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USING COMPUTERS IN EDUCATION--SOME PROBLEMS AND SOLUTIONS.
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POSSIBLE SOLUTIONS TO THE PROBLEM OF THE DESIGN OF COMPUTER-ASSISTED INSTRUCTION (CAI) PROGRAMS ARE TO COPY EXISTING METHODS, TO USE SCIENTIFIC METHODS, OR TO DESIGN PROGRAMS FITTED TO LOCAL NEEDS. THE BEST ANSWER TO THE PROBLEM OF INSTRUCTIONAL MANAGEMENT SYSTEMS NEEDED FOR CAI PROGRAMS IS COMPUTER ANALYSIS OF STUDENT PERFORMANCE DATA. TRAINING EDUCATORS, USING COMPUTER SPECIALISTS, AND DEVELOPING NATURAL LANGUAGE PROGRAMS FOR COMPUTERS ARE MEANS OF HELPING EDUCATORS TO WORK WITH COMPUTERS. COSTS MAY BE REDUCED BY USING NEWER AND LESS EXPENSIVE COMPUTERS, BY PURCHASING LESS EXPENSIVE INPUT-OUTPUT UNITS, AND BY USING TIME-SHARING AND LESS EXPENSIVE TRANSMISSION FACILITIES. INTEGRATION OF CAI PROGRAMS INTO OTHER SCHOOL FUNCTIONS IS AIDED BY PREPLANNING AND THE INCLUSION OF DATA PROCESSING INTO THE COMPUTER PROGRAM. GRADUAL PROGRAM BUILDUP, ADEQUATE STAFF TRAINING, AND SELF-EVIDENT RESULTS CAN OVERCOME THE PROBLEM OF GAINING SCHOOL STAFF ACCEPTANCE OF A COMPUTER PROGRAM. THIS PAPER WAS PRESENTED AT THE UNITED STATES AIR FORCE IN EUROPE EDUCATION SERVICES CONFERENCE (WIESBADEN, OCTOBER 4, 1966). (HM)

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ABSTRACT

An instructional management system is described as an interim step to computer-assisted instruction. The rationale for the instructional management system stems from the consideration of several problems in using computers in education; problems of system development, cost, communication, system integration, and user acceptance are considered.

Using Computers in Education: Some Problems and Solutions

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Almost every day we hear about the great benefits to be derived from the use of computers in education. Instant access to distant libraries, individualized instruction, and relief from the many clerical chores associated with school administration are among the advantages frequently listed. These are reasonable objectives, but the problems involved in realizing them are often ignored. This paper discusses six questions frequently asked about the use of computers in education.

The first question is: "How does one go about designing a computerized instructional system?" One popular approach to this problem is to copy what others are doing: Many who are planning new schools are hard at work collecting the latest information on computer-assisted instruction (CAI) and on flexible scheduling; they visit all the current sites in California, New York, and Florida on "brain-picking" expeditions and return reassured that their own plan has everything offered by the centers that were visited.

Another approach to the design of an instructional system is to look to science for suggestions. Learning theorists and educational researchers have never been so popular. There is hardly an education conference these days that doesn't feature a main address by a prominent researcher describing his remedy for the ills of education and citing several research articles that support this remedy. Unfortunately, if the school designer reads the articles, he will often find that the experimental situations and objectives described have little in common with his own, or that the results obtained are not of sufficient significance to form the basis for practical decisions.

A third approach involves de-emphasizing abstract models and innovations and concentrating on what one is trying to accomplish in the particular instructional system, adopting a cut-and-fit procedure to achieve the desired goals. This procedure can be illustrated by a brief description of our work at System Development Corporation.

Approximately eight years ago, SDC started a project to explore programmed instruction technology. Our survey revealed that existing programs provided for individual differences in rate of learning but did not provide for differences in skill level during the course of instruction. That is, identical material was presented to all students; those who learned quickly finished the instruction sooner but they were not permitted to skip sequences on the basis of demonstrated proficiency. A computer-based teaching machine was therefore developed by project members to provide for individual differences in skill. The computer was tied to a rear-view random-access slide projector and an electric typewriter terminal. The student, seated at the typewriter, viewed the slides and typed his responses; the machine then evaluated his answers. The computer program permitted students who performed well on test items to skip instructional segments, while those having difficulty on particular concepts were branched to remedial segments.

A number of institutions are now experimenting with similar forms of computerized instruction. Universities such as Stanford, Illinois, Pennsylvania State, and Pittsburgh, as well as private organizations such as IBM, Bolt Beranek and Newman, and System Development Corporation, are working in this area. Of course, the effectiveness of such systems depends mostly on the quality of the instructional materials programmed into the machine. Consequently, a good deal of activity is devoted to finding ways of developing better materials.

In an attempt to design improved instructional materials, we have conducted a fairly extensive series of experimental comparisons. The most notable result of these comparisons was that only marginal statistical differences among experimental treatments were obtained. Different sequencing procedures, cueing techniques, and confirmation procedures had but limited practical effect on student learning.

One procedure we tried, however, was successful. This consisted of a careful specification of learning objectives in behavioral form, followed by a succession of evaluation-revision cycles. As each defect in the instructional material was detected, the behavioral components involved were reanalyzed and specific changes were made to the defective segment. Ideas for possible changes were obtained from interviews and individual tutorial sessions with students. Gaps were filled, irrelevancies eliminated, and frames modified. Repeated evaluation-revision cycles were conducted until new students exposed to the materials consistently achieved a given set of absolute objectives. This process is quite different from a one-time comparison of the first version of a new package with so-called "conventional" procedures. It is more like the cut-and-fit engineering process, where the development activity is followed all the way through the final stage of implementation. It is an extremely costly process, since building a product to specifications can be an endless task. Rather than a single evaluation to decide whether or not to adopt a new set of materials, the engineering approach implies a commitment to <u>make</u> the new material work, since most things fail on the first try anyway. The traditional comparative study, on the other hand, seldom goes further than a research report and has little impact on classroom practice.

Persistent use of the evaluation-revision cycle will eventually produce quality materials that work--but that doesn't completely solve the problem of designing an effective instructional system. Even if large quantities of self-instructional material of high quality were available, many difficult implementation problems would remain. For example, if students move through the instruction at their own rate, how will it be possible to keep track of them? How is it possible to detect those who are not performing correctly and to diagnose the source of their trouble?

One of the greatest deterrents to individualized programs is the difficulty of managing the instruction--it is far easier to keep everyone in lockstep groups, even at the expense of optimal learning. The resistance to individualized instruction may not stem from conservatism as much as from the management problems associated with the newer techniques. The inefficiencies in classroom management can be so gross that the beneficial effect of finely polished instructional material may be relegated to the noise level. A smaller class group is not the whole answer: Even ratios of 15:1 do not permit detailed monitoring of individual student performance. How is the teacher to decide who receives help, what materials to change, or how much review is required if he lacks the data on which to make such decisions? The usual decision is made by giving help to the most vocal student--who may need it least! Some kind of management system is required to monitor student performance.

The second question, then, is: "What kind of management system should be established?" An instructional management system requires some means of collecting performance data from the student, some means of analyzing the data, and some method of displaying the result to the teacher. Manual procedures would only add to the teacher's already excessive clerical burden, so let us assume that a computer is available for this task. A host of subsidiary questions is immediately raised by the introduction of a computer into the instructional management system. One example is my third question: "How will school personnel and students, untrained in the field of computing, communicate with the machine?"

One reason why some school personnel reject systems involving computers is that they cannot control the operation; they can only direct the machine through an intermediary programmer. The programmer, not unnaturally, builds a system for his own convenience, and once it is built he is reluctant to make major changes in it. The user soon recognizes the rigidity of the system that was supposed to serve him, and either relinquishes his responsibility to the programmer or bypasses the machine system with an informal manual system of his own.

Occasionally a school administrator or teacher will learn programming with the intention of designing a truly user-oriented system. However, he is soon caught up in the excitement of learning a new skill. His tolerance for complexity undergoes a gradual metamorphosis, his expectations concerning the user's preparatory training unconsciously increase, and he soon comes to disregard the plight of the occasional naive user whose cause he had originally championed. His interests drift away from user-oriented problems, toward those more easily solved by the computer. This problem-avoidance behavior may be cured by a strict adherence to the same evaluation-revision cycle prescribed for the improvement of instructional material: Computer-naive experimental subjects are asked to try a new computer program; and if they have difficulty with it, the program is revised until even the most machine-shy female has no trouble in using it.

At SDC we have recently developed a user-oriented computer language that allows a nonprogrammer author to prepare a lesson on a computer for subsequent presentation to a student. This language, called PLANIT, interprets for the computer the lesson design that is typed by the content expert (the teacher) in his own natural English. For example, PLANIT will begin operating by typing a message to the author asking him to choose one of several kinds of lesson frames. The author types the letter indicating his choice, and PLANIT then requests the text of the frame. The author types a text or a question such as: "WHO INVENTED THE ELECTRIC LIGHT?" PLANIT asks for anticipated answers and the author types such expected responses as Marconi, Edison, and Bell. PLANIT next asks the author what actions should be taken, depending on the particular answer given by the student, and the author types feedback messages and appropriate branching decisions for various answer possibilities. When the lesson is ready to be executed, the student types "GO" and receives the instructional items in the designated sequence. A special feature of this language is that it allows the student to <u>ask</u> as well as answer questions in his natural (occasionally ungrammatical and misspelled) English. This question-answering capability is a new development that promises to add greatly to the effectiveness of computerized instruction. The main advantage of a user-oriented language like PLANIT is that it enables the nonprogrammer author to communicate directly with the machine by merely sitting at a typewriter keyboard and writing the instructional sequence.

User-oriented program languages such as PLANIT restore the teacher's or administrator's control over the computerized instruction; however, there still remains the problem of how to facilitate the communication between the <u>student</u> and the machine. Ideally, the state of the art should permit the transformation of stimuli from a given sensory mode to any other more convenient sensory mode. The machine should interpret all vocal and tactile responses of the student and in turn should be capable of generating meaningful auditory and visual stimuli. For example, in the teaching of reading or foreign languages, the computer should have peripheral input equipment capable of evaluating student pronunciation. Young children should not have to learn how to type in order to insert responses into the machine. Current research and development on interface equipment to meet such requirements is quite active and promises some real breakthroughs. At SDC we have developed a display that allows the teacher to draw graphic problems on a rectangular surface with a pen. As soon as the drawing is completed, it can be electronically erased or saved in computer memory for subsequent presentation to the student. The student can see the problems displayed on the same surface and use the pen to draw his solutions on that surface. The computer evaluates the solutions and makes subsequent displays contingent on the student's solutions as prescribed by the teacher.

The fourth question raised by the introduction of a computer into the instructional management system is: "<u>How can a school afford the cost?</u>" Anyone seriously considering the installation of a computerized instruction system need only calculate the rental charges of the computer, the cost per student terminal, and the transmission line charges (not to mention the backup costs of personnel who tend the needs of the system for new materials, and maintenance services), to be convinced that a sober reappraisal of the budget is in order prior to such innovation. There have been estimates that the cost of one console hour of instruction per student is eighty cents to one dollar, but it is doubtful that such rates include all the hidden costs involved. The cost problem, salesman arithmetic to the contrary notwithstanding, is an important deterrent to the widespread implementation of computerized instruction.

Several alternatives that promise to alleviate the cost problem are available. Present hardware developments indicate that great reduction in cost will be achieved in a few years. In addition, the new technique of computer time-sharing promises to reduce the cost per student. Prior to time-sharing, the machine spent most of its time waiting for a new response from the user. With time-sharing, each of the various programs associated with different users is shuttled in and out of storage, operated in a fraction of a second, and replaced by another. In this fashion, better computer utilization is achieved and costs of computer time are shared, yet each user appears to have direct and instant access to the entire machine for himself.

Transmission costs may be reduced by using a communication satellite to obtain large-area coverage. A space vehicle with modest transmitter and receiver requirements could be used to bridge long distances between computer centers and schools, providing an alternative to the present system with its high transmission line charges.

Another method of reducing the cost of an instructional management system is to degrade the system to some less costly compromise configuration. For instance, instead of providing an input terminal for each student, the system might employ a smaller number of terminals to be shared among students who are scheduled (by the computer) to use the terminal at different times during the day. Still another method is to use a simple button-box input with small feedback lights instead of the more elaborate "rich" terminal with its TV tube, keyboard, random-access film, sound, etc. In an even cheaper configuration, the "rich" terminal is reserved for the sole use of the teacher in querying the record of student performance. The student responses are entered in printed booklets treated with a material that changes color when the page is marked in the correct fashion, providing the student with immediate knowledge of results. The pages are sent to a central office each day where they are read by a test-scoring machine that puts the data on magnetic tape. The tape is read by the computer, and the data are analyzed and sent back to the school over telephone lines to generate special displays (at the single "rich" terminal) indicating to the teachers which students are having difficulties, what kinds of problems they are having, and what materials may be helpful to them. This alternative saves the high cost of a terminal for each student, but it requires optical scanning equipment to read the data from the students' booklets.

Although the problem of alleviating the cost of the physical configuration seems manageable, little optimism is warranted for the solution of the backup logistics problem, which lies waiting like a submerged iceberg. To maintain the reliability of the physical system, to develop new computer programs and instructional material, and to continually evaluate and revise the system, there must be a staff of well-trained specialists whose ongoing price far exceeds the already substantial outlay required merely to install the system. Too often, school boards ignore the ongoing backup cost, buy the tangible physical system, and later wonder why it isn't used. The fact that the necessary services may be supplied by the manufacturer doesn't alter the cost; it merely moves it to a different budget category.

The difficult part of the cost problem is that we haven't translated our subjective valuation of student learning into dollar terms. Thus, by default, the economic analysis is reduced to the principle of maintaining the existing budget level. This principle requires that the innovation of a computer system be justified not by its instructional value, but by its elimination or reduction of some other budget category, like teachers' salaries. Even the backup costs and the lack of cost/effectiveness criteria, however, may be alleviated somewhat by integrating instructional management with other school functions that may also benefit from the system and be able to share its cost. The fifth question, then, is: "How can an instructional management system be integrated with other existing school functions, such as counseling and administration?"

A little thought about the total school system soon convinces one that it is more than desirable to integrate all the school functions--it is necessary. Unless major student difficulties are quickly brought to the counselor's attention, and unless the administrative planning and routine data processing procedures reflect the individualized mode of instruction, only chaos will result. Fortunately, a computer-based system lends itself to combined functions. For example, the same language used by the author-teacher in specifying computerized instruction may be used to specify an automated counseling interview--which can be subsequently conducted on the same terminal that was used for instruction. Furthermore, this language may be used for conversational interaction between the machine and the school superintendent who is planning his budget or scheduling classes.

At SDC we have used the PLANIT language for instruction, counseling, and administrative planning functions. If student performance records are being compiled, it is also possible to collect data on educational and vocational aspirations, as well as routine administrative information, on those same students. All kinds of information can be stored in the same data base. The information-retrieval program can use these data to generate graphic displays for administrators and counselors as well as for teachers. Once the data are in the computer, it is also relatively easy to generate lists and multiple copies of various reports whose manual preparation currently takes exorbitant amounts of time away from the staff's more professional duties--those duties involving interpersonal exchanges with students. The price to be paid for an integrated system is agreement on various procedures, such as the use of common formats to insure that data collected from different sources will be compatible with the computer programs used to process them.

Obtaining agreement among school personnel concerning standard procedures is always a roadblock in itself. However, an even greater obstacle to the optimal use of computers in education is the problem of acceptance. My sixth and last question, then, is: "How can one build acceptance of new computerized school systems?" One response to this question is involvement of the user. Although school people will not be producers or manufacturers of computerized instructional systems, I think it is important that they participate in designing the systems to be used in their schools, because--unlike textbooks--these systems are a completely new commodity and, if pushed too fast, may be totally rejected.

I think it may be unwise for a manufacturer to start out by building a complete hands-off system that is supposed to anticipate everyone's needs. Rather a library of small modular program segments should first be constructed as needed. These procedures may be used as building blocks by different users. Teachers, administrators, and other staff members may combine these segments in different ways to produce individual packages to meet their unique functional requirements. This is an evolutionary approach to system development. Instead of trying to sell a full-blown instructional management system to a school (and such a package could be readily assembled by any one of a number of manufacturers), it is probably a better strategy to start with a single typewriter terminal that is tied into someone else's time-shared computer system--then the only new item added to the school is a harmless-looking typewriter.

If staff members can have on-line access to the computer by merely sitting at the typewriter, and if there are available user-oriented languages to facilitate communication with the machine, then someone will soon be "hooked" on the potential of the new toy. (A visit to most computer centers late at night, even on weekends, will convince the skeptic of the infectious nature of this game. The only way to get some programmers to go home and eat is to turn off the machine.) Once a few staff members become excited about the programs being used, they will want more programs and more terminals. The system will grow to fill the capacity of the computer, regardless of how large it is, and soon the school will require its own computer. It will first be used for routine data processing, payroll, attendance accounting, and report generation; later, for counseling functions, information retrieval, prediction studies, simulation, and planning. Finally the system will be used for instructional management and may be used by specialists in the development of instructional materials.

The kind of evolution described above will probably first appear in the secondary schools and colleges. Later it will move in both directions--toward the lower grades and toward adult retraining, where both the need and the potential benefits are greatest.

I am convinced that if a tool is really useful, it will eventually be accepted in education. General-purpose tools introduced in one school will be carried to another by people trained to use them. Others will carry the technology to the next school, and so on. The installation of equipment per se confronts school people with a tangible problem of adjustment, almost forcing change by its very presence. Much of the concern about political obstacles to innovation may in fact merely reflect a healthy resistance to tools that either do not work or are more time-consuming than they are useful.

Finally, one of the prerequisites to acceptance of computers in education is an effective staff training program. The instructional management system should contain a capability for generating synthetic data that can be used for staff training purposes. Working with the simulated data, the staff can learn how to use displays, make queries, and react to problems prior to hooking up all the student terminals. Simulation exercises might begin with relatively easy problems and gradually build up to real-life situations with some actual students working at terminals. Gradually the live system can replace the simulated data. The advantage of such simulation training is that it provides a capability to condense realistic problems into a short time period to test and improve the diagnostic troubleshooting skills of the staff in a safe environment. Such exercises are very popular now for training teachers, counselors, and administrators. The effectiveness of this training is best measured by whether or not the students of simulation-trained staff members learn more efficiently. If the simulation exercises are so designed that the consequences of staff actions accurately reflect what would really happen, and if staff members are given a conceptual framework to tie their simulated experiences together, the training can be of some value. Here again, as with the improvement of both instructional materials and computer program systems, the simulation ought to be evaluated and revised until the student learning criterion is affected. It is easy to simulate, but not so easy to develop simulation training programs that work when assessed by an external criterion.

A final point which should be made is this: As instructional management systems are developed and used, data will be available to justify the need for school reorganization to allow for individualized instruction. Such reorganization will, in turn, lay the foundation for computer-assisted instruction on a wide scale. Extensive use of computers, however, is still a number of years away, despite the present CAI experiments that receive so much publicity.