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## ABSTRACT

Three characteristics of computer-assisted instruction (CAI) make it suitable for individualizing instruction: adaptive response by the student, continual evaluation of the student's responses, and adaptability of instruction to the individual's responses and his achievement levels. CAI systems are being used for laboratory computing, record keeping and retrieval, simulation, and tutorial instruction. CAI is difficult to compare with traditional instruction because of differences in objectives and techniques. Still, CAI has been shown to teach a comparable amount of material with a considerable time saving. However, use of CAI requires quantities of suitable curricular materials which have not been available. Cost effective use also requires after school use of facilities for adult or inservice teacher education and administrative applications which would utilize night hours. Five institutions in Pennsylvania have been concentrating on various aspects of CAI research and development. The Learning Research and Development Center (University of Pittsburgh) has focused on systems software and student terminal development, while Pennsylvania State has been concerned with curriculum development and implementation. Three school districts in the state are oriented toward the classroom application of computers. (MT)

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**COMPUTER ASSISTED INSTRUCTION LABORATORY**

**COLLEGE OF EDUCATION · CHAMBERS BUILDING**

**THE PENNSYLVANIA · UNIVERSITY PARK, PA.  
STATE UNIVERSITY**

**Computer-Assisted Instruction:  
Status in Pennsylvania**

by

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**July 1970**

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**COMPUTER-ASSISTED INSTRUCTION:  
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PENNSYLVANIA DEPARTMENT OF EDUCATION  
Computer-Assisted Instruction

Overview

Individualized Instruction

Many devices and machines have been proclaimed in the past to provide improved instruction in the schools. Among these are motion pictures, television, language laboratories, programmed instruction, and teaching machines. None of these techniques have lived up to their early promise in making contributions to the instructional program in the schools. This finding results from the inherent lack of theory upon which the materials and use of the machines have been based. There is little learning theory to undergird the use of most of these devices. For the first time in education, a new technology--computer-assisted instruction--has the promise of providing some of the quantum jumps in instruction that have been hoped for in the past. Computer-assisted instruction has the flexibility and capacity for individualizing instruction, which seems to be necessary for achieving adaptive education. There are three fundamental characteristics of computer applications in instruction which suggest that significant steps in improving instruction can be achieved through the utilization of computers. The first of these characteristics is the ability of a pre-stored program in a computer system to evaluate the student's responses and provide information regarding the correctness of these responses. In a typical classroom of 30 students only the very bright, aggressive students will be able to respond and receive feedback from the teacher as many as five times each period. The poorer and reticent students may receive feedback two or three times each week during the school year. Results to date show that students receiving instruction from computers respond anywhere from once every four seconds to once every thirty seconds. This means that each student whose instruction is being provided through computers is responding and receiving feedback from 40 to 600 times during a 40-minute session at a computer terminal.

A second characteristic of computer-assisted instruction is active responding by the student. Generally, high ability or advanced students are able to

sit down with a textbook or a reference book and learn through reading and other study skills. However, this is often the very problem that a slow student encounters--he simply cannot learn by reading alone.

A third characteristic of computers for instruction is their ability to individualize instruction not only at the level of achievement but in reference to the specific interests and abilities of the student taking the course. The computer can keep a record of the student's performance and progress through a course and alter that course based upon the immediate past history of the individual student in studying that subject matter. This dynamic characteristic of CAI (computer-assisted instruction) makes it possible to begin considering not the passage of time nor the covering of a specific text nor doing a given number of problems as criteria for progressing through the curriculum, but the opportunity to base student assessment upon the mastery of predetermined criterion levels.

### History of Computer-Assisted Instruction

Sidney Pressey in the early 1900's and B. F. Skinner in 1954 provided the earliest attempts to "automate" instruction. Both Pressey and Skinner developed techniques of administering instructional materials to students by means of teaching machines or through programmed texts. Much of Skinner's work was based on his experimental studies in training pigeons to perform certain tasks--some very simple and some very complex. It was soon discovered, however, that programmed texts and teaching machines were extremely limited in the extent to which they could adapt to individual differences among students or provide a stimulating responsive environment for students. The obvious limitations of these devices prompted the investigation of applying computers to instructional tasks.

In 1959, researchers at IBM developed a course to teach stenotype and binary arithmetic by computers. At the same time, refinements were being made in computer systems, terminal configurations, and in the number of terminals that a given computer could support. Some of the original systems would support one terminal, but later systems were able to support 40 to 50 terminals simultaneously. Currently computers such as the system in New York City are able to support as many as 200 terminals concurrently (Butler, 1969).

One of the basic problems in the early development of computer-assisted instruction was that most systems were built around modified business computers and terminal devices. The use of modified business equipment resulted in systems and terminals which were not appropriate for instructional purposes. An analogy might be an individual purchasing a Greyhound bus for primary use as a family car. It is true that the bus would get a man where he wanted to go, but it would not be very convenient or practical.

In 1966, IBM announced the development of the 1500 Instructional System. Although several prototype models were delivered prior to December 1967, the first production line model was delivered and installed on that date. The 1500 System was the first computer system which was designed and developed specifically for instructional purposes. Systems developed in the late 50's and early 60's used either an electric typewriter or a teletype terminal as an interface device by which the student received information from the computer and through which he transmitted information to the computer. The system which was designed specifically for instructional purposes and others which have been designed since 1967 have utilized a small television screen as the major display device for the student. The television set has a typewriter keyboard and often a light-pen through which the student can input responses to the program. More complete systems include random access audio, playback/record capability, and random access image projectors all under program control.

### Types of CAI

In considering the concept of computer-assisted instruction, it is important to recognize the differing applications of computers in instruction which are referred to collectively as computer-assisted instruction (Mitzel and Brandon, 1967). The first of these applications is the use of a computer as a laboratory computing device which is perhaps the most common use of computers in public education. A single terminal (generally an electric typewriter or teletype) is placed in a classroom and provides direct access to a computer at some remote location. The students are allowed to develop programs related to the course work which they are taking. This use most often occurs in a mathematics, physics, or chemistry class. There are an estimated 500 high schools in the United States with this capability. (Entelek)

A second definition of computer-assisted instruction involves the use of the computer as a record keeper and retriever which is primarily used by faculty members or administrators for batch processing of data regarding students or regarding instruction in the school. This category of use quite often includes the scheduling of classes, printing of report cards, and the storage and retrieval of test results which are utilized by guidance counselors and other staff.

A third form of CAI can be defined as simulation with the computer responding adaptively to learner input. A great deal of work in this application of computers to instruction has been done in the field of medicine. Sim One (Abrahamson, Wolf, and Denson, 1969) is a life-like device having a plastic skin which resembles that of a human being in color and texture. It has the configuration of a patient lying on an operating table, the left arm extended and ready for intravenous injection, right arm fitted with blood pressure cuff, and chest wall having a stethoscope taped over the approximate location of the heart. Sim One breathes, has a heart beat, pulse and blood pressure (all synchronized), and opens and closes his mouth, blinks his eyes, responds to four intravenously administered drugs and two gases administered through a mask or tube. The physiologic responses are in real time and occur automatically as part of a computer program. At Bolt, Beranek, and Newman, Inc., (Feurzeig, 1968), a computer has been programmed to simulate the conditions of a patient brought into a hospital emergency room. A physician in training sits down at a teletype terminal and by requesting information, tests, and symptoms from the computer regarding his "patient" is able to eventually provide a diagnosis of the specific injuries that the "patient" has received. An even more elaborate diagnostic simulation program is under development at the University of Illinois Medical School at Chicago.

The fourth definition of CAI involves the computer in the role of a tutor. There are various forms which this definition might assume--the most common being that of providing drill and practice problems to students at a terminal and the most complex being that of sequential exposition which provides the primary source of instruction for the student. In this latter form a relatively complete course is presented to a student by means of a computer.

## Research Findings

Studies have shown either the superiority or at least equal progress for students learning through computer-assisted instruction when it is compared to conventional instruction (Hansen, 1967) (Hickey and Newton, 1967) (Mitzel, et al., 1967). Suppes (1966) reports that for experimental classes, in Hattiesburg, Mississippi, which have been provided ten to fifteen minutes each day with drill and practice at a computer terminal, the range of the average mathematics advancement of the pupils has been from 1.10 to 2.05 years among the experimental classes as compared to 0.26 to 1.26 years in the control classes. Butler (1969) also reports similar results in New York City in 1958 and 1969 in the fourth and fifth grades of the classes which were studied. It is very important to point out that this record achievement is the result of only ten to fifteen minutes each day at a computer teletype terminal for drill and practice of mathematics materials. It is difficult to predict what the results would be if students of this kind were utilizing a computer terminal which could provide more sophisticated applications of computer-assisted instruction for a longer time period each day.

One of the difficulties in evaluating computer-assisted instruction today is in the choice of an adequate criterion. When instruction is individualized and is adapted to the specific weaknesses and strengths of the pupils, it is inappropriate to use a norm-referenced measure for evaluating student progress. A more appropriate approach is to utilize a criterion-referenced measure to determine when the students have reached the desired level of achievement. The difference in objectives and evaluative devices makes it difficult to compare progress in CAI with progress in the conventional classroom. Even with these problems of evaluation, a consistent result in the use of computer-assisted instruction has been that the same amount of material has been learned in a CAI environment as in a conventional classroom although with a considerable savings of time in favor of CAI.

The attitude of students has also been an important question with respect to computer-assisted instruction. Quite frequently it is asked whether or not CAI makes the student just another number in a group of students; or does the student feel that this is an impersonal means of instruction. Although

preliminary findings suggest that students on CAI do not feel depersonalized, adequate empirical data will not be available until students have been exposed to CAI over a number of years in varying subject matter areas.

### Administrative Considerations

#### Developmental Sequence

A concept which is common among school administrators is that of "instant CAI." The "myth of instant CAI" is prevalent not only among school administrators but also among the vendors of computer systems. It has been difficult for manufacturers and vendors of computing systems to realize that educators cannot invest money in a system for which there is no curriculum. They have difficulty in realizing that a computer system for CAI must be made available for a long enough period of time to allow the necessary curriculum development before schools will be justified in acquiring systems for operational uses.

The CAI community is just now approaching a point where there is a quantity of materials available which are compatible with other CAI installations and which could be shared by cooperating institutions (Lekan, 1970). By the fall of 1970, there will be just the bare minimum of curriculum available to make it economically feasible to install a system in a large public school for operational uses. To adequately utilize a CAI system, there should be quantities of curriculum suitable for full daytime use by students in the school, appropriate curriculum for adult education or inservice education for teachers during the after-school and evening hours, and finally, administrative applications which would utilize the midnight to 8:00 a.m. time period. By combining these various applications on a computer it would be economically feasible to install systems in many school districts.

#### Cost of CAI

One of the questions which invariably arises in discussing computer-assisted instruction is "How much does it cost?" The apparent range of costs for CAI is not too different from the range of costs for conventional education.

The cost of public education in the State of New York ranged from \$400 per pupil year to \$4,000 per pupil year. Assuming a 200-day school year and a 6 hour school day, this cost estimate provides a range from 33 cents to \$3.33 per pupil per hour. E. N. Adams (1965) has shown that a fully operational computer instructional system available today costs about \$3.00 per pupil per hour to operate; and Bitzer (1968) has projected (for a system which he is developing) that it will cost 27 cents per pupil per hour.

Four contingencies seem to be operating which may affect the probability of public schools accepting CAI. The first contingency is the relative cost of CAI and other modes of instruction. Three dollars per student hour may seem high, but it is not as high as some specialized instruction such as remedial education, vocational education, or homebound education. Neither is it high if the social costs of allowing individuals to remain undereducated are considered. Another contingency is the fact that technology costs are decreasing. On some of the earlier modified business machines which were utilized for computer-assisted instruction, the cost per pupil hour was as high as \$35 or \$40. With the development of a computer system designed specifically for instructional purposes, this cost dropped drastically to \$5 per hour or slightly less. A third contingency is the rising personnel costs in the public schools. To some extent, public schools and the U. S. Post Office have had similar problems; and to some extent, have responded to the problems in a similar way. There is an ever increasing amount of work which needs to be done in both instances and in both instances the solution to this increasing workload has been increasing the number of personnel to do that work. The increasing number of personnel and the increasing cost of this staff suggests that schools should very seriously consider modern educational technology as an alternate approach for meeting some of these goals. One of the goals of CAI development should be to establish a differentiated staffing program in the instructional environment so that much of the routine clerical and administrative work which teachers quite frequently do can be done with paraprofessional help and thus release the experienced teachers' time for the specific task of attending to the individual needs of the students.

The fourth operational contingency which may increase the acceptance of CAI in the public schools is the fact that a computer system which is installed

primarily for computer-assisted instruction may serve well for administrative functions of that school district. Much of the cost of a CAI system could be justified on this basis. In this connection it is probably wiser to take a computer system designed for instruction and adapt administrative computing to the available time and equipment configuration. The prospect of taking an existing administrative computing system and grafting an instructional application onto it seems to have low probability for success.

### Significant Instructional Applications of CAI in Pennsylvania

Computer-assisted instruction activities in the Commonwealth of Pennsylvania have been concentrated within five agencies of the State: the Learning Research and Development Center at the University of Pittsburgh; the CAI Laboratory at The Pennsylvania State University; the Altoona Area School District; the School District of Philadelphia; and the School District of Pittsburgh. The range of interests and emphasis among these organizations is as broad as the range in interest and emphasis is nationally and encompasses all of the types of CAI mentioned earlier.

#### University of Pittsburgh

The computer-assisted instruction activities at the University of Pittsburgh are housed administratively within the Learning Research and Development Center which was established in April 1964 (Ragsdale). The CAI program has two principal objectives which guide the scope of the effort within this group. The first objective is to provide facilities and services needed to support the research and development effort of experimental psychologists and others working in the field of instructional technology. The second objective of the group is to conduct experimental work related to 1) the development of languages which educators can use for implementing subject matter programs, 2) the development of student stations that will provide a high degree of interaction between the student and the subject matter, and 3) the development of curricula for experimental purposes.

### The Pennsylvania State University

The Computer Assisted Instruction Laboratory (established in 1964) at The Pennsylvania State University functions as an integral part of the College of Education at the University and as such CAI is making contributions at the elementary (Demshock and Riedesel, 1968) and secondary school level (Mitzel, Hall, and Igo, April 1970) as well as at the undergraduate and graduate level in both preservice and inservice teacher education (Hall, et. al., 1970; Long and Riedesel, 1967). The staff at the Laboratory has devoted considerable time and effort in developing inservice teacher education programs--one such program was a course in modern mathematics which has been taken by more than 500 public school teachers. Another program in identification of handicapping conditions designed for elementary school teachers will be made available to approximately 1,000 inservice teachers per year beginning in the fall of 1970 by means of mobile computer-assisted instruction facilities.

A marked difference between the efforts of the CAI Laboratory at Penn State and the CAI Laboratory at the University of Pittsburgh is that the staff at Penn State has chosen to focus on curriculum development and implementation for public school and higher education whereas the University of Pittsburgh has focused on computer systems software and student terminal hardware development.

One of the main interests in the College of Education at Penn State is the improvement of preservice and inservice teacher education. There are a large number of elementary teachers in rural Appalachia who have not had the opportunity to participate in institutes, workshops, or college courses since they left college 20 to 25 years ago. One of the factors contributing to this situation is that a majority of the elementary school teachers are also doubling as housewives with families. It is often impossible for them to leave their families for the summer and go to a university or college to update their background and skills. In February 1969, Penn State mounted an inservice education program in three locations in rural Appalachia (Hall, et. al., 1970). A complete computer system with 16 student stations was moved sequentially into three different rural communities. The system was installed and made operational with a program in modern mathematics for elementary teachers. In the three settings, the program served a total of 387 educators. Mobile computer-

assisted instruction has demonstrated the potential for providing high-quality individualized, inservice education to large numbers of students in sparsely settled areas.

### Altoona Area School District

As one might expect, the public schools in Pennsylvania that have been involved with computer-assisted instruction have been oriented toward the application of computers in the classroom (Heslep). The computer facility in Altoona began in 1964 as a small unit for the instruction of about 200 vocational students. Altoona now has time-sharing computer facilities serving about 4,000 students in the areas of mathematics and science in 16 public and parochial high schools in 5 counties of Pennsylvania. What originally started out as basic vocational instruction in computers has expanded into three separate computer applications: computer technology for the vocational-technical high school, unit record instruction for business students, and problem-solving in mathematics and science by remote terminal on the time-sharing system. The use made of the computer in these latter courses is generally described as problem-solving. In chemistry, for example, students are taught to write simple computer programs for the solution of problems involving Boyle's Law, Charles' Law, and gram-equivalents. In mathematics, programs to solve quadratic equations, square roots, areas and perimeters of plane surfaces, and solutions of right triangles using trigonometric functions are written. In physics, students learn the fundamental principles by writing computer programs for applying the laws of falling bodies, calculating angular velocity, moment of inertia, and heat exchange problems. Students are also required to write simple computer programs "off-line" for some secondary school courses. A paper tape is prepared for inputting the program into the computer through the teletype terminals. The student then receives a printout which tells him whether or not the program was written correctly. Students react very favorably in this learning situation. Most comment that the computer is extremely helpful to them in understanding the meaning of the laws and principles for which they themselves programmed exercise material. It is hypothesized that because the computer does the actual calculation, the student can more easily attend to and concentrate upon the principles and their applications.

### School District of Philadelphia

The School District of Philadelphia established the Division of Instructional Systems in 1966 to facilitate and coordinate the implementation of computers in the instructional programs in Philadelphia (Charp, 1968). The uses being made of computers in the educational process in Philadelphia include demonstrations of computer applications, gaming and decision making for elementary children, courses in computer concepts for junior high school students, problem solving applications, and tutorial mathematics, reading, and biology programs for high school students. The equipment and facilities include unit record tabulating facilities, remote teletype terminals, and complete computer installations with cathode ray tube terminals in certain public schools. The involvement of staff members in the Division of Instructional Services has ranged from curriculum development to the development of complete computer systems for instructional purposes.

Biology and reading (Diamond, 1969) have been taught in two high schools and two junior high schools during the 1968-69 and 1969-70 school years as part of project GROW (Germantown High School, Roosevelt Junior High School, Overbrook High School, and Wanamaker Junior High School). The achievements of the CAI students were compared with that of students in traditional classes. The findings show promise but are not definitive because of the normal problems encountered when undertaking an innovative program of this kind--equipment reliability, appropriate standardized testing instruments for new curricula, and independent (non-confounding) experimental treatments.

### School District of Pittsburgh

The School District of Pittsburgh established a pioneering position in CAI by organizing a consortium effort to apply the existing CAI experiences within the Commonwealth toward the development and implementation of two ninth grade mathematics courses. This effort may very well become a model for CAI curriculum development efforts in the future. It offers the advantage of focusing curriculum development on the specific needs of large city school districts while drawing on the research and development experience of the state university and the curriculum coordinating function of the Commonwealth Department of Education.

Four educational agencies within the Commonwealth of Pennsylvania (the School District of Pittsburgh, the School District of Philadelphia, The Pennsylvania State University, and the Department of Education) have entered into a consortium to apply their individual strengths and backgrounds to the development of a ninth grade general mathematics course and a ninth grade algebra course to be administered in an individualized program, a portion of which is via computer-assisted instruction. Teachers from each of the school districts were in residence at the University for eighteen months to participate in the development of a new curriculum in cooperation with mathematics educators and CAI technical staff at the University.

One of the goals of the project was to develop a utilization pattern which would fit within the existing environment of public high schools. Therefore, it was determined that the students would be assigned to a given class for a period and would remain in the class during the entire calendar year. In order to follow this procedure and still maintain a high degree of individualized instruction, the basic mathematics skill materials were programmed on the computer for the two courses. It was assumed that on the average each student would spend half a period each day at a computer terminal and the other half period working on off-line or in-depth enrichment materials. It was assumed that the very slow student would probably need to spend most of each period each day of the week at the computer terminal and the very fast students might spend only ten or fifteen minutes during any week to achieve the basic skills which they needed. The off-line activities provided the enrichment or extension of knowledge which the teacher in the classroom felt that each pupil needed. This program is currently undergoing a field trial in Schenley High School in Pittsburgh and Lincoln High School in Philadelphia. A computer system has been installed in each school with eight terminals in one classroom. Sixteen pupils and one teacher are assigned to that classroom each period. Revisions and improvements in the curriculum are being made to suit the specific needs of the students based on the student records which have been collected on a daily basis. The computer system retains a file of information regarding the progress of each student. A summary of this progress is given to the teacher as he requests it to guide him in his interactions with the students. The attitude of the students toward the mathematics that they are learning and

toward school itself as it exists in these classrooms has been extremely encouraging. Comments by the students indicate that they feel as though they are growing in the field of mathematics and also that they and the teachers are working cooperatively in determining the direction that each pupil should take and the goals for which they are striving.

#### Summary

Computer-assisted instruction has the flexibility and capacity for individualizing instruction which is necessary for achieving adaptive education. Three characteristics of computer applications in instruction make this possible: 1) active responding by the student; 2) continual evaluation of the student's responses, and 3) adaptation of the instruction to individual responses, level of achievement, and in reference to the specific interests of the student taking the course.

Early uses of computers for instruction date back to 1959. Earlier systems using typewriters or teletypes for the student stations would support only one station at a time. Later systems have been developed using more sophisticated cathode ray tubes as student stations and will support as many as 32 stations simultaneously. Other systems using teletypes or typewriters can support up to 200 terminals concurrently. These various systems are being used for laboratory computing devices, record keeping and retrieval, simulation, and tutorial instruction.

Differences in objectives and evaluation techniques make it difficult to compare student progress in CAI with student progress in the conventional classroom. When instruction is individualized, it is adapted to the specific weaknesses and strengths of the pupils and it is therefore inappropriate to use a norm-referenced measure (which is quite acceptable for conventional classes) for evaluating student progress. In the same vein, a criterion-referenced measure which is appropriate for use in measuring student progress in CAI is inappropriate for evaluating student progress in traditional classes. Even with these problems of evaluation, investigations have consistently shown that the same amount of material has been learned in a CAI environment as in a conventional classroom although with a considerable savings of time in favor of CAI.

Operational use of a CAI system requires quantities of curriculum material suitable for full daytime use by students in the school, appropriate curriculum for adult education or inservice education for teachers during the after-school and evening hours, and administrative applications which would utilize the midnight to 8 a.m. time period. The combination of these various applications make it economically feasible to install systems in many school districts. The range of costs for CAI is not too different from the range of costs for conventional education--from \$3.00 per pupil per hour for highly sophisticated systems to \$.27 per pupil per hour for less sophisticated drill and practice systems. Decreasing technology costs, rising personnel costs, and multiple uses of computer systems all indicate that computer-assisted instruction will be able to compete very favorably for instructional dollars when it is compared with the conventional kinds of instruction.

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