major curriculum redesign. The intent is to make education even more relevant to living in today's world, and more responsive to the present-day needs of our students.

Morgan and Bushnell have come to call a curriculum that is learner-oriented and adaptive, an organic curriculum. If successfully administered, such a curriculum should contain no sharp demarcation between academic and occupational training. Here also, "Each activity relates logically to all other activities and leads to the efficient attainment of behavioral goals" (*24*). Such a curriculum, of necessity, must depend on self-instruction and accommodate to the individual differences in learning styles and rates.

The full extension of this concept will also create many new problems and questions. How can school accreditation be achieved without the traditional "Carnegie units"? Would the system function better on a full-year time cycle, with 4-week or staggered student vacation periods? How shall class position or grades be assigned?

Early experiments such as those carried out at the Massachusetts Institute of Technology, the University of California at Richmond, and at special Job Corps projects have indicated that adaptive curriculums can turn many potential dropouts into high school seniors who are eager candidates for technical training programs at community colleges.

The full analysis and correlation of all behavioral objectives, including vocational ones, with appropriate combinations of method and media for students of varying abilities and interests is a natural job for a computer.

The findings from major programs supported by the United States Office of Education, such as Project TALENT, show that current educational programs in the elementary and secondary schools make inadequate provision for the very large individual differences among age or grade groups in today's schools (*25*). Assembling all of the major elements described above has been the goal of the United States Office of Education's Educational System for the Seventies.

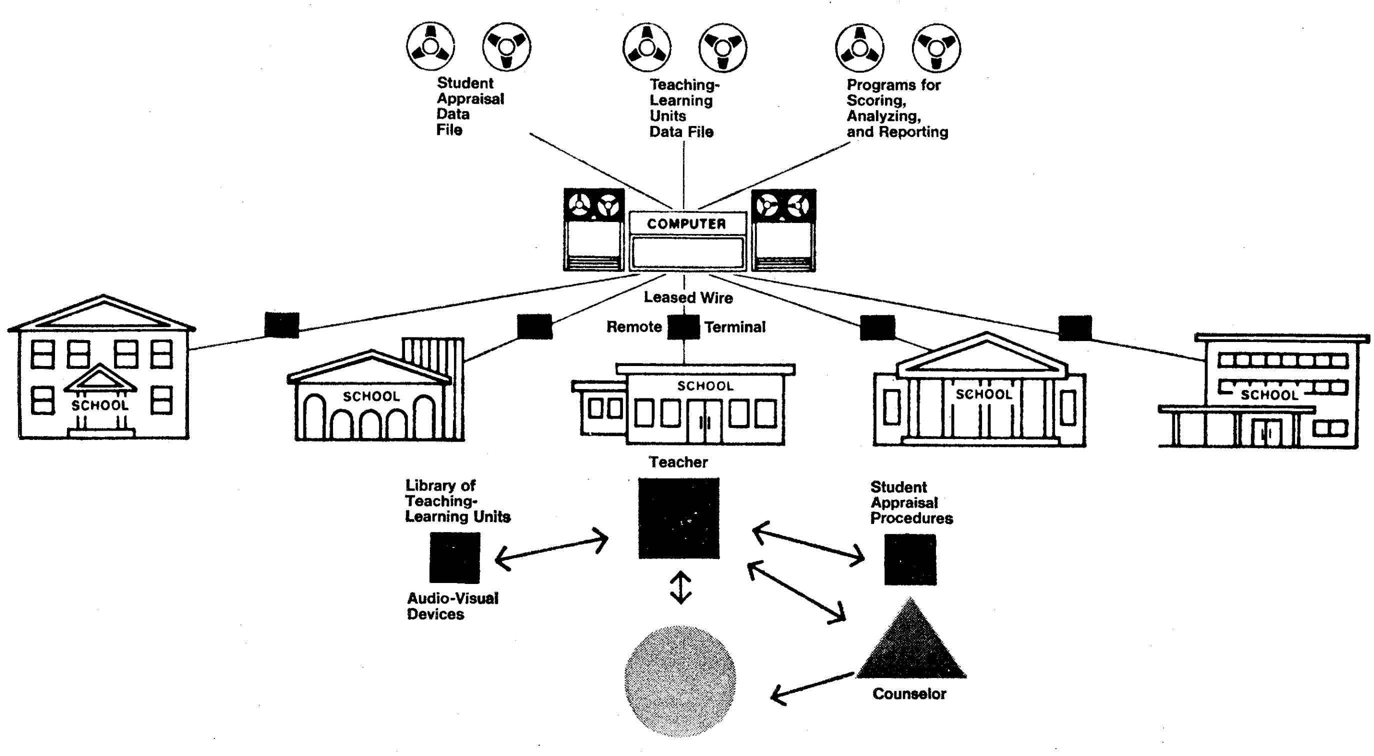

Fig. 2. Schematic representation of a system for computer-managed instruction.

Computer-Managed Instruction

A systematic integration of the four important developments described above has been started. A Program for Learning in Accordance with Needs (Project PLAN) has been functioning for over a year in representative school districts across the United States—in Bethel Park, Pennsylvania; Hicksville, Long Island; Pittsburgh, Pennsylvania; Quincy, Massachusetts; Parkersburg, West Virginia; San Francisco, California; Fremont, California; San Carlos, California; San Jose, California; Redwood City, California; and Hughson, California. More than 4000 students are presently enrolled (Fig. 2).

Computer-managed instruction is flexible enough to be used now. The principal addition at each school building is a single computer input-output terminal. Stored in the central computer are information on each student in the system including special aptitudes, learning patterns, and background. The computer also stores a complete file listing guides to instructional materials for each curriculum segment.

For each module of instruction, several of these guides or units are available, differing in use of media, learning styles, and vocabulary. All of these units for each module, however, have the same objectives and are evaluated on the basis of the same terminal test. Teaching-learning units are provided in all major subject areas (language arts, mathematics, science, and social science), and specially developed motivational, guidance, and career materials are also blended into the system. Last year the system ran in grades one, five, and nine, and this year grades two, six, and ten have been added.

The student interacts with his teacher, the instructional guide units, multimedia materials, and guidance personnel when available, and other students.

How does computer-managed instruction function in a classroom? First, with a battery of tests the student's overall achievement status and learning characteristics are determined, so that an appropriate set of objectives can be chosen. The computer then recommends a program of study and a matching set of teaching-learning units to the teacher. The teacher may modify the choices, but only with documented explanation. After implementing the program of study associated with each teaching-learning unit, the computer again aids in evaluating progress. The teacher is not only told which questions were missed but, more important, which behavioral objectives were not learned. The student can then be recycled through the same or more appropriate teaching-learning units, or remedial activity related to the missed objectives can be assigned, and the process can be continued. In its most fully developed form, the computer system is involved not only with test scoring but also with correlation and documentation (Fig. 3).

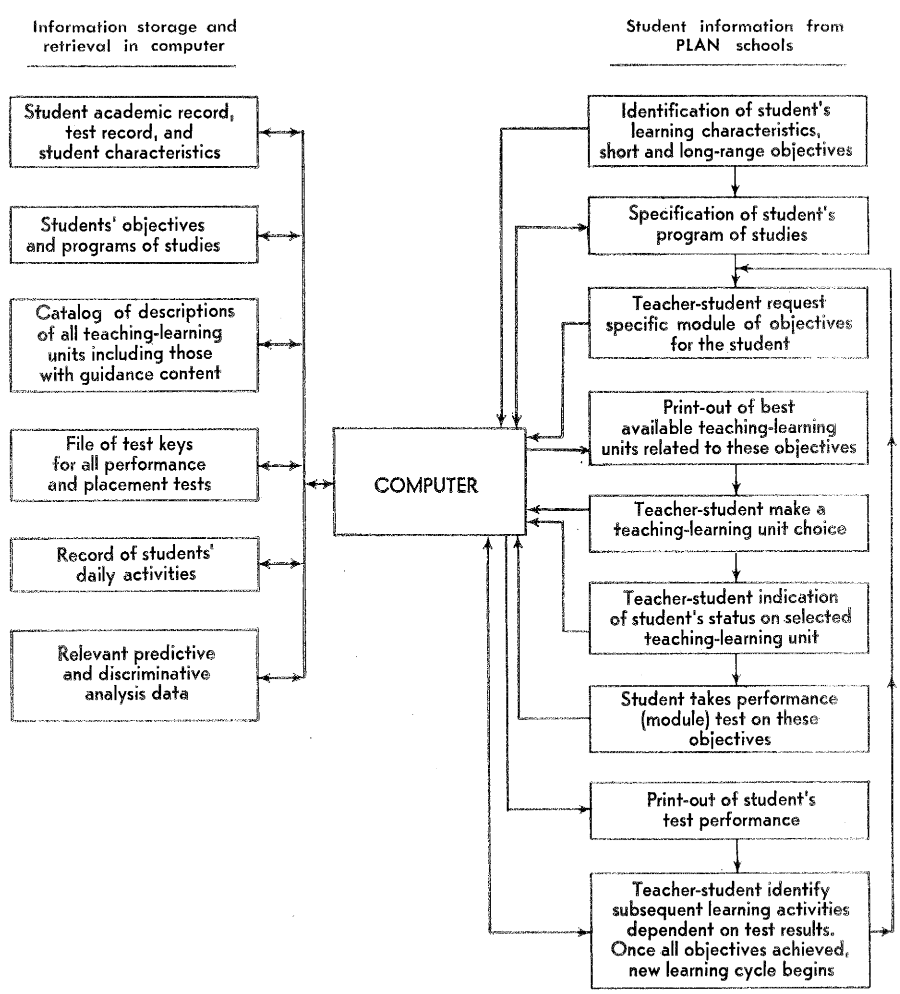

Fig. 3. The student and the computer within Project PLAN, based on a description by G. Brian Jones.

For example, a fifth-grade teacher with 30 or more students in four major subject areas, each consisting of some 100 teaching-learning units, is immediately presented with some 10,000 combination patterns of students and teaching-learning units. To shape these patterns and keep track of each student's set of over 1000 behavioral objectives exceeds the teacher's memory and capacity to correlate, but is a trivial job for a third-generation computer system.

The computer monitors and operates an informational system to support the teacher who can then spend much more time with the students. The computer in an individualized instructional system is a highly desirable but not an essential ingredient. The system can run without it, but not as well and less economically since it is necessary to replace the computer by a staff of clerical personnel to take data, score tests, and correlate information. In computer-managed instruction, computers handle these clerical tasks.

Another and perhaps even more valuable indirect effect of computerized instruction is that it is possible to correlate subject matter with learning characteristics. The computer system, therefore, can evaluate materials, and the conditions under which they are most effective in relation to student characteristics.

All of the instructors who participated in the PLAN program during the 1967–

68 academic year were surprised at how well they knew their students after just a few months in the program. The bright students covered and learned more than twice as much material as usual and, more important, the slow and average students also successfully completed their objectives. These results lend support to Bruner's (*26*) statement, that the outside observer might think that a permanent revolution in education was at hand.

Other Extensions

As indicated, individualized instructional systems have also been used in junior colleges and universities. The Bloomfield Hills, Michigan, Oakland Community College effort (*27*) was one of the early successes in this area. Programs are now under way at Pierce College in Southern California and at the U.S. Naval Academy, in addition to those already cited, and many others. One can imagine Brown's "ungraded" high school system (*28*) operating in many areas, including graduate and professional schools.

One of the areas under exploration is the use of computer-managed instruction for postgraduate training, or review. In the not too distant future, a professional desiring a refresher course—say, in basic physiology—may go to a computer-managed instruction center and take a diagnostic test reviewing the factual content and behavioral objectives for this subject. On the basis of his performance, he would then be referred to appropriate validated learning units and associated, current materials. Upon completion of the various objectives, his performance would be reviewed, and any necessary correction introduced. Our postgraduate student in physiology might be required to learn 41 new neurophysiology objectives, even though his knowledge of respiratory functions remained almost intact. At each step, data can be correlated with other regional and nationwide norms.

Problem Areas

Computer-managed instruction, like all systems for individualized instruction, has problem areas. Programs for teacher training, reorientation, and the redefinition of the teacher's role in the classroom are in relatively early stages of development. The preparation of proper behavioral objectives, as agreed to by programmers, learning materials specialists, and the new tutorial teachers, is another basic area of potential conflict. Mager (*29*) has done much to provide a common basis of approach and understanding in the preparation of effective instructional objectives.

Grade determination in individualized settings is another area of concern. Here, however, the information bank of the computer-managed instruction system can provide the teacher with a perspective by supplying local and regional norms.

New approaches for homework assignments are still not fully accepted. Nor are all of the snags in the computer system worked out. While the basic hardware components of the administrative information system are readily available, reliability of computer terminals and long intervals between failures are yet to be fully achieved. There is also much room for the generation of computer program routines to correlate more closely the appropriate teaching-learning unit with the student in order to reach a given set of learning objectives. This determination is especially important in the use of computer-managed instruction in ghetto and disadvantaged settings where vocabulary, cultural orientation, and reading levels must be considered.

All of the above problems are still being worked out. However, even small expenditures and early efforts have provided significant returns. Most project leaders in this field feel that we are only a year or two away from highly effective, fully operational systems. Practical computer-assisted instruction systems must probably wait 5 to 10 years for new equipments.

Computer-managed instruction systems cost much less than comparable computer-assisted instruction systems. In their most highly developed form, environmental factors should also be designed to support the total system. Gores (*30*) and the Educational Facilities Laboratory staff have done much to pioneer the architecture for individualized systems. These costs and those for optimum sets of support multimedia learning materials are yet to be fully appraised. However, current developmental programs indicate that systems can work extremely well in present settings and with learning materials now on hand.

Summary

Modern systems of computer-managed instruction involve branching, individualized programs of study, and information flow to help the teacher to monitor, test, evaluate, and direct student progress. Each student receives a variety of materials suited to his individual abilities and learning style, and all students cover basic objectives. Much of the drudgery of administering individualized systems can be eliminated by appropriate use of computers, and important aspects of motivation and guidance can be blended into the total approach.

A goal of American education is not just to reach all the students but also to provide them with appropriate capabilities, skills, and relevant information. In the past two decades, the groundwork has been developed for a major integration of our science and technology with all areas of education. Computers and computer-managed instruction systems can be expected to play a major role in transforming the educational process by giving the teacher a sophisticated aid to allow for flexible, multi-media, individualized education at a relatively small increase in cost.

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Quantification, Conservation, and Nativism

Quantitative evaluations of children aged two to three years are examined.

Jean Piaget

Mehler and Bever's paper on the cognitive capacities of very young children (*1*) presents some new and interesting data on the development of quantitative evaluations from the age of 2½ years onward. Although, unfortunately, these novel results have hardly been subjected to any analysis regarding the possible factors at work, and although they have nothing to do with conservation (whatever the authors may say), they yet are suggestive of a useful complement of information on the development of quantification. In addition, Mehler and Bever's thesis regarding the role of innate structures—like Chomsky's (*2*) which inspired it—provides an effective antidote to the exaggerated simplifications that usually form part of learning theories; but having chosen the other tack, they encounter a series of new problems which it may be instructive to investigate, the better to avoid the Charybdis of empiricist learning as well as the Scylla of rationalist nativism.

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Quantitative Evaluations Based on Correspondence, Order, and Crowding

At the level of operatory conservation, children judge two collections to be equal or unequal by looking for a one-to-one correspondence between their elements (even if one collection covers a larger area or is spaced out with greater intervals). At an earlier stage, children judge one collection to be more numerous than the other (or to contain "more" elements, even if they admit that in counting the elements one gets the same number in each) as soon as the line formed is of greater length. How should this length factor be interpreted?

Mehler and Bever analyze this factor briefly but inadequately, since they seem to believe that everything is taken care of once "perception" of length is invoked, as if this perception were sufficient to suppress momentarily an otherwise correct notion of numerical quantity. Evaluation by length is actually based on an ordinal quantification which is already of a conceptual nature, and which is far more complex and general than the experiment on number alone would lead us to suppose. Research on the concept of length (of paths, for example) has shown that, at the level of development in question, "longer" means "going further," not because of a dominance of perception, or because of a verbal or semantic confusion, but because the first quantifications that become possible before the synthesis of number (a synthesis of order and inclusion) and that of measure (a synthesis of partition and displacement) are based on an order of the points of arrival. This may be explained by the following. Before the child becomes capable of reversible operations, his thinking proceeds by "functions" in the modern sense of "mappings" (one-way mappings) or of "ordered couples." Psychologically, functions are the expression of action schemes, and every action (particularly an action whereby a certain distance is covered) is a series of ordered movements which will come to an end (at the point of arrival). This concept of "function" explains the dominance of ordinal considerations that underlie quantitative evaluations of and by length between 3 to 4, and 6 to 7, years of age.

But the results obtained by Mehler and Bever seem to show that prior to these purely ordinal evaluations there exists between 2 years, 6 months and 3 years, 2 months an even more primitive mode of quantitative evaluation, which with their display, Fig. 1*b*, leads to 100 percent correct answers. In the light of what we have said about ordinal structures, let us try to understand what kind of factors may be involved in these reactions. In the first place, we should not forget that, as far as space is concerned, children start with topological structures based on proximity, separation, enclosure, and frontiers (interiority or exteriority), before they consider length or even rectilinearity; in a recent work, Laurendeau and Pinard