PROTOTYPE COMPUTER-ASSISTED INSTRUCTIONAL SYSTEMS

by

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B. A., Sterling College, 1962

A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

College of Education

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1967

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ACKNOWLEDGEMENTS

The author wishes to express his gratitude to Dr. Russel G. Drumright for his guidance and constructive criticism in the preparation of this report, and to Dr. S. T. Parker for his interest and assistance in obtaining supplementary material.

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I. INTRODUCTION

In recent years the demands upon our educational system have increased almost exponentially. More and more students crowd understaffed schools on all levels. Physical plant expansion has been unable to cope with the increasing tide of students, while the teaching profession has been unable to attract and train sufficient numbers to staff the existing schools. Colleges and universities are being forced to be more selective in their admissions policy because of severe lack of personnel and facilities.

Yet our society demands more and better trained young men and women. The advancing technology requires highly skilled and well educated persons to fill existing positions, and many new and diverse positions are being created daily.

How is our educational system to cope with these demands? Perhaps the technology which predicates these demands also suggests a plausible solution to the problem it has created. Fundamental to the progress of our advancing technology is the capability to acquire, process, and interpret data or information, and to make logical decisions based on such interpretations. The device which contributes largely to the rapid processing of data is the electronic digital computer, the central device in advanced electronic data processing centers.

Interest in the application of digital computers to alleviate some of the aforementioned educational problems has been exhibited by many. Actual systems utilizing computer-based teaching machines have been developed and are currently operational.

Purpose: It was the purpose of this paper to discuss such computer-assisted instructional systems: their conception, design and organization, and their application. A further purpose was to indicate briefly what work was in progress toward more advanced and sophisticated systems in 1966.

Limitations: This study was limited to published work carried on by colleges and universities, and research and development segments of business organizations, both profit and non-profit, located in the continental United States. In addition, the study was concerned only with relevant literature available in the Kansas State University library published between the years 1956 and 1966, supplemented by materials obtained directly from the research groups making significant contributions to computer-assisted instruction.

Definitions:

Computer-assisted instruction system (CAI system)--refers to an instructional system which actively uses an electronic digital computer as an integral part of the instructional process, not only as a computational tool, but as a reactive, responsive device capable of controlling the learning environment.

Teaching logic--refers to the strategy used in a computer program for the presentation of CAI material. It includes the selection and organization of: (1) appropriate stimuli, (2) branching criteria, (3) information pertaining to the interaction which is to be recorded, and (4) replies the computer makes to student responses.

Terminal equipment--refers to the devices used for computer-student communication. This equipment may be remote--several hundred miles from the central computational facilities.

II. PRINCIPLES OF LEARNING AND TEACHING WHICH UNDERLIE CAI

Many deficiencies in our present educational system arise from the inability to implement basic teaching principles. Chapman and Carpenter[1] list eight principles of teaching which have evolved over the centuries:

1. Information should be presented in a logical, step-by-step sequence.
2. Learning should proceed from the known to the unknown.
3. Instruction should proceed at a student's own pace.
4. Efforts should be made to insure the student's understanding of each point before he proceeds to the next.
5. Misunderstandings should be detected and corrected immediately.
6. New ideas should be made meaningful in terms of the student's own experience.
7. The student should actively practice what he is learning.
8. Instruction should be fitted to the comprehension of the learner.

Thought given to the manner in which these principles might be applied in our present school situations will indicate that it is not feasible to implement four of these principles. Because a teacher must supervise more than a single student,

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[1]R. L. Chapman and J. T. Carpenter, "Computer Techniques in Instruction," Programmed Learning and Computer-Based Instruction, J. E. Coulson, editor (New York: Wiley and Sons, 1962), pp. 242-43.

often twenty or more, it becomes impossible to allow each student to proceed at his own pace. Nor is it possible to determine whether each understands the present point before proceeding. Misunderstandings are often detected only when tests are given, far too late for immediate and effective correction. And even though ability grouping is used in attempts to make classes more homogeneous, this does not insure that each student is capable of comprehending the same material as the others in his group.

Psychological research has resulted in the identification of principles involved in learning and concept formation. Although many are being incorporated in conventional methods of presentation, some inherently cannot be. In an analysis of modern learning theories, Suppes[2] lists four pertinent tenets:

1. There exist significant differences in individual rates of learning.
2. Immediate reinforcement leads to more efficient learning.
3. Overt correction procedures have been shown to be of importance in learning.
4. Response latency has been found to be a more sensitive index of learning than the response errors themselves.

These factors imply that instruction should be individualized. Rigney[3] cites research which further emphasizes the

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[2] P. Suppes, "Modern Learning Theory and the Elementary-School Curriculum," American Educational Research Journal, 1:79-88, March, 1964.

[3] J. W. Rigney, "Potential Uses of Computers as Teaching Machines," Programmed Learning and Computer-Based Instruction, J. E. Coulson, editor (New York: Wiley and Sons, 1962), pp. 166-68.

importance of providing for individual differences. These findings indicate (1) surprisingly broad ranges of intelligence and achievement exist in any one grade level, (2) several different kinds of learning curves exist, (3) several different learning abilities exist, and (4) aptitude patterns shift as learning progresses.

Technology now enables us to utilize individualized instructional techniques with a large number of students simultaneously by using a computer's inherent powerful logical capabilities. Other considerations lead to the use of large-scale computational facilities. The desire for flexibility is met by such an installation. Not only is the computer capable of branching on a number of predetermined criteria, and thus adjusting to the individual learner and his unique learning problems, but complete teaching logics and instructional sequences may be quickly interchanged. Since present work will undoubtedly lead to modifications of CAI systems, this flexibility will mean that only minor programming changes will be required instead of costly redesign, development and installation of improved electronic devices, or deletion of previously developed devices. Thus, when the equipment is being used as a research tool, the computer's operation can be quickly altered between training sessions when such alterations arise during investigation of different training procedures or machine characteristics.

It is more economical to have one appropriately large, fast decision making device necessary for adequate individualization located centrally compared with less flexible and slower computers located at each student station. The advantage of sophisticated data storage, retrieval and analysis also encourages the use of a large-scale computer.

To prepare course materials for use with CAI systems, a computer program must be written. Programming languages engineered for mathematical and scientific applications exist, permitting a mathematician or scientist with little knowledge of the basic computer language to write programs for the solution of their problems. The computer uses an assembly routine to translate these programs into routines readily useable by the computer. Likewise, programming languages for course authors are being developed to permit such an author, with little knowledge of the computer or its repertoire of commands, to write a complete program. Using an assembly routine, the computer can translate this program into a routine which it can accept and execute. Such assembly routines require fairly large processing facilities for their use.

III. POTENTIALS OF CAI

The potentials of CAI exist in two categories. There are features which affect the learner engaged in CAI interaction at the time of the interaction, or "primary potentials." Subsequent learners benefit from "secondary potentials." These potentials have some areas of overlapping.

Primary Potentials

Primary potentials of CAI allow more complete application of learning theory. Some of the psychological principles of learning can be incorporated in our present educational system, such as making the learning meaningful to the learner and organizing material in a logical order, leading the student from one point to the next. However, CAI permits various other psychological principles to be utilized in the process of instruction.

Organization of stimulus materials. In preparing a course for presentation via CAI, each contingency must be anticipated--each step of significant size must be supplemented with auxiliary material to help along those who do not grasp the content of the item in the main sequence of material. The logic and organization of the material must be continuous and orderly, and finally, the sequence must be submitted to experimental use where, by analysis of response data, it can be empirically revised and improved. Thus the presentation is soon sharpened into a logical sequence of items proceeding from the known to the unknown.

Accommodation of individual differences. Computer technology provides for accommodation of individual differences in a number of ways. It permits the student to start at his present level of performance and gradually advances this achievement, in a manner independent of other learners, to a specified level of performance by branching him forward, backward, or laterally--

giving additional help where and when it is needed throughout the sequence of materials. It permits the use of a variety of display and response modes depending on the type of learning and communication skills for which the student shows the greatest aptitude. It permits continual tracking of the student's abilities and aptitude patterns and can subsequently shift teaching logistics to increase learning efficiency. Instruction is automatically fitted to the comprehension of the learner by branching on the basis of the response, response latency, etc., associated with questions embedded in the sequence of material. The student progresses at his own rate, unencumbered by lagging slower learners and inefficient methods of instruction. The computer can ultimately be programmed to respond to the learner in a manner dependent upon his personal data such as aptitude, intelligence, personality traits, etc., thus making the interaction interesting and challenging without severe frustration. As an example, consider a student with an aggressive personality. If his failure to respond correctly resulted in the computer indicating only "wrong," he might react unfavorably, whereas an encouraging "no, not quite!" might challenge him to more concentrated efforts.

CAI increases motivation by interacting individually and by continually adjusting item difficulty or pacing to such a point that the learner does not become bored by simplicity, nor despondent because of discouragement with material which is too difficult. Consequently, a student may find drill and recitation more interesting if sufficiently appropriate and discriminating remarks are interspersed throughout the sequence. Finally, CAI, by relieving the teacher of the burden of too many students, too much routine and drill, grading, testing, and record keeping, permits more time for personal interactions between the teacher and the student. Moreover, this relationship may be warmer because of the greater depth of friendship possible when tiring routine and paperwork and frustrating situations have been eliminated. More encouragement and assistance can be given the slow learner while the fast learner can proceed under closer supervision toward even higher levels of attainment.

Data acquisition and analysis. Computer technology permits rapid and accurate acquisition and analysis of pertinent data. As a result of the interaction between the computer and the learner, the following data may be obtained: (1) a complete record of each interaction, i. e., the specific constructed or selected response(s) to a given stimulus frame, (2) the inclusive response latency, (3) the total time per item, (4) the particular route taken through the material, and (5) the total time of the interaction. Subsequent analysis of these data yields information such as the number of correct responses, the number of incorrect responses, the number of responses satisfying a given criterion (e. g., responses within a given interval following the presentation of a stimulus), specific types of learning problems, learning rate, learning efficiency, etc. Also, improved measures of student achievement are possible, which may replace weekly or unit tests. Further analysis of information relating to student learning problems permits more accurate counseling and direction in a student's program of studies. More important, however, is the potential for continuous student classification and placement--engineering the student's curriculum to his expressed needs.

Knowledge of results. CAI yields immediate knowledge of results and therefore reinforces correct responses while discouraging the learning of incorrect responses. If an incorrect response is given, the fact that the response is incorrect can be revealed without informing the learner of the correct response. Remedial help at this point leads the student toward the correct response. Misconceptions are thus cleared up before proceeding to the next point. Questions may be included in the instructional sequence to determine whether the student has mastered the immediate material. If he has not, he is branched to remedial sequences. Only after successfully answering these questions is the student permitted to continue.

It has been demonstrated that overt correction procedures enhance learning. The incorporation of such procedures in the teaching logic is easily accomplished and the computer can check the student's corrected response to see that it is acceptable.

Timing and pacing. Since the individual is interacting with a device capable of making timings, the previously mentioned response latencies can accurately be measured for each associated stimulus-response item. As this variable has been shown to be a more sensitive index of learning than the actual response, branching can take place on this criterion, insuring that the student really understands the item and has not simply guessed at an answer.

Pacing in skills included in arithmetic, reading, spelling, typing, vocabulary, etc., can be accomplished by continually decreasing the acceptable response time and requiring increasing performance.

Meeting external criteria. It is possible to program the computer to meet external criteria such as producing favorable attitudes toward the subject involved or the method of presentation utilized, the speed with which learning is desired, or the terminal achievement level to be attained.

Secondary Potentials

Secondary potentials of CAI are those capabilities which affect subsequent learners. Using CAI, a given instructional technique can be evaluated more objectively than with other methods of presentation, because more variables can be controlled. It becomes possible to develop new testing techniques involving test items dependent on student profiles or incorporating response latencies. CAI provides a more controlled environment for the administration of standardized test items, and in fact, allows standardized tests to be prepared under more controlled circumstances. CAI makes easier the introduction and development of many standard skills such as those involved in arithmetic, spelling, reading, vocabulary, etc., in a straightforward and systematic manner. It may become possible to raise the standards we expect students to meet in subjects requiring drill and practice, and ultimately to raise the quality of education.

Group data analysis will yield information identifying ineffective instructional sequences. These sequences may then be revised and tested. Eventually the result will be a highly effective instructional sequence. These data will produce information which will assist the curriculum developer to evaluate and modify the entire curriculum.

Probing psychological studies of subject-matter learning and transfer among concepts will become feasible, since data can now be accumulated in sufficient quantity and under sufficiently controlled conditions to lend validity to the results of such analyses. The understanding of human learning will also be given a more substantial basis through the acquisition and analysis of valid data.

Over the years, a finite number of solutions to a finite number of learning problems encountered in specific instructional programs and curriculum materials will be delineated. The computer, having access to this information, will be able to select appropriate solutions for an individual's identified problems.

IV. PROTOTYPE CAI SYSTEMS

Many of the potentials mentioned above have already been realized. Since the first article published in 1960, much work has been carried out, primarily by psychological research facilities, by the manufacturers of computers, and by corporations with vested interest.

CAI may be conveniently subdivided into four categories, based on the type of interaction involved. These include (1) simulation systems, (2) drill and practice systems, (3) tutorial systems, and (4) dialogue systems.

Simulation systems. Simulation systems are based on methods of simulation. Usually a mathematical model for some process is developed, then used with the aid of a computer to study the effects of changing different parameters involved in the process. In this system, the computer acts more as a calculational device rather than as an instructor.

One application of a simulation system has been made by Wing[4] in a school in Westchester County, New York. The "Sumerian Game" provides experience for the sixth-grade student in the field of economics. The student becomes king of a fictional early civilization and is responsible for decisions relating to the use of grain in his kingdom. In a short time he

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[4]R. Wing, Status of Current Project (Yorktown Heights, N. Y.: Board of Cooperative Educational Services, June, 1966), pp. 1-3. (Mimeographed Attachment of report on USOE Project No. 2841 entitled "The Production and Evaluation of Three Computer-Based Economics Games for Sixth Grade.")

is confronted with several years of problems such as drouth, population increase, etc., and must decide how much grain to allocate for planting to assure abundance, for storage in case of famine, and for consumption without depleting supplies on hand. If he is successful, he is permitted to reign as a second monarch who must apply his grain surpluses to the development of crafts. Success in this reign permits him to rule as a third monarch, this time responsible for the solution of trade problems and foreign policy.

A second game, the "Sierra Leone Development Project," simulates economic problems confronting a newly emerging nation with secondary emphasis on the culture of the country.

In "The Free Enterprise Game," the student becomes a small toy store owner and makes decisions pertinent to the operation and expansion of such an enterprise.

The "Ersatz Laboratory" utilizes a different aspect of the simulation technique. Adams[5], of IBM, describes such a substitute laboratory similar in use to the traditional laboratory, but without the usual equipment. This type of laboratory permits investigations of phenomena which take place so slowly or so rapidly that actual laboratory investigation is impractical. Simulated experiments would be harmless whereas free experimentation in areas such as Chemistry are potentially

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[5]E. N. Adams, Roles of the Electronic Computer in University Instruction, IBM Research Report RC 1530 (Yorktown Heights, N. Y.: IBM Watson Research Center, October 29, 1965), p. 8.

dangerous.

As an example, Adams describes a program designed to give a student experience in organic chemical analysis by allowing him to specify a test to be performed on a hypothetical sample. He is informed of the result by being shown a still color picture of the state of the sample after the test. He then requests the performance of a subsequent test. In this way he becomes familiar with many kinds of chemical compounds as well as the logical scheme used to identify some unknown sample.

Bitzer[6] describes a simulated laboratory for clinical nursing instruction, under study at the Coordinated Science Laboratory of the University of Illinois. After viewing a film concerning a clinical nursing situation, the student nurse can experiment with the patient by (1) giving or changing activity, (2) giving or changing diet, (3) giving or changing nursing care, or (4) giving or changing drugs. Provision is made for checking conditions of the patient, or checking laboratory norms. The information obtained from this simulation is used to answer questions relating to the filmed situation. In addition, the computer provides dictionary help as well as remedial help in answering these questions.

Drill and practice systems. The most basic instructional systems, drill and practice systems are designed to supplement

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[6] M. Bitzer, Self-Directed Inquiry in Clinical Nursing by means of PLATO Simulated Laboratory, Report R-184 (Urbana, Ill.: Coordinated Science Laboratory, December, 1963), pp. 11-15.

the regular curriculum as handled by a teacher. They may be used to teach skill subjects such as arithmetic, foreign language vocabulary, spelling, and stenotypy.

In drill and practice systems, a stimulus is first displayed. The student responds to this stimulus and the computer evaluates the response. The student is informed of the quality of the response and the computer then selects the next item for presentation. Should the response be correct, the computer chooses the next item in the sequence. If the response were incorrect, the stimulus might be displayed again with a cue, or it might be placed in a missed group to appear later in the lesson for a second try.

Uttal[7] describes a drill and practice system at IBM used to teach stenotypy. The instructional sequence includes the following steps:

1. The word to be encoded is presented to the student. According to his record of experiences with this word, it might appear with appropriate abbreviation and/or cue lights.
2. The student keys his response into the keyboard. When all keys have been released, the information is entered into the computer.
3. The computer evaluates his answer and indicates whether he is correct or incorrect.
4. A new item is presented to the student, or the same item is repeated, as determined by the branching logic programmed into the computer.
5. After a number of these items has been presented, a lesson is considered complete, and the student is querried to determine if he wants to

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[7] W. R. Uttal, "On Conversational Interaction," Programmed Learning and Computer-Based Instruction, J. E. Coulson, editor (New York: Wiley and Sons, 1962), pp. 178-79.

> continue. While awaiting the student's reply, the computer assembles a new set of items from lists of new or missed items.

Another drill system has been developed by Licklider[8] at Bolt Beranek and Newman Inc. Designed to teach German vocabulary, this system first presents a German word from a set by computer-controlled typeout. The student responds by typing its English equivalent. If the response is correct, he is so informed, a hypothetical score is posted, the student is complimented, this item is removed from the original set of words, and another is selected. If the student gives an incorrect response, the computer indicates this, places the item in a missed set, and asks if the student wants to try it again, or if he wants to see the correct response.

When the student finally replies appropriately, the computer posts a score, makes a suitable remark, and presents another item from either the original set or the missed set. It should be noted, however, that the student must see the correct response before he continues to the next item. If he does not know the English equivalent and must ask to see it; it is presented and the student must copy it before continuing.

Arithmetic drills have been prepared by Suppes[9] at

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[8] J. C. Licklider, "Preliminary Experiments in Computer-Aided Teaching," <u>Programmed Learning and Computer-Based Instruction</u>, J. E. Coulson, editor (New York: Wiley and Sons, 1962), pp. 219-23.

[9] P. Suppes, M. Jerman, and G. Groen, <u>Arithmetic Drills and Review on a Computer-Based Teletype</u>, Technical Report No. 83 (Stanford, Calif.: Institute for Mathematical Studies in the Social Sciences, November 5, 1965), pp. 4-5.

Stanford University for use with CAI. The student types in his name and the computer then types the first problem, leaving a blank for the response. The carriage of the typewriter is then repositioned so the response will appear in this blank. A correct response is reinforced by the display of the next problem, indicating his success on the previous item. An incorrect response results in the word "wrong" being typed out and the correct answer being displayed. If missed, the problem is repeated to permit a correction response. An error on the correction response causes the message "wrong" to be typed and the correct answer is again given. The next problem is then presented without requiring a correction.

Pacing is accomplished by requiring a response within a ten-second time limit. If no response is made until ten seconds have elapsed (known as a time out), the computer notifies the student with the typeout "time is up", the correct response is given and the item is repeated for a correction response.

Upon completion of a lesson, the computer summarizes the results of the interaction by displaying the total number of errors, problems missed and their identification, and total elapsed time. The student retains this copy of his interaction with the computer. At the end of the day when all students have completed their work, the teacher obtains a summary of the day's work including the number of students making errors or time-outs on each problem, the number of students making 0, 1, 2, etc., errors or time-outs, and a distribution of the total elapsed time for the class, etc.

A more advanced drill system at IBM is reported by Adams.[10] The system is designed to encompass five types of exercises in learning German grammar. (1) Aural discrimination training is attempted by reproducing sounds via computer-controlled tape recorder as the stimulus, and requiring suitable written symbols as the response. Advanced exercises include judging and rating utterances which are intentionally poor by comparing them with previous models. Tests for aural discriminations are included to indicate the need for remedial repetition. (2) Vocal reproduction training attempts to develop the correct production of all combinations of sounds which occur in a language, complete with stress and intonation. The computer directs the presentation of a vocal message spoken by a model speaker, records the student attempt to reproduce this message, replays the model utterance followed by the student's attempt, then accepts an index number from the student, rating the degree of imperfection which he has detected in his own response. The computer selects the next item based on this rating. If no imperfection is noticed, no further practice is required. If some imperfection is noticed, several more attempts are allowed for improvements. These computer-controlled sessions are

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[10] E. N. Adams, A Proposed Computer Controlled Language Laboratory, IBM Research Report RC 1558 (Yorktown Heights, N. Y.: IBM Watson Research Center, March 2, 1966), pp. 4-7.

alternated with remedial sessions under the direction of a human instructor who can request a review of the student's recorded tape to determine what remedial instruction is necessary.

(3) Aural comprehension is accomplished by presenting a spoken dialogue followed by a multiple choice question, both in the foreign language. If the student's response to the question is incorrect, the sequence is repeated. Correct responses result in the display of the next item in the sequence. (4) Aural comprehension is also enhanced by having the student identify and transcribe spoken messages into written language. (5) Written grammar drills require the student to construct gramatically, syntactically, and semantically correct German sentences. The computer directs the student by asking him a question in German then accepts the student's typed reply. The reply is edited to eliminate any unusable parts, and word order is rearranged if necessary. The edited response is displayed with incorrect word endings or misspellings indicated by dashes replacing the incorrect part. The student makes the necessary correction and the new response is evaluated. Perfection of the response permits the student to proceed to the next item in the sequence.

Tutorial systems. Tutorial systems are designed to provide nearly complete instruction in a particular subject, not merely to supplement instruction. Virtually all the tutorial systems at present are based on a core of material--a main line sequence which must be completed by each student. In addition, provision is made at each point in the sequence to branch to a remedial sequence. The criteria for branching have been summarized by Bushnell[11] and include:

1. Characteristics of student response--the promptness and/or definitiveness of his reply.
2. Nature of his response--was it right or wrong, what specific errors were committed by the student?
3. History of student learning behavior--his previous response pattern, problem areas, and reading rate.
4. Relevant student personal data--his IQ, sex, personality, aptitudes.
5. Nature of subject matter.
6. Degree of student motivation.
7. Student-generated requests for re-routing.

Uttal[12] describes a CAI course in Psychological Statistics and a course in German Reading prepared at IBM for college students. The student, after identifying himself, is directed by the computer to read a numbered paragraph in his text. At the end of this paragraph the student finds a code number which he keys into the computer. This causes the computer to select a relevant problem which is then presented to the student by computer-controlled typeout. The problem may be a multiple choice item, or a constructed response item. The student responds, and the computer selects the next item based on this response. If the response is correct, the next item in the sequence is presented. If the response is incorrect, the student is guided through progressive levels of remedial material until

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[11] D. D. Bushnell, "Computer-Based Teaching Machines," The Journal of Educational Research, 55:528-31, June-July, 1962.

[12] Uttal, op. cit., pp. 181-88.

he masters the concept or technique being studied.

A system with more sophisticated display features and branching flexibility has been developed by Bitzer[14] at the Coordinated Science Laboratory. Known as PLATO, an acronym for Programmed Logic for Automated Teaching Operations, this system is designed to permit the presentation of a wide variety of subject material.

The computer selects an appropriate item and displays it via closed circuit TV. Instructional items are followed by diagnostic test items requiring student response. The response keyed by the student is displayed in the proper blank appearing with the question on the TV screen. The student presses the "Judge" key and receives an evaluation of his response. If he is wrong, he may request remedial help by pressing the "Reverse" key which permits review of previous material, or by pressing the "Help" key which branches him to a simpler, but related sequence. Once the student identifies the cause of his error, he may leave the remedial sequence by pressing the "Aha!" button which returns him to the main question he has missed. By pressing the "Erase" button, the incorrect answer is electronically removed and the student then keys the corrected response into the machine. He asks the computer to judge his response and is permitted to continue only when the accepted response is

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[14]D. L. Bitzer, E. R. Lyman, and J. A. Easley, Jr., "The Uses of PLATO: A Computer Controlled Teaching System," Audio-visual Instruction, 11:16-21, January, 1966.

obtained.

PLATO has been used to teach subjects ranging from number theory to French grammar by simply replacing the slides to be shown by closed circuit TV and by reading into the computer a new set of parameters specifying correct responses, the positions responses are to assume in the displays, and locations of remedial sequences. Two students may independently use the system simultaneously without any noticeable delay in the processing of his requests.

When more than one student has access to the computer through "time-sharing", queuing is used to insure that requests are processed in the order they are received, or in an order based on a predetermined priority. It is possible to estimate the number of simultaneous users which the computing facility can handle with little delay by analyzing the type and frequency of requests which are input to the system and how long processing of these requests takes. Such queuing studies indicate that as many as one thousand students engaged in up to eight different courses can be handled simultaneously with no noticeable delay in computer responses to student requests.

CLASS[15] (Computer-based Laboratory for Automated School Systems), developed by the Systems Development Corporation at Santa Monica, California, provides another interesting example

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[15]J. E. Coulson, "A Computer-Based Laboratory for Research and Development in Education," Programmed Learning and Computer-Based Instruction, J. E. Coulson, editor (New York: Wiley and Sons, 1962), pp. 191-203.

of a tutorial system. This system is designed for simultaneous use by twenty students, although the data processing facility could handle many more.

The student identifies himself and a number appears on a special terminal device. The number tells the student which frame he should view on his film strip viewer. He advances the film to that frame, reads it and responds to the multiple choice question included. If he answers correctly he is so informed by a green light, and is permitted to continue. An incorrect response causes a red light to come on and a number indexing a remedial frame appears. The student turns to that frame and again responds to the included question. He is returned to the main sequence only after successfully completing the remedial sequence.

A teacher is present to supervise these twenty students and has access through a special console to information concerning the progress of each student. If too many response errors occur for a given student, this is indicated to the teacher by a flashing light. Computer-generated displays tell what topic the student is currently working with, how many errors have been made on that topic, and how many errors have been accumulated throughout the lesson. The teacher can follow the individual's step-by-step progress through the material noting the responses which are made by the student. This information may serve as a basis for the assignment of supplementary material or for individual assistance by the teacher in overcoming the particular difficulty.

A group mode is also available to the teacher wherein stimulus material is presented via closed circuit TV, film, or discussion. The responses to questions in the presentation are summarized immediately for the teacher. Thus, weak points may be readily identified and remedial information may be interjected to clarify these misunderstandings.

In addition to performing tutorial services, the computer can assist in counseling and administrative tasks. Counseling can be based on the computer's analysis of detailed student records. Available to the counselor is a wealth of information about the student which assists in the early diagnosis of learning problems. The counselor, by working closely with the teacher, can help to alleviate these problems, and curricula appropriate to the needs and abilities of the student can be planned. As a further aid to the counselor, a class assignment program may be used to relieve him of routine clerical work involved in assigning students to classes, thus freeing him for more individual counseling.

The computer can also aid in the administration of the school by storing, analyzing and retrieving records of students' class attendance, background data, and school performance as well as school staff salary information, operating expenses and budget projections.

Under development at the Training Research Laboratory of the University of Illinois, is a system which is capable of tutorial instruction. This prototype system is known as

SOCRATES[16] (System for Organizing Content to Review and Teach Educational Subjects). No literature was found concerning its application beyond psychological studies of basic and applied learning.

The system being developed by Suppes[17] is also capable of tutorial instruction, and work is in progress toward a program to instruct fifth and sixth graders in mathematical logic.

Dialogue systems. Dialogue systems are envisaged as systems in which dialogue is possible between the student and the computer. Several technological problems have inhibited the progress of workers in this area. First, it is extremely difficult to write a program to recognize freely constructed questions which may be general and complex. Once it becomes possible to recognize such questions, the problem becomes one of giving a suitable answer. The point is illustrated by the question, "What effect did railroads have on the settlement of the state of Kansas?" Obviously no short answer exists, even if the recognition of the question has been accomplished.

A second, related problem pertains to the recognition of spoken language. Young children are capable of asking fairly complex questions, many of which could be answered in a few

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[16] D. J. Davis and L. M. Stolurow, Computer-Based Systems--The New Research Aid, Technical Report No. 6, Nonr 3985(04) (Urbana, Ill.: University of Illinois Training Research Laboratory, November, 1964), pp. 3-7.

[17] Suppes, op. cit., p. 90.

sentences. Since these youngsters are incapable of typing such questions, the recognition of spoken language is necessary.

Despite these difficulties, some success has been realized in dialogue systems. Swets and Feurzeig[18] at Bolt Beranek and Newman Inc. report efforts to establish a "Socratic System" as a basic dialogue system. The problem of the recognition of questions is circumvented by specifying a vocabulary of phrases to be used by the person interacting with the computer. The problem is further simplified by limiting the scope of the interaction to a specific type of situation.

The "Socratic System" has been used to train medical students in the diagnosis of hypothetical medical cases. The computer requests the student's name then presents a general background description of the case. By selecting an appropriate phrase from the vocabulary the student can "converse" with the computer. The following sample illustrates the type of interaction possible. The student's comments are capitalized.

> Please type your name, the date, and a slash.
>
> MYRA BREEN, AUGUST 1963/
>
> It is mid-December. Late this afternoon, a patient was admitted to the hospital. He is a well-developed, well nourished, 34-year-old Negro coal miner. He was brought in by his wife who reports that he has had "the grippe" for about 4 days. During the past 3 days she has given him fluids and aspirin every 6 hours with no sign of improvement. Today he suddenly became much worse. For the past 2 days he had complained of feeling very warm and of pain in his belly.

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[18] J. A. Swets and W. Feurzeig, "Computer-Aided Instruction," Science, 150:572, October 29, 1965.

This morning he had a severe shaking chill that was so bad his teeth rattled.

You, the admitting physician, are requested to diagnose the case. To obtain the information you need to make this diagnosis, you are required to perform a methodical physical examination of the patient and to order all pertinent lab tests. This is done by typing questions to the computer. The set of questions you may ask is listed in the vocabulary you have been given. The computer will respond to each question with an answer or comment.

. . . .

PHYSICAL EXAM?

Fine. What in particular would you like to know?

CHEST EXAM?

It is common practice in the medical profession to begin an examination by checking the patient's general appearance.

GENERAL APPEARANCE?

Acutely prostrated, lying in bed on his right side. Looks acutely ill, sweaty, apprehensive, but alert. Paroxysmal cough, bringing up a little rusty streaked sputum. Breathing with difficulty.

EENT EXAM?

Check all of the vital signs first!

TEMPERATURE?

103.

BLOOD PRESSURE?

150/84.

PULSE?

100 a minute. Occasional extra systole.

RESPIRATORY RATE?

20 a minute and shallow.

. . . .

After many more tests are conducted and the results obtained, the student is asked if he is ready to make the diagnosis. He continues:

PULMONARY INFARCTION.

Fine. Pleural pain, dyspnea, fever and the physical exam signs and symptoms are certainly consistent with pulmonary infarction. Do you think that shaking chills and the presence of rusty sputum further support this diagnosis?

NO.

Right. Though the white count is consistent, isn't it?

NO.

Wrong. The white count is consistent. This should further support your diagnosis. We've considered one possibility. Do you have another diagnosis in mind?

NO.

In that case I'd like to talk about viral pneumonia. The tachycardia, high WBC, elevated respiratory rate, shaking chills, bloody sputum, and severe pleural pain all lend weight to that diagnosis--right?

YES.

You're way off base. There's not an iota of truth to any part of what I just said; in fact, the opposite of what I said is true. You'd better review some elementary medicine, doctor.

. . . .

Even though the student is not allowed to querry the computer in freely constructed sentences, little is lost in the interaction. The computer can respond in complicated patterns because the author of the program provides these responses.

A problem in business management has been developed by the same group as well as an interesting demonstration program involving the identification of an unknown letter of the alphabet by requesting the number of curves, horizontals, verticals, obliques or loose ends making up the letter.

V. ECONOMIC FEASIBILITY OF CAI

Educators realize the situation facing the schools, and many are also aware of the potentials of CAI. The success of CAI in drill and practice as well as in tutorial interaction has been demonstrated. Concern now centers around the question of the economic feasibility of CAI.

It appears that the expense of CAI would prohibit its use in every way excepting research. Large-scale data processing systems are quite expensive, and the necessary terminal unit or units and interconnections only add to this cost. However, computer manufacturers have taken advantage of many cost-reducing developments and, in fact, often sponsor such developments in their own research departments. Meanwhile, advances in electronic technology are constantly resulting in more compact, higher speed and more reliable components. This increases the capability of equipment while decreasing the size, maintenance and subsequent loss of operating time while maintenance is being performed. All these factors point to the probability of significantly reduced cost of adequate data processing facilities.

As the demand for data processing systems increases, large-batch production techniques will permit the further reduction in per-unit cost. Slower machines, made obsolete by the larger, faster machines, will appear in abundance. This used equipment, although unsuited for some applications, will undoubtedly be capable of serving well in many CAI systems. This point is illustrated by the work conducted by Uttal,[19] who has used an unsophisticated IBM 650 RAMAC vacuum tube computer for his experiments at IBM.

Time sharing has been incorporated in several systems at present, but in each system it is being expanded to encompass a much larger number of students. Queuing studies made in connection with the PLATO system indicated the possibility of simultaneous use by one thousand students. Although the cost of terminal devices needed to accomplish this potential would be significant, the savings in computer time would likely overshadow this expense.

If the school system were small, or not financially prepared to incorporate CAI on a large scale, terminal units could be installed at the school and the communication between student and computer could be carried by telephone lines between the remote data processing center and the school.

The cost of preparation of materials suitable for use in CAI is also prohibitive at present. This problem is being overcome by the development of programming languages for use primarily by educators. Course authors now have access to

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[19]Uttal, op. cit., p. 173.

COURSEWRITER,[20] prepared by IBM, which speeds the preparation of materials. A great deal of routine clerical work is also handled by the computer, reducing the number of complications, or "bugs" which plague lengthy programs.

With the increasing size and complexity of school systems and the difficulties introduced by joint state and federal finance, record keeping and analysis becomes a sizeable problem. When classes are not in session, the computer facility could be used to handle such information.

The most important consideration, however, is that of how the instruction benefits the student. If learning can be made more interesting and challenging, more efficient and meaningful, and less time consuming and frustrating, the moderate increase in cost may well be worth the investment.

VI. SUMMARY

Certain psychological principles of learning exist which cannot be used in our present school systems. The key principle is that of individualization of instruction. If individualization of instruction is accomplished, many other factors, shown to enhance learning, can be put into effect. (1) A student can move at his own pace. (2) It is possible to assure his understanding of a given point before continuing. (3) Errors and misunderstandings can be identified and corrected immediately.

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[20] R. T. Miller, "Computer-Assisted Instruction," _IBM Research Reports_, 2:3, January, 1966.

(4) Instruction can be geared to the comprehension of the learner.

Individualization of instruction can be accomplished by using CAI systems. These systems are capable of using student data and responses to modify the instructional sequence. Thus, it is possible to provide a responsive learning environment, designed to adjust to the needs and abilities of the individual.

The use of computers allows the gathering and processing of large amounts of data pertaining to the interaction between the student and his learning environment. Analysis of these data can lead to the identification of a student's learning problems, to the tracking of his achievement in a given subject, and to the revision of course materials. Continuous classification and placement of a student are also possible.

CAI yields immediate knowledge of results; therefore, correct responses are reinforced while incorrect responses cause the presentation of remedial material to clarify the point.

Skill subjects can be systematically introduced and developed. Pacing, which can easily be accomplished via CAI, may result in increased performance in these skills.

Since course materials for CAI require extremely careful planning, and are constantly subject to revision, they soon evolve into highly efficient sequences.

Psychological studies into human learning and understanding are more readily accomplished because experimental conditions and procedures are more easily controlled. It also becomes possible to acquire and process large amounts of data necessary to provide a solid basis for subsequent inferences.

Some of the potentials of CAI have been exploited by researchers. Simulation techniques permit students to experiment with processes otherwise inaccessible to them. Drill and practice systems have been developed to aid in the teaching of skill subjects. Tutorial systems have been encouragingly successful in wide applications. Dialogue systems are still in their infancy, but hold great promise.

At present, CAI systems are expensive; however, technological advances should soon reduce costs to a level which will permit their use in public schools.

VII. CONCLUSIONS AND IMPLICATIONS

For many years individual differences among students have been known to exist. Prior to the development of CAI, little had been done to allow for these differences in our educational system. Now something is being done to individualize the instructional process.

Although much work has been performed to develop prototype CAI systems, much more research is required before the widespread use of CAI becomes possible. More definitive theories of learning must be developed. Experience must be gained in the preparation of materials for use in CAI.

Even as CAI promises eventual solution of many educational problems, a number of questions remain to be answered. Does CAI make learning more permanent, or more efficient?

Will individual differences be made even greater through individualized instruction? Can students be taught how to learn and how to think for themselves?

How will interaction with inhuman machinery for a significant fraction of school time affect the learner? Will great gains in knowledge accrue at the expense of learning to live in harmony with others? Will the student mature with little mastery of self-discipline? In a word, will the socializing function of the school be helped or hindered?

How should CAI be incorporated in present school systems? How will school systems be affected by this new pedagogical tool? How will the teaching profession be affected? How will the entire educational effort be affected?

The answers to these and other questions yet unasked will come only with painstaking research and experience.

Our educational system cannot afford to ignore the implications of CAI. Research in CAI should receive more than token finance. Research at the point of application should be instigated. School systems should make special efforts to assist in such research in the classroom by releasing sufficient facilities and faculty to permit the installation and staffing of experimental CAI systems. Course materials should be prepared by these staffs and controlled experiments should be performed with the CAI systems.

The implications of CAI are far-reaching. In the near future we will undoubtedly see the installation of CAI systems in schools for experimental purposes. Gradually their use will become more widespread. Within a few years our educational system will feel the influence of CAI. Students on all levels will be involved in CAI, from the pre-school to the post-graduate, from the unemployed involved in retraining for a new position to the professional keeping abreast of the new developments in his field.

Uttal[21] aptly summarizes the impact of CAI:

> "With highly individualized instruction and completely flexible branching, it is entirely possible to adjust the education process to each student's needs and abilities and thus accelerate the trend away from the 'survival of the mediocre' in our current educational structure. Fully automated education will represent not merely a set of new teaching methods but, rather, a major sociological revolution."

[21]Uttal, op. cit., p. 172.

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PROTOTYPE COMPUTER-ASSISTED INSTRUCTIONAL SYSTEMS

by

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B. A., Sterling College, 1962

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements of the degree

MASTER OF SCIENCE

College of Education

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1967

It was the purpose of this paper to discuss computer-assisted instructional systems: their conception, design and organization, and their application. A further purpose was to indicate briefly what work was in progress toward more advanced and sophisticated systems in 1966.

Principles of learning and teaching which underlie computer-assisted instruction (CAI) were presented, many of these pointing toward the need for individualization of instruction. The potentials of CAI were developed from such principles. These potentials were classified as "primary potentials," or those that affect the learner at the time of the interaction, and "secondary potentials," which affect subsequent learners.

Primary potentials include: (1) efficient organization of stimulus materials, (2) accommodation of individual differences, (3) data acquisition and analysis, (4) immediate knowledge of results, (5) timing and pacing, and (6) meeting external criteria. Secondary potentials involve the (1) objective evaluation and revision of instructional sequences, (2) development and presentation of standardized tests, (3) development of new testing techniques, (4) systematic introduction of standard skills, and (5) the possibility for probing psychological studies based on more reliable and reproducible data.

Prototype CAI systems were grouped into four categories depending upon the type of interaction between the student and the computer. These categories are: (1) simulation systems, (2) drill and practice systems, (3) tutorial systems, and (4) dialogue systems.

Simulation systems utilize the simulation technique to assist learning in areas where experiments are potentially dangerous, where expensive and sophisticated equipment would be needed to observe a phenomenon, or where experimentation would otherwise be impossible. An organic chemical analysis program, a clinical nursing laboratory, and several economic games have been prepared for use with simulation systems.

Drill and practice systems are used to supplement regular classroom instruction in subjects involving skills, such as arithmetic, reading, spelling, and foreign language vocabulary. Prototype drill and practice systems to assist the learning of stenotypy, German vocabulary, and arithmetic have been developed in addition to a more advanced computer-assisted language laboratory.

Tutorial systems are designed to provide nearly complete instruction in a particular subject, not merely to supplement instruction. Courses in Psychological Statistics and German Reading have been under study for several years at IBM. PLATO has been used to teach subjects ranging from number theory to French grammar at the Coordinated Science Laboratory of the University of Illinois.

CLASS, a computer-based laboratory for automated school systems, developed at the Systems Development Corporation, includes not only a CAI system capable of tutorial instruction, but also uses the computer to assist in the counseling of students and in the administration of this experimental school systems.

Dialogue systems, although in their infancy, offer great possibilities in instruction. At present it is very difficult to write a computer program to recognize freely constructed questions which are typed into the computer, and to yield appropriate answers to such questions. Also, recognition of verbal speech patterns is possible only on a very limited basis. However, an interesting dialogue between a medical student and a computer concerning the diagnosis of a hypothetical case is included to illustrate the complexity of dialogue which is possible at present.

Although prototype CAI systems are rather expensive, it is projected that costs of commercially available systems will decrease substantially, permitting their widespread use in several years.

Much work remains to be done in CAI. Research into human learning and understanding is necessary, and experience in the preparation of CAI course materials must be gained. Although many questions remain unanswered, CAI holds much promise as a new pedagogical tool.