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The educational applications of computers for instruction, administration, and vocational guidance are herein reviewed. Reports on recent trends in computer-assisted instruction and computer-managed instruction toward forming behavioral objectives and reducing learning time and implementation costs provide an introduction for a description of the Office of Education's proposed program, a Computer Utility for Educational Systems (CUES). The CUES program, designed to provide demonstration centers of feasible and economic computer applications (including administrative data processing, a course in computer technology, integrated problem solving, and vocational training) is defined at some length, and the problems and costs of implementing computer systems are discussed. Next, the value of computers in career decision processes and in individualizing instruction (including the development of sequenced behavioral objectives) is illustrated through references to projects. Finally, barriers to change are examined and a case is presented for the utilization of a systems approach to effect educational improvement. A bibliography is included. (SP)

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A REVIEW OF EDUCATIONAL APPLICATIONS OF THE COMPUTER, INCLUDING THOSE IN INSTRUCTION, ADMINISTRATION AND GUIDANCE

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A Review of Educational Applications Of the Computer, Including Those In Instruction, Administration and Guidance

The use of high speed computers in education has been the most dramatic and publicized application of technology to instruction and, indeed, for many people is the sum and substance of instructional technology. The computer seems to loom larger than life, deified by some and feared by many. These grey, blue or green boxes need to be placed in perspective by educators and be examined in terms of what they can do today, and what that costs, and what they are likely to be able to do in the next five or ten years and what that can be expected to cost. (A note of caution: Ones personal prejudices can operate effectively in the face of empirical data; they are particularly potent in the absence of data.)

Perhaps the most extensive coordinate use of computers in attacking instructional problems in a school setting has been the effort in the Philadelphia Public School system directed by Sylvia Charp (Charp & Wye, 1968). Dr. Charp has used the computer with students in (a) simulation and games, (b) problem solving, (c) vocational training, and (d) computer-assisted instruction. She has used both Philco and IBM hardware.

Computer-assisted instruction has been investigated by a group of researchers, including Pat Suppes of Stanford, Harold Mitzel of Penn State, Don Bitzer of the University of Illinois and Duncan Hansen of Florida State University. It might be argued that Hansen's work is more legitimately computer-managed instruction in that the learner is routed off-line for some 90 percent of his instruction. The distinguishing characteristic of CAI is that the machine and the learner interact, with the machine performing an instructional role. This instruction may take the form of drill and practice as in the case of Suppes' work or the computer may perform as a tutor with characteristics of the branching program of instruction.

While it is too early to draw anything but tentative conclusions about CAI, on the basis of results to date one might make the following generalizations. CAI reduces time to completion of a learning task. While of interest to the psychologist as a dependent variable, reduced learning time is not a compelling sales point with schools, which in discharging their custodial function must still use up 100% of the students' fixed school time (Randall and Blaschke, 1968). Don Bitzer has retention data on students taught by CAI which suggest the forgetting curves of Ebbinghaus do not apply. His students showed little performance loss through time. Generally, the students learning by CAI have not been shown to be superior to students traditionally taught (Kanner, 1968).

The largest barrier to CAI's widespread use is its prohibitive cost, which would be a factor even if its teaching power were unequivically demonstrated (Zinn, 1968; Kopstein & Seidel, 1968). A study by Booz, Allen and Hamilton found that with commercially available equipment the cost of drill and practice by CAI would be in excess of $2 per hour per student. Drill and practice is probably the least expensive form of CAI (Carter and Walker, 1968). Tony Oettinger of Harvard University has taken a pessimistic stance in regard to CAI and speculates that it will be years, if ever, before schools can afford CAI (Oettinger and Marks, 1968).

Assuming that the teaching effectiveness of CAI is eventually shown, there are some considerations that would surely alter the probability of its use in schools. First, even $2 per student hour of instruction is hopelessly non-competitive with most in-school instruction–but not with all. Some vocational education and special and remedial education probably cost more, and CAI could be efficiently employed in these areas. Second, technological developments could substantially reduce the cost of CAI. Don Bitzer and Dan Alpert have developed prototypes of a plasma screen student terminal which could be served in large number (as many as 4000) by a central processing unit (Bitzer, 1969). Their projections of costs for a full system with five-year amortization of development costs would provide instruction at 25c per instructional hour. A third development which could effect the timing of CAI use is the rising personnel costs in the schools. Teacher militancy with its associated increases in teacher pay may accelerate the pace of adoption of instructional technology in general. A fourth development is the use of computer systems by schools to perform functions other than instruction where the bulk of costs are borne by these other functions (such as administrative data processing). It may be that what would otherwise be machine down-time could be used for CAI, at high per-hour cost, but with little increase in the total system cost.

Ongoing CMI Efforts

A more recent trend in instructional application of the computer is *computer-managed instruction.* There are several efforts presently ongoing, no one of which is far enough along to permit evaluation of this approach. Though the principals might not all agree that they are working on a CMI model, the following projects may be so classified: Harry Silberman's work with the Southwest Regional Educational Laboratory and the Los Angeles Public Schools; Robert Glaser of the University of Pittsburgh, working with the Oakleaf School in Pennsylvania, and Donald Torr of Sterling Research Institute, Don Tosti of Westinghouse Learning Corporation and Alexander Schure of New York Institute of Technology. The latter three are working with the U.S. Naval Academy (Manion, et. al., 1968). All of these projects are sponsored by the U.S. Office of Education. Another large project involving CMI is headed by John Flanagan under the sponsorship of the American Institute for Research and Westinghouse Learning Corporation (Flanagan, 1967).

These studies differ in a variety of ways such as reliance on off-the-shelf materials as opposed to developing new instructional resources. They also address different academic levels and areas. Their similarities are greater than their differences, however. All are designing learning interventions based on carefully specified behavioral objectives and all are using the computer to mediate between the student, his individual performance on the objectives, and the inventory of instructional resources related to the objectives.

In a sense, these projects are programming the instruction in modular pieces, using a variety of media with redundancy across the pieces. The computer, based upon earlier validation data, can select a mosaic of learning experiences whose particular make-up is uniquely tailored to the student. The instructional power of this approach is yet to be demonstrated but will need to be very dramatic to justify the developmental costs, which are estimated at around $30,000 per instructional hour as contrasted with around $2,000 per hour for programmed instruction (Rogers, 1968). Since the principle function of the computer in CMI is to prescribe and schedule, it could serve thousands of students daily and the operational costs of CMI should be less than traditional instruction.

Work by Leslie J. Briggs of Florida State University and David Markle of the American Institutes of Research suggests that the potential instructional power of this approach is great (Briggs, 1967). In the empirical development of an instructional system for a first aid course built for American Telephone and Telegraph Company, Markle was able to reduce the time to completion by 25% and increase the average final test score from 145 for the traditionally taught group to 270 for the experimental group (Markle, 1967). The standard deviation was reduced from 42 to 9 and the worst performer of the experimental group scored 44 more points than the best performer of the traditionally taught group. This study employed a mix of tailored media which underwent three revisions based on learner data. While this study is not conclusive, it does suggest that more effective instruction can be developed even without the computer.

More Needs To Be Known—

The Naval Academy studies by Stirling Institute, Westinghouse and New York Institute of Technology were designed to yield answers to some questions not dealt with in Markle's study (Manion, et. al., 1968). How powerful can such a system be in terms of how much is learned in what period of time? Can we find principles governing media selection as opposed to blind trial-and-error? How much reckoning must be taken of what Jerome Bruner calls "learning style"? What roles can the computer effectively play in such a system? What is the minimum computer power required and what is the maximum that can be efficiently used? What are the most effective uses of human resources as contributors to the operating system? What different instructional approaches will need to be taken as course content varies from high-structure to low structure? What are the real development and operational costs of computer-managed, multi-media courses? What kinds of organizations can be expected to develop this type of curriculum? In a sense these studies should be guideposts for future curriculum development efforts, and their importance should not be underestimated. They are responsive to the criticism made by Oettinger that much more needs to be known before widespread operational use is made of educational technology. One of the more promising immediate uses of the small computer in vocational-technical education is in simulating defects in a trouble-shooting exercise. A technique devised by H.R.C. Dale requires the student to make systematic tests using a schematic diagram in order to find the cause of improper equipment performance (Bryan, 1968). The difficulty of the simulated defect search can be increased as the learner gains sophistication. The computer permits many more diagnostic exercises in a given time than would be possible using real equipment. NASA and the AEC have made wide use of this technique and it is coming into use in electronic and TV training programs.

The USOE's Five Conclusions

In the past half-dozen years the U.S. Office of Education has sponsored projects on computer applications in education costing several million dollars (Morgan, 1968). Applications research include those projects previously described plus investigations of computer-based guidance systems and flexible scheduling. Federal agencies such as the National Science Foundation and the Department of Defense have also been sponsoring education-related studies involving the computer. USOE, in an attempt to assess the state of development, formed an Ad Hoc study group to determine what had been accomplished and what were the most pressing priorities for future computer applications support. This study group collected information on the progress of the various on-going research projects and solicited the views of a number of computer technology experts both from within and outside the government.

The major conclusions drawn from this analysis were:

1. Of the several kinds of computer applications being researched, some should become operationally feasible before others.

2. With the existing hardware, many of the more exotic applications (CAI, CMI and computer based guidance systems) would not become feasible for wide-spread school use unless significant reductions could be made in per student cost.

3. There are a number of non-exotic but useful functions which could be furnished to schools with the available technology.

4. Computer systems for schools should be developed to provide services currently available and be able to accommodate the expected newer functions at a future time with minimum disruption and systems modification.

5. The services provided by such a computer system probably should not increase the per student per year costs by more than 2%. In order to provide a range of services within this cost level it is reasonable to assume that a large central computer service with terminals extended to participating schools and school districts would be required.

As a consequence of this survey and analysis the Office of Education decided that one of its highest priorities would be to study the feasibility and desirability of supporting the establishment of such a computer center. In the planning phases this program has been called "A Computer Utility for Educational Systems" (CUES). In response to competitive bids, two contracts were awarded, one to International Business Machines and the other to General Learning Corporation to study this problem and to make recommendations for an approach.

Questions that these two contractors were asked to address included: what are the services that are needed by schools today which can be offered with least delay, what numbers of students and numbers of schools in what geographic range would be required to meet the desired per student cost, what kind of equipment at the computer center and what kinds of terminals would be appropriate in what numbers for providing these services, what programming and what kinds of systems analysis would be required at the school and district level, what would be required in the way of non-computer software for supporting the services, and what requirements would there be for staff-orientation and training?

While there were significant differences in the findings of the two investigators there were some remarkable similarities as well. In order to develop rapprochement between the two studies and refine the analysis a third contract was let to Computation Planning, Incorporated, under the direction of Herb Bright. All the studies concluded that, without extensive research and development, certain services could be provided to a network of schools: administrative data processing, a basic course in computer technology, integrated problem solving and vocational training. Studies assumed that computer managed instruction, computer guidance and career information systems, and library services could be added later. Each of the four services to be offered from the onset of the program are already in operation in several schools in the nation, but only a few large school districts have all four of the services.

The administrative data processing would include such functions within the school as student scheduling, classroom use, payroll and various other normal record-keeping functions.

The basic course in computer concepts would be offered for all students, probably at the ninth grade level, and would cover basic fundamentals of computer technology. It would be designed primarily to provide basic information about computers to the students but would also equip them with some rudimentary programming skills. This course would be regarded as part of the students' general education program.

The third use of the computer would be as a problem solving device in appropriate courses within the existing curriculum. Problem solving exercises involving the use of the computer would be integrated into physics, chemistry, mathematics, business education and other courses. The use of the computer within these courses would be a standard part of the sequence of learning experiences for each student.

Vocational training application of the computers would be to prepare students as key punch operators and it should be possible for the students to actually punch the programs written by other students. Since all of the schools will have a remote card reader and printer and will require some form of production control, selected students can gain experience at an elementary level in that aspect of computer facility operation. Certain students in the vocational area should be equipped as beginning programmers.

The computer time required will not be equal for all three instructional applications. It is expected that each student will have six to seven programs per year, on the average, to be processed by the central processing unit. Problem-solving and vocational training students will have a larger number of programs, but there will be fewer of those students. The course in computer concepts will have large numbers of students enrolled but each will use only a limited amount of machine time.

An early additional application anticipated – computer managed instruction - has already been described.

Time-Sharing: Twice as Expensive

The analysis compared time-sharing systems to multi-programming batch systems and found a cost differential of about two to one favoring batch processing. A decision was made to design the system for multi-programming batch processing. Cost estimates for CUES on an operational basis ranged from $15 to $22 per student per year, depending on the number of students to be served by the system and whether the system is leased or purchased. With 200,000 students in fifty to one hundred schools within a 75 mile range, the cost of purchasing the central system and terminals with leased lines would be about $15 per student. This would be with five year amortization of purchase cost and would assume an average line length of 30 miles. These figures do not take into consideration any cost displacement or savings for administrative uses of the computer, and the $15 per student should be accordingly reduced to arrive at the instructional expenditure for each student. The non-recurring expenditures for development and demonstration are not included in the operational costs and would be expected to be approximately five million dollars.

It is anticipated that the hardware required for the CUES System will consist of commercially available equipment, including a computer and related hardware at the central site and medium speed card readers and printers in the remote schools. Since the work load requirements cannot be estimated precisely at this time, it is not feasible to determine the exact central facility equipment requirements. The computer will be a high speed device with approximately one-half million characters or one-eighth million words of main (directly-addressable high speed) memory. Both high and low speed secondary storage will be provided for input/output, library routines, and so forth. Four magnetic tape drives are to be provided in addition to one card read/punch and one high speed printer. The remote input/output station for the proposed system will include card readers capable of reading 200-250 cards per minute. Printers will be used which combine medium speed (over one-hundred characters per second) and relatively low unit cost. Part of the administrative work load for which only limited input/output is required will be sent to and from the central facility via courier. The instructional functions of CUES will have first priority, with most administrative jobs being processed after the end of the school day.

The next step is for a contractor and school district (or a group of districts) to be selected for the actual development of a CUES center. The advantages to educational planners and decision-makers should be several. Computers are expensive and unwise expenditures by schools can and have resulted in enormous waste of money. CUES should demonstrate what reasonable and desirable uses can be made of the computer in an operational school setting, and what these services cost. School representatives will have a place to see the program in operation and will be able to talk to the actual school users of the system. Of significant value will be the detailed specifications of the required hardware systems, both central and remote, and the existing software—all of which can be borrowed or copied by other schools.

It can be anticipated that after CUES is developed and refined it can become a profitable enterprise. If this turns out to be correct, then it may be reasonable to assume that private enterprise, on its own initiative and with its own capital, will replicate the CUES model, working in cooperation with other school districts. It has been estimated that thirty strategically located centers, like that envisioned for CUES, would bring instructional computer services to almost 90% of the nation's school population.

Computer Presented Career Specifications

Another use of the computer is in the vocational guidance area. The information available in most schools about career opportunities and training requirements is not adequate. The student doesn't know enough about the jobs nor about himself to make wise career decisions, and the result is that thousands of youngsters drift into jobs for which they are ill equipped in terms of training and aptitude. Many will shift several times in their occupational life, often to jobs which are no more suitable for them, virtually precluding a rewarding career pattern. David Tiedeman of Harvard University has been studying the career decision processes of students for the past several years and has developed a career information system which permits machine storage of information about a large number of careers in which there are employment opportunities in the region. His system permits the student to examine these career specifications and relate his own qualifications to specific jobs.

Using the computer, the student can simulate a series of decisions that are like those one would actually make in systematically analyzing a career progression. Tiedeman's project hasn't been underway long enough yet to determine whether a student's career pattern will be affected by these organized experiences and it will be several years before the real effects can be assessed. However, the approach appears to be logical and eminently sensible and on the basis of its face validity it will probably be utilized by other schools when its development is complete. John Flanagan is developing a similar program as a coordinate part of Project PLAN, which is likely to be operational before Tiedeman's program. Frank Minor of IBM is also developing a career information and guidance system using the computer.

Perhaps the most promising development in instructional technology at the present time is individualized instruction. It is promising because there is evidence that such approaches can be locally developed and operated without exotic equipment and without great additional operational expense. There are several programs of individualized instruction in operation and continuing development today. The two that have been underway the longest and are the best known are the Nova high school program in Broward County, Florida, and the Oakleaf elementary school program in Pennsylvania. Both are being evaluated as development continues, and in neither case is the data conclusive.

Gary Foster of Florida State University has been in residence at Nova for the past four years collecting comparative data on the students in the program, and while his data analysis is not complete, the experimental students do not appear to be excelling the matched control students. The evaluation data on the Oakleaf project is being collected by Bob Glaser and his colleagues at the University of Pittsburgh and is equally tentative.

Interim and Terminal Performance Objectives

Two other projects are underway in the Duluth, Minnesota, and the Bloomfield Hills, Michigan, public schools. Thorwald Esbensen of Florida State University (formerly Assistant Superintendent of Duluth) was the project director of the Duluth program, and Robert Boston, assistant superintendent, directed the Bloomfield Hills effort. Both of these are too recent for any meaningful evaluation to have taken place. While there are differences between the four projects they are sufficiently similar for a description of one to suffice. In Bloomfield Hills, the entire curriculum for three schools has been individualized. The three schools, an elementary, a junior high and a high school, provide a kindergarten through 12th grade test environment. Teams of local faculty members in these three schools, working with central district office specialists and outside consultants, developed specific behavioral objectives for the entire curricular offering. There are terminal performance objectives, the sum of which make up a defined course of study, and interim performance objectives, a sequential group of which lead to a terminal objective.

After developing the objectives, the teachers analyzed the instructional materials available in the system and encoded portions of these materials against the objectives. For certain objectives, they judged no material to be suitable and developed their own instructional resources. Their next step was to develop instruments or techniques for determining whether or not a performance objective had been attained by a student at the specified level of proficiency. Finally, the products of these efforts were organized into "student learning packets," which for a given block of instruction told the student what was expected of him in objective terms, what resources (including teachers) he might fruitfully employ in achieving these objectives and, finally, how he was going to be evaluated on the objectives. The student could then proceed at his own rate, calling for assessment on any given objective whenever he felt he was ready. Indeed, many of the students were able to demonstrate proficiency on some of the terminal objectives at the beginning of the learning sequence, thus avoiding spending time on things they already knew.

A visit to any of these four programs, and talking to students and teachers, is a convincing experience even in the absence of evaluation data. While the youngsters are moving through the curriculum at variable rates, they tend to go faster than the traditional pace. A major problem which will have to be faced shortly in these individualized programs is what to do with the students who finish the present offering of the school before they reach graduation age.

What Needs to be Done?

Much of the impact for instructional improvement by using instructional technology is lost because of the apparent inflexibility of the educational system and because the products of technology are usually employed in a piecemeal fashion, if at all. There are many critical variables in the educational system which affect student learning and these variables do not operate in isolation from one another. These include the instructional objectives, the role of teachers and administrators, the physical environment, the motivation and background of students, the administrative practices, and the instructional processes. Research has been done on all these variables, usually treating one independently of the others. Yet maximizing the effect on student learning of any one of these is constrained if the educational researcher is not free to appropriately change the other variables. If all the major components in an educational program are to be optimally articulated, one might conclude that the smallest experimental unit for significant educational change is a whole school.

An application of systems approach to the re-design of the total educational program for a school is exemplified by a cooperative program presently underway called "Educational Systems for the Seventies" (Morgan and Morgan, 1968). The U.S. Office of Education's Bureau of Research has joined with eighteen local high school districts in fifteen states to design and develop a new educational program. These schools will serve as a flexible staging area where the interactive effects of the important components of the educational process can be tested and revised in terms of both contribution to student learning and cost benefits. The eighteen schools currently participating in the planning of this program will serve as test sites for its major components, and will later serve as demonstration schools for the operation of the total program.

The overall plan will identify all the activities that must be completed before the total new curriculum can become operational. These activities generally can be classified as research or development or demonstration. Because of the magnitude and complexity of the task, many diverse institutions and organizations will be involved in the effort. These will include universities, profit making and non-profit organizations, and professional associations. The local schools will have primary responsibility for the definition and acceptance of the program as well as the demonstration activities.

The specific tasks to be done range from the preparation of inservice training programs for staff to the analysis of design requirements for facilities. The plan anticipates that courses, as we now know them, may be changed and that Carnegie Units as a measure of student progress may become inappropriate. Therefore, new accreditation and student certification practices may be necessary. The activities having the most pressing priority are setting the educational goals and operationally defining the performance objectives. The performance objectives define the output specifications for the system and must precede the design of the system. The "Educational Systems for the Seventies" schools have already agreed upon their broad aims (Morgan and Bushnell, 1967). Each graduate of this yet to be built program will receive a comprehensive education. He will have the requisite academic attainment for college entry and he also will have salable job skills. He will be equipped to cope with the socio-economic environment as an adult. These are ambitious goals and will require a powerful educational system if they are to be realized for all students. For these goals to become purposeful in a design of a new system they must be operatively defined in terms of behavioral outcomes.

An important reason for specifying the outcomes of educational systems is that it is necessary for longitudinal validation of the effectiveness of public education in preparing young people to cope with the social and economic environment when they leave school. Unless we know with what behavioral attainments a youngster enters the adult world. there is little basis for relating his later success, or lack of it, to his school experience. Another reason for needing behavioral objectives relates to the cost effectiveness of educational programs. The American taxpayer will inevitably grow weary of continuing to vote increased taxation for education with no tangible evidence of the effect of these funds on the education of his children. With the performance objectives it should be possible to associate behavioral change with program cost. Student learning should certainly be the most important, if not the only, basis upon which cost effective analyses are made in education.

Once these objectives are set, and agreed upon, all the other variables in the educational program need to be arranged in such a way as to optimize student attainment of the objectives. It should be possible to experimentally manipulate the other variables disregarding, where possible, the traditional constraints found in the educational system. This can be done by careful and systematic planning.

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