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ABSTRACT

Approximately 70 seventh grade mathematics students worked individually in self-instructional booklets for a period of 15 weeks. Upon completion of each booklet, the student was evaluated by direct contact with a computer through teletype terminals. If criterion was not attained, half the students received first remediation through the computer and half from the teacher. Further remediation, if necessary, was from the teacher for both groups. The two methods of remediation were equivalent overall, but there was some indication that low ability students found teacher remediation more supportive. Analysis of economic factors in relation to performance measures indicate computer remediation of student performance is not economical at present. However, opposing cost trends for computer hardware and personnel indicate computer remediation could be feasible within a decade. (Author/RH)

CAI CENTER

TECH REPORT

A FEASIBILITY STUDY: REMEDIATION BY COMPUTER WITHIN A COMPUTER-MANAGED INSTRUCTION COURSE IN JUNIOR HIGH SCHOOL MATHEMATICS

Edwin P. Durall

Tech Report No. 25
August 1, 1972

Computer-Assisted Instruction
Florida State University
Tallahassee, Florida 32306

FLORIDA STATE UNIVERSITY

TECH REPORT SERIES

The FSU CAI Tech Report Series is intended to communicate the research findings from studies and sponsored projects that have direct implication for the role of computers in education and training. The rationale for the tech report series is fourfold. First, the tech reports provide a convenient document format for reporting the results of all phases of large CAI projects. These projects typically span too many areas to be reduced into the more conventional research article format. Second, major computer systems designs will be presented in their entirety within the tech report series. Third, this series will provide colleagues at the FSU CAI Center an opportunity to develop major conceptual papers relating to all phases of computers and instruction. And fourth, all the dissertations performed at the CAI Center will be published within this series.

In terms of content, one can anticipate a detailed discussion of the rationale of the research project, its design, a complete report of all empirical results as well as appendices that describe in detail the CAI learning materials utilized. It is hoped that by providing this voluminous information other investigators in the CAI field will have an opportunity to carefully consider the outcomes as well as have sufficient information for research replication if desired. Any comments to the authors can be forwarded via the Florida State University CAI Center.

Duncan N. Hansen
Director

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ABSTRACT

Within a terminal-oriented CMI system, this study investigated the feasibility of presenting remedial instruction to students by computer as compared to remedial instruction presented by a teacher.

Approximately 70 seventh grade mathematics students worked individually in self-instructional booklets for a period of 15 weeks. Upon completion of each booklet, the student was evaluated by direct contact with a computer through teletype terminals. Half of the students, if the criterion of 80% was not attained, received remediation from an instructional sequence programmed into the computer. The other half of the students received remediation from their teacher. The remediation for both groups consisted of the student working through a sample test question while recieving feedback at each step in the solution. The student was then required to work a second sample problem without assistance. When the student had successfully solved the second sample problem, the test was readministered. If the test was failed a second time, the teacher worked with the student until criterion could be attained.

The computer-remediated (CR) students demonstrated equivalent academic performance, rate of movement, and attitudinal measurements as compared to the teacher-remediated (TR) students. These results are particularly encouraging for high ability students. Analysis of the performance data according to ability level, however, discovered significant differences among the lower ability students favoring the TR group. The computer remediation was not detrimental, but apparently the teacher remediation was more supportive for lower ability students. Within ability levels, there was no significant difference between CR and TR groups as to the rate of movement through the instructional materials.

Highly positive attitudes toward mathematics in general, CMI, and individualized instruction were exhibited by students in both remediation groups at the end of the study. Due to very high initial attitude measurements, no significant pre-post gains were demonstrated. During the study, the attitudes of the CR students toward CMI tended to become more positive while the comparable attitude of the TR group tended to become less positive.

The teacher in the program, freed from clerical burdens, was able to concentrate on the higher level professional tasks involved in interacting individually with students as they worked in the booklets and as they required remediation following a test. A closer, more personal relationship was developed between the students and teacher in the individualized setting compared to the traditional lecture and demonstration classes which existed prior to the study.

Analysis of economic factors in relation to performance measures indicate computer remediation of student performing below grade level is not feasible at present. Rising personnel costs and lowering computing hardware costs, in concert with the equivalent performance between high ability groups, indicate computer remediation for high ability students could be feasible within a decade.

It is interesting that no significant difference existed between remediation modes in the amount of time spent in contact with the computer. However, the lower ability students spent a significantly greater ($p<.01$) amount of time on line than did the high ability students. These findings would indicate that when considering the economics of implementating a terminal-oriented CMI system, ability level of the students appears to be a more important factor than mode of remediation.

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My wife and children, who perhaps bore the heaviest burden of all: me. They demonstrated exceptional patience and understanding, for which I am most grateful.

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I. BASIS FC UL

Introduction

For centuries, teachers have been attempting to devise better methods of helping students learn in accordance with their abilities. But, apparently due to the complexities involved, the full potential of individualized instruction has not been realized.

Two recent developments, the formulation of a systematic approach to the generation of instructional materials and the proliferation of computers, have given educators the means not only to devise models for individualized instruction but also to realize progress in the quest for a better instructional system. The systems approach provides a more efficient means of generating instructional materials and of organizing learning environments. However, it was not until the computer gained widespread educational usage in the processes known as computer-assisted instruction (CAI) and computer-managed instruction (CMI), that the individualization of instruction began to make substantial progress.

CAI is a process whereby the student receives instruction directly from a computer through some type of terminal which serves as the student/computer interface. Typical terminal devices are typewriters, teletypes, or cathode-ray tubes (CRT). A CRT is a television-like screen upon which instructional materials may be displayed and which contains a typewriter keyboard and/or light-sensitive pen which the student may use as response devices. Since the student spends large blocks of time in direct contact with the computer, CAI is considered to be somewhat expensive.

CMI, a more cost-effective use of the computer, relies upon a variety of multi-media or textual materials to provide the bulk of the instruction, while the computer is involved with functions which may be considered primarily as managerial in nature. These functions include the recording of student responses, prescription of learning activities, maintenance of a student date file, and other tasks of essentially clerical nature which the classroom teacher is normally expected to perform. A typical CMI mode of instruction contains the following steps: (a) the student studies material relevant to a particular unit or objective; (b) the student is tested over the material studied; (c) if he fails to attain the acceptable performance criterion, the student studies the material again or is given remedial assistance; (d) if the student attains the acceptable level of performance, he is allowed to progress to the next segment of instruction. CMI is usually found in conjunction with a program of individualized instruction in which the student is allowed to progress through the learning materials at his own rate.

Within the paradigm known as CMI there are two models presently in operation: batch-process and terminal-oriented. Batch-process CMI is a procedure wherein the student does not come in direct contact with the computer. Tests are answered on mark-sense answer sheets or computer cards which are collected at the end of the school day, taken to a computer center to be analyzed, and returned to the school the following day. This is an economical use of the computer in that the data from large numbers of students can be processed at one time and the computer system does not need to be dedicated to that particular program, as is the case in some CAI operations. Disadvantages include the need for a middle man to handle the data and the likelihood of an overnight delay in receiving feedback regarding performance.

In the terminal-oriented CMI procedure the student interacts directly with the computer in the testing phase of the instruction. Rather than marking answers on paper sheets or cards, the student is presented questions via a computer terminal and the response is recorded immediately by the computers. It is assumed that the direct student-computer interaction will allow the merging of the instructional capabilities of CAI with the managerial capabilities of CMI into a highly efficient system for the individualization of instruction. Hansen (1970a) has set forth three factors considered to be advantages of a combined CAI/CMI instructional system: (a) the capability to utilize CAI techniques in providing remedial assistance when desired; (b) elimination of a source of error in that the student is directly responsible for the information flow to and from the system; and, (c) student receipt of immediate feedback regarding his performance.

The literature contains numerous accounts of the application of CAI as an instructional system. There are also numerous reports of the application of CMI techniques as being distinct and different from CAI. There is, however, a scarcity of empirical evidence to support the assumption that CAI and CMI can be merged into a single instructional system or that the factors enumerated above are indeed advantages of such a combined system. In particular, when considering the use of CAI techniques to provide remedial assistance, an important question arises: Can a computer provide remediation as well as a teacher? This study is directed toward that specific question.

Statement of the Problem

The feasibility of computer remediation as compared to teacher remediation was investigated through the following questions:

1. Do students who receive computer remediation perform as well as students who receive remediation from their teacher?
2. Does the mode of remediation received affect the rate at which students progress through the instructional materials?
3. Does the presence of computer-managed individualized instruction have an effect on the student's attitude toward mathematics?
4. What effect does the presence of computer-managed instruction have upon the functions and daily actions of the teacher?
5. What are the costs of a terminal-oriented CMI system?

Description of the Study

In order to investigate the feasibility of CAI remediation within a CMI format, two groups of seventh grade students received 15 weeks of mathematics instruction (February 8, 1971 through May 21, 1971) via individualized booklets. Each booklet comprised a single unit and was concerned with one topic in mathematics (see list of topics in Appendix A). Upon completion of a unit of work, each student received a test from a computer via a teletype terminal. Half of the students, upon failure of a test, received remediation from an instructional sequence programmed into the computer. The other half of the students were referred to the teacher for assistance if they failed a test. Thus each aspect of the instructional process was held constant except the mode of remediation, allowing the feasibility of computer remediation as compared to teacher remediation to be investigated.

For the purposes of the study, remediation is defined as the presentation of examples similar to questions the student had received on a test which had been failed. In the first example the student was required to respond at intermediate steps in the solution in order to determine the source of misunderstanding. The student was then presented a second example to work without assistance. A correct response to the second example was considered an indication that the student understood what he had done wrong and was prepared to proceed with the next step in the instructional process. The rationale for this remediation pattern is based on two aspects: (a) consultation with the mathematics teacher in the experimental classes; and (b) experience gained by the author in ten years of teaching in the public schools at both elementary and secondary levels. In those ten years, through observation of the techniques of a large number of mathematics teachers, it has been observed that almost all of them use essentially the same remediation system as was used in this study: working through a problem with the student and then requiring him to work one without assistance. Both the teacher remediation and computer remediation in this study followed this same pattern.

Through the investigation of the five questions listed in this chapter, the researcher is attempting to contribute to the literature of educational research through the implementation and investigation of a combination CAI/CMI instructional system. It is hoped that this prototype system can make a positive contribution toward the individualization of instruction within the schools.

To provide a background of previous research and formulate the basis for this study, the next chapter presents a review of selected literature concerning CAI and CMI as they are particularly related to the individualization of elementary and junior high school instruction.

II. REVIEW OF LITERATURE

In the late 1950's it became apparent to innovative educators that the computational capabilities and managerial functions of the computer, which were making such an impact on the business and scientific community, could be applied to education. The computer was seen as a means of presenting instruction, but additional advantages would be in the storage and analysis of data generated by student responses and the use of these data in the prescription of the instructional program for the student. In this manner a truly individualized course of study could be designed for each student according to his unique capabilities, and through the use of the data generated by the student himself, the course of study could be updated and revised quickly and efficiently.

Computer-Assisted Instruction

The initial attempts to apply the computer to the individualization of instruction were made in the area of providing instruction directly by the computer. This instructional paradigm became known as computer-assisted instruction (CAI) and quickly developed several levels of instructional sophistication: drill and practice, tutorial, problem solving, simulation, and evaluation (Hansen, 1970b). Emphasis herein will be placed on the basic instructional levels of CAI as they pertain to this study; i.e., drill and practice, tutorial, and evaluation.

The reader is referred to Bushnell (1967) for discussions of simulation and problem solving applications.

Drill and practice. The pioneer in drill and practice applications of CAI is Suppes (1967) of Stanford. This type of student-computer interaction can be thought of as a supplement to the regular curriculum taught by the teacher. Building upon evidence that students need a great deal of practice in order to obtain mastery of basic arithmetical skills, programs were designed which allowed students to work individually at various levels of difficulty. The student may be moved up or down in difficulty level depending on his level of performance. A typical procedure is for the teacher to introduce the mathematical concept in class; the drill and practice by the student is accomplished at the computer terminal. The teacher is thus freed to pursue other more important functions. The advantages of this mode of application are that the student receives immediate feedback as to his performance, and the teacher receives a complete report of student performance (Suppes & Jerman, 1969).

A significant application of Suppes' drill and practice material via CAI was in the McComb, Mississippi, school district. Students in the first six grades were divided into experimental and control groups and their grade placement in mathematics was determined. At the end of the school year their grade placement was again measured. The difference between pre-and post-grade level placement favored the CAI group and was significant at the .01 level in all six grades (Suppes & Jerman, 1969).

Tutorial. At the second instructional level of application of CAI are the tutorial programs which have the capability of real-time branching contingent on a single response or series of responses (Atkinson, 1969). In other words, the tutorial level of CAI is one in which functions of the teacher may be assumed for certain periods of a school day. During this time the student may receive instruction in areas which redundantly consume teacher time. For example, a student could be shown a sentence in which there are three different words he may choose from to use as the verb in the sentence. He chooses the verb which causes the sentence to make sense. This type of work, with its accompanying error messages, can easily be provided by a computer, but would consume great amounts of teacher time.

One of the first programs to utilize CAI in a tutorial mode was the reading program developed at Stanford for use in the Brentwood School in East Palo Alto, California. This program consisted of a core of problems which the student was required to master. The problems could be branched around by passing pretests, solving correctly, or solving incorrectly, in which case they were branched to remedial material. At the end of the year there was between fastest and slowest students a difference in problems completed of over 4000 problems; on achievement measures, the CAI group outperformed the control group at either the .05 or .01 levels of significance in nine of the ten measures (Atkinson, 1969).

A major public school program involving CAI at the tutorial level in both reading and mathematics was the rural county CAI project in Wakulla County, Florida. Developed in conjunction with the Computer-Assisted Instruction Center at Florida State University, this three year project's data show significant positive improvement in reading and mathematics skills from year to year. Due to contamination of control groups brought about by large scale shifting of students when the district underwent total desegregation, comparative results were somewhat mixed. However, the data show steady progression of black students upward toward more normative achievement test means as adjusted by Kennedy (1969) for southern rural black students (Hansen, Johnson, Durall, Lavin, & McCune, 1971).

Evaluation. Research has indicated that CAI can be utilized in performing testing and evaluation functions. Using elementary students as subjects and teletypes as computer terminals, Ferguson (1970) reports that computer-based criterion-referenced testing can be as reliable and valid as conventional testing and that computer-based testing consumes less time.

At Florida State University CAI has played an important role in the formative evaluation of the Intermediate Science Curriculum Study, a program designed for grades 7-9. After three years of instructional material presentation via CAI, three factors appear to be particularly interesting: (a) CAI provides a much more detailed evaluation than is possible through field trials; (b) evaluation information can be fed back to curriculum revisors with a greatly reduced lag time; and, (c) after approximately four hours a week of exposure to CAI throughout three years, thus logging more CAI time than any other known group, the students still indicated a strong positive reaction to CAI and a willingness to continue in a CAI program (Hansen, O'Neil, Brown, King, & Rivers, 1970).

To summarize, it may be noted that the use of CAI has grown considerably since its inception as witnessed by the fact that in 1963 one public school was utilizing CAI whereas this had increased to 77 by 1969; in 1959 one university had CAI capabilities and this had grown to 50 by 1969 (Tuttle, 1970). In a broad sampling of journals and institutional reports Bundy (1968) reports the following conclusions: (a) students learn as well with CAI; (b) CAI can provide equivalent learning in the same amount of time; (c) CAI adjusts quite well to individual differences; and, (d) students generally have a positive attitude toward CAI. Keeping in mind the relative infancy of CAI, these conclusions must be considered tentative, but it may be noted that CAI is apparently a viable instructional and evaluation system, and, as such, is expected to play a major role in the individualization of instruction in the future.

Computer-Managed Instruction

Many educators recognized the contribution CAI could make toward a program of individualized instruction, but most were wary of the costs of implementing CAI and the concomitant large developmental efforts that were required. Out of this quandry grew a second application of the computer to the instructional process. It was proposed that the computer be utilized in the management and record keeping aspects of instruction, but that students work from a variety of off-the-shelf or textual materials. Thus, existing instructional materials could be utilized without an expensive developmental effort. Further savings would be realized by removing the computer from the teaching phase of the instructional process, but at the same time the advantages of the high speed data handling, storage, and retrieval functions of the computer could be used to full advantage. This model became known as computer-managed instruction (CMI) and quickly assumed importance in elementary and junior high school individualized instruction efforts. Three of the major CMI projects are worthy of detailed consideration.

Project PLAN. Project PLAN (Program for Learning in Accordance with Needs) was originated in 1966 through a joint venture involving the American Institutes for Research, the Westinghouse Learning Corporation, and twelve school districts throughout the country (Flanagan, 1970). It has now spread to 24 cities involving 20,000 students (Rogers, 1971).

> The proposed function of the new educational program is to provide a flexible system in which the student can be assisted to take as much responsibility as possible in the planning and carrying out of his own educational development (Flanagan, 1970, p. 2).

The five major components of the PLAN system are: (a) a set of educational objectives; (b) learning methods and materials; (c) evaluation; (d) guidance and individual planning; and, (e) teacher development (Flanagan, 1970).

The role of the computer in PLAN involves a great variety of functions. The computer processes the daily tests taken by the students and provides printouts of these results for the teachers. These data are used to constantly update and revise the student's program of studies. A weekly status report is also provided. In addition to the daily and weekly processing functions, the computer assists in registration of the student and in the actual planning of his course of study, including the placement of the student in the program of studies, establishing a quota in terms of numbers of modules to be completed, and a selection of the actual modules of instruction to be received by the student (Flanagan, 1970). The constant updating and revision of student data and the planning and prescriptive usage are critical features in making this type of computer application practical. In an effort to facilitate the flow of information to and from the computer, each of the Project PLAN schools has recently received a terminal through which the teachers can interact directly with the computer (Rogers, 1971).

System Development Corporation/Southwest Regional Laboratory. Working outside the realm of individualized instruction but designed to assist teachers in a traditional elementary school setting achieve a measure of individualization, a CMI effort was originated under the joint sponsorship of the System Development Corporation and the Southwest

Regional Laboratory for Educational Research and Development (Silberman, 1969). This CMI system was designed to help the teacher monitor the progress of the students and make decisions on the pace of instruction, the grouping of children, the sequence of lessons, and the individualization of instruction. The four primary components of the information management system are objectives, tests, reports, and prescriptions; it helps teachers by providing information about each child's achievement, suggesting activities to help a pupil understand a lesson, and providing a framework for making decisions on classroom management (Geddes & Kooi, 1969).

Individually Prescribed Instruction. Perhaps the most far-ranging effort in the CMI field was the Individually Prescribed Instruction (IPI) project instituted in the Oakleaf School System in Pittsburgh by the Learning Research and Development Center of the University of Pittsburgh. The IPI program is based on an instructional model consisting of the following sequence of operations:

1. The goals of learning are specified in terms of observable student behavior and the conditions under which this behavior is to be exercised.
2. Diagnosis is made of the initial capabilities with which the learner begins a particular course of instruction. The capabilities that are assessed are those relevant to the forthcoming instruction.
3. Educational alternatives adaptive to the initial profile of the student are presented to him. The student selects or is assigned one of these alternatives.
4. Student performance is monitored and continuously assessed as the student proceeds to learn.
5. Instruction proceeds as a function of the relationship between measures of student performance, available instructional alternatives, and criteria of competence.
6. As instruction proceeds, data are generated for monitoring and improving the instructional system (Cooley & Glaser, 1969, p. 96).

Automation is not a prerequisite for the implementation of the IPI model and the project initially operated in the nonautomated form, much as it is being used in school systems across the country at present. After three years of operation in the nonautomated form, batch-process computer capabilities were added to the program in the form of a Management Information System (MIS).

> There are four major functions which the MIS can provide in an individualized school: (1) collect data; (2) monitor student progress; (3) provide prescriptions; (4) diagnose student difficulty. These functions have two primary objectives: to increase the effectiveness of the model for individualizing instruction and to maximize the productivity of the teacher operating the IPI system (Cooley & Glaser, 1969, p. 106).

Through supporting the IPI instructional system with the functions of the MIS, IPI/MIS has been shown to be one of the leading projects in the research and implementation of individualized computer-based instruction. Cooley and Glaser (1969) admit that a shortcoming of the IPI/MIS system is that each school has only one terminal and it is not in the classroom. They speculate that the next step in the development of IPI/MIS is to add classroom terminal capability so that both students and teachers will have access to computer terminals. The paper on computer-based testing by Ferguson (1970), an associate of Cooley and Glaser, indicates that IPI/MIS is moving in that direction at the present time.

Thus we can see that IPI/MIS is unique in that it is the only project which has existed in a nonautomated form, moved to batch-process CMI; and is now moving into the other CMI mode, which was earlier described as terminal-oriented CMI.

Terminal-oriented CMI. The model toward which IPI/MIS appears to be moving is in full scale implementation at Florida State University, where the majority of the CMI activities are directed toward university undergraduate and graduate instruction. Since this study was conducted on the junior high school level, these university level instructional activities, with the exception of one research study, will not be discussed in this paper. However, the reader is referred to the FSU CAI Center annual reports authored by Hansen, et al. (1970); and Hansen, Brown, O'Neil, Merrill, & Johnson (1971).

The study which relates most directly to the research described in this paper is the terminal-oriented CMI investigation conducted by Lawler (1971). With university undergraduate health education students as subjects, Lawler examined the efficacy of providing remedial prescriptions for students who failed to attain criterion on unit tests, thereby forcing the students to attain mastery on each test. The prescriptions were usually hints as to which portions of the instructional materials should be studied again or were suggestions as to which references should be pursued closely. This can be considered a somewhat limited use of the terminal-oriented capabilities to provide remedial activities nor does this use capitalize on the full power of CAI techniques that are available to provide remedial instruction. Nevertheless, significant differences were observed in favor of the prescription-forced mastery CMI group over a CMI group which did not receive prescriptions and was not forced to attain mastery. In addition, significant differences in performance and attitudes, in favor of the CMI groups as opposed to a control group taught by conventional classroom techniques, were observed.

III. METHODOLOGY

CMI Model

The model for computer-managed individualized instruction developed for this study is one which incorporates the tutorial capabilities of CAI within the managerial capabilities of CMI, as discussed in the previous chapter. A flow chart of the steps in the instructional system is depicted in Figure 1.

Learning Materials

The learning materials consisted of self-instructional booklets generated through a curriculum project in Palm Beach County, Florida (Palm Beach County Board of Public Instruction, 1969). The project was funded by State of Florida Educational Improvement Expense and ESEA Title III funds. On its staff were a total of 34 mathematics teachers and other personnel experienced in curriculum planning and development. The materials were provided for this research in return for documentation of their use in a computer-based program.

The systematic technique utilized in developing the instructional units involved several steps beginning with the statement of performance objectives for each unit of instruction. Instructional strategies and activities designed to lead the student toward the performance criterion were designed in conjunction with existing textual materials. Other

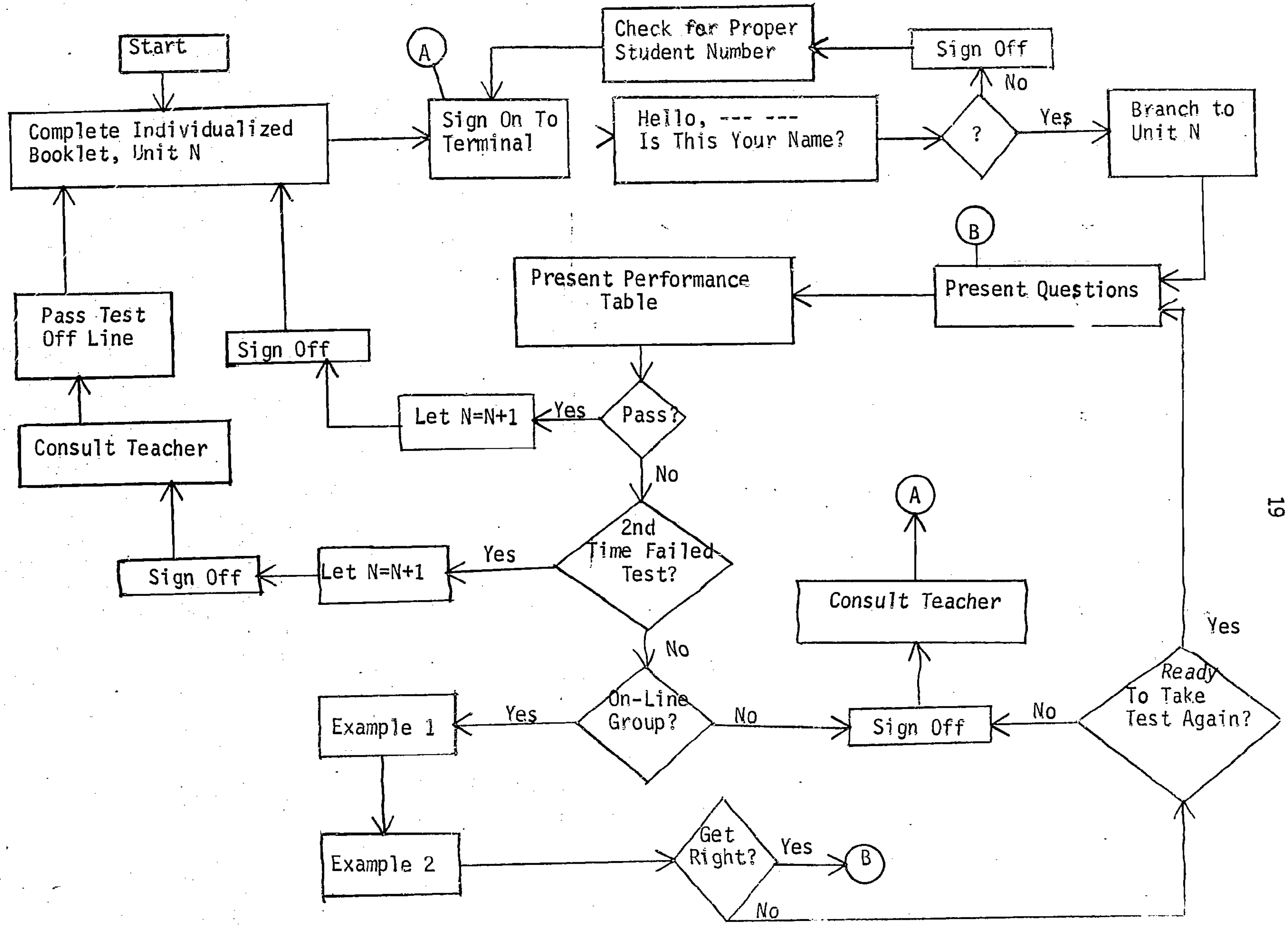

Figure 1.--Steps in Instructional System.

state-adopted textbooks were used as supplementary reference sources. Evaluation of student performance was conducted within each unit and at the end of segments of units pertaining to a general topic (e.g., multiplication of fractions). The results of the evaluations conducted during the initial year of implementation provided data for the revised version of the materials, portions of which were utilized in this study.

The particular materials used in this study were selected to maintain continuity with the topics which had been discussed during the first semester of the school year and to generally follow the content outline presented in the state-adopted textbook in use in the school. See Appendix B for a sample unit booklet and its accompanying unit evaluation.

Each booklet, which comprised one unit concerned with a single topic, contained behavioral objectives pertaining to the skill to be acquired in the study of that topic. The students were provided instruction regarding the topic and worked at their own pace through problems which led them toward the skill required to fulfill the objective for the unit. Upon completion of the work required in the booklet, and when they felt they were prepared to be evaluated, the students proceeded to a teletype terminal and received the test questions from the computer. The examination consisted of five criterion-referenced multiple choice questions designed to test the skill required in the behavioral objective for that unit. Upon completion of the examination the students were provided immediate feedback through presentation of a table summarizing performance on the test. A sample table is shown in Appendix C and represents a basic form of a data management system integral to any CMI system.

If the student achieved criterion (80%) in the test, he was told to proceed to the next unit.

Remediation

If the student failed the test, the performance table was presented and the remediation proceeded according to the following steps: (see also Appendix D):

A. Teacher-remediated group.

   1. The student was directed to consult the teacher for help and was signed off.

   2. After being assisted by the teacher, the student returned to the terminal and the test was presented again.

      a. If the student passed the test he proceeded to the next unit.

      b. If he failed again, he was once more directed to see the teacher, who worked with the student until he could pass a test off line (away from the computer). The second failure branched the computer to the next unit.

B. Computer-remediated group.

   1. The student was presented a sample problem similar to the problems on the test. In this first problem, the student was required to respond at intermediate steps in the solution in order to determine area of difficulty. Error messages intended to alleviate the difficulty were then presented.

2. A second example was presented which the student was required to work without assistance as in a test situation.

   a. If the student answered this second example correctly, he was presented the test again.

      (1) If he passed the test he proceeded to the next unit.

      (2) If he failed the test the second time, he was signed off and sent to the teacher for assistance. No further computer remediation was attempted. The teacher worked with the student until he could pass a test off line before proceeding to the next unit.

   b. If he answered the second example incorrectly, he was told the correct answer and why it was correct.

      (1) If the student was aware of what he did wrong, he could elect to take the test again at this point.

         (a) Step 2.a.1. above.

         (b) Step 2.a.2. above.

      (2) If the student still did not understand the problem following the second example, he could elect to sign off and consult the teacher. He was required to sign on again to retake the test.

         (a) Step 2.a.1. above.

         (b) Step 2.a.2. above.

<u>Instruments</u>

The evaluation instruments for this study were:

<u>Individual unit tests</u>. These were five question criterion-referenced multiple choice tests taken directly from the Palm Beach County

materials. The tests were generated concurrently with the instructional materials through the major State and Federally funded curriculum effort in Palm Beach County. The tests had been in use and had undergone one revision. See Appendix B.

Review tests. At the end of major topical sections of the materials were ten question review tests which were presented to the student at the computer terminal. The questions on these tests were equivalent forms of the individual unit test questions. These tests occurred at units 10, 19, 26, and 31, and no remediation was presented on these units.

Posttest. The posttest was a 25 question multiple choice test administered individually away from the computer terminal upon completion of the first 31 units of the instructional materials.

Upon completion of the unit 31 test the student was allowed the next class period to study for the posttest, which was then administered the following day. In a very small number of cases, a weekend was involved in this procedure. However, none of the instructional materials was taken home by the students and all studying was done in class. The procedure for allowing one class period of study time for the posttest was adhered to for all students.

Since the students moved at different rates through the instructional materials and completed unit 31 at different times, it was felt that some method of providing equivalent, but not identical, tests had to be devised. This was accomplished by forming a pool from all questions received in units 1 through 31 (excluding review units 10, 19, 26, and 31).

This pool was then stratified according to the four major topic areas which were represented by the first 31 units. A routine was devised so that the computer randomly generated 25 questions in such a manner that the posttest questions reflected the same concentration of topics as was reflected in the 31 units themselves. By signing on to teletype terminals located in the CAI Center with each student's individual identification number, a separate test for each student was generated by random selection from this pool of questions.

Because each student received a different set of questions during the posttesting, it was not possible to calculate a reliability coefficient for the instruments. However, when the posttest scores were correlated with the retention test scores (coefficient alpha reliability = .79), a correlation coefficient of .76 was realized. This correlation was significant well beyond the .01 level of probability, where a coefficient of .325 was sufficient for significance (N=64, 62 d.f.). Thus, concerns about the reliability of this instrument were somewhat alleviated.

Retention test. The same routine as described above for the posttest was used to generate the retention test (see Appendix E). By signing on to a teletype terminal at the CAI Center with an unused student identification number, another 25 question multiple choice test was generated. This test was then duplicated and administered to all students in the study on the same day.

In the case of the retention test, a true measure of retention that was not affected by study time was desired. Therefore, at the end of the 15 weeks of the study, all work in the materials ended on Friday, May 21. No materials were taken home over the weekend. Monday's class period was fully consumed by administration of the CMI/Individualized Instruction attitude scale, and the retention test was administered on Tuesday, May 25.

The reliability of the retention test became a matter of concern when it was learned that the students had been involved in a softball game during the period prior to the testing and were to return to the game following completion of the test. Administering an important achievement measurement between innings of a softball game is apparently one of the unknown factors a researcher must be prepared to face when field testing a program in the public schools. When the retention test scores were analyzed, however, the coefficient alpha reliability was calculated to be .79.

Mathematics attitude questionnaire. Studies reviewed by Aiken (1970) have indicated that attitude plays a significant role in achievement in mathematics. To assess the effect of the experimental program on the student attitudes, mathematics attitude measurements were taken prior to the beginning of the investigation and again upon completion of unit 31. The attitude questionnaire presented was derived from that developed by Dutton and Blum (1968), and used most often in mathematics attitude studies at the junior high school level (Aiken, 1970). Dutton has reported a Spearman-Brown Test-Retest Reliability coefficient of .84 for the instrument.

The questionnaire contained 25 items calling for responses ranging from 1 to 5, where 3 was a neutral response. The students' scores were obtained by summing all responses after reversing negatively worded items. A score of 75, therefore, would be considered a neutral score. A copy of the questionnaire is included in Appendix F.

CMI/individualized instruction attitudes. A questionnaire concerning attitudes toward CMI developed by Brown (1966) was revised to be compatible with a junior high school situation; a subscale regarding nonautomated individualized instruction was included. This questionnaire was administered at the end of the second week of the study to measure initial reaction and again at the end of the 15 week period. The total instrument, containing both the CMI and individualized instruction subscales, was made up 36 items calling for responses ranging from 1 to 5, where 3 was a neutral response. These scores were also obtained by summing all responses after reversing negatively worded items. A score of 108, therefore, would be considered a neutral score. Brown reports an alpha reliability coefficient of .86 for this questionnaire. A copy of the instrument is included in Appendix G.

Subjects

Two classes of seventh grade mathematics students taught by Mr. Randy Anderson at Wakulla County High School, Medart, Florida, served as subjects for the study. Seventy-one students participated at the beginning of the program, but attrition reduced this number to 65 by the conclusion of the study. Mr. Anderson taught two other classes, but it was found through interviews with the students in the other two classes that the reading level of the mathematics materials, even though it was about fourth grade level, was too difficult for them. The students participating in this study, therefore, were those who were generally able to follow the directions in the booklets. There existed within this group a wide range of mathematical and reading abilities as evidenced by the scores on the Comprehensive Tests of Basic Skills (California Test Bureau, 1968) administered in September, 1970. In reading, the grade equivalents for this group ranged from 2.0 grades to 12.6 grades, with a median of 6.6 grades. The mathematics grade equivalents also ranged from 2.0 to 12.6 grades, with a median of 6.3 grades.

The students at Wakulla High School are grouped according to ability. The two classes participating in this study comprised the high and medium ability groups in the seventh grade. The median grade equivalents in reading and mathematics showed a deficiency of .4 and .7 grades, respectively, for these groups, while school testing records indicate the average seventh grader was 1½ years below grade level. See Appendix H for a description of the Wakulla County community.

The students were randomly assigned to treatment groups within each class so that half of each class received computer remediation and half received teacher remediation. The intent of this procedure was two-fold: first, to avoid the chance assignment of a majority of one class to the teacher remediation group, thus working a hardship on the teacher and causing undue delays for the students; and secondly, to distribute the possible effect of the teacher across student groups.

All of the subjects had prior experience with the use of the teletype terminals which comprised the student-computer interface. They had participated in the CAI mathematics and reading project developed through the CAI Center at Florida State University. Therefore, any novelty effect which might have been a factor in the students' achievement should have been considerably reduced.

Apparatus

The computer and terminals that were utilized in the study are components of the Computer-Assisted Instruction Center at Florida State University. The computer is an IBM 1500 CAI instructional system composed of an 1800 central processing unit, two 1810 disk drives, and a 1502 station control unit.

The IBM 1500 CAI system is equipped with a dual magnetic tape drive upon which all student responses are uniquely identified and recorded. The staff of the FSU-CAI Center has developed a data management system which compresses, sorts, merges, and summarizes this data for theoretic analyses. This system was utilized to collect and analyze data for this study.

Late in 1968, a telecommunications capability was added to the FSU 1500 CAI system. This was accomplished by the addition of a Digital Equipment Corporation 680 Switching System. This device collects and sends data to local or remotely located teletype terminals under control of a PDP-8 computer. This system is interfaced with the IBM 1502 Station Control Unit in such a way that the 1500 system will service remote teletypes in the same manner it would a local 1518 typewriter. At the time of this study, fourteen teletype terminals were supported via the 680 system. Six of these teletypes were located at the CAI Center and four in Shadeville Elementary School in Wakulla County.

The remaining four teletypes, located at the Wakulla County High School, comprised the student-computer interface for this study. The teletypes were housed in a room reserved for this purpose which was very near the classroom. Two capable adult proctors were present in the terminal room during school hours and were responsible for signing the students on to the program and assisting them in the use of the terminals.

Experimental Design

The research design for this study is essentially a Post Test Only-Control Group Design (Campbell & Stanley, 1963), with the computer remediated group receiving the "treatment" and the teacher remediated group acting as a control. A deviation from the design presented by Campbell and Stanley exists in that the post-testing occurred as the students completed a fixed amount of instructional material, and thus varied in time. Time, therefore, was an uncontrolled variable, but this is inherent in an individualized instruction setting where students are free to work at their own pace.

Procedural Schedule

A graphical representation of the activities of the study is shown in Figure 2. In summary form, the procedural schedule was as follows:

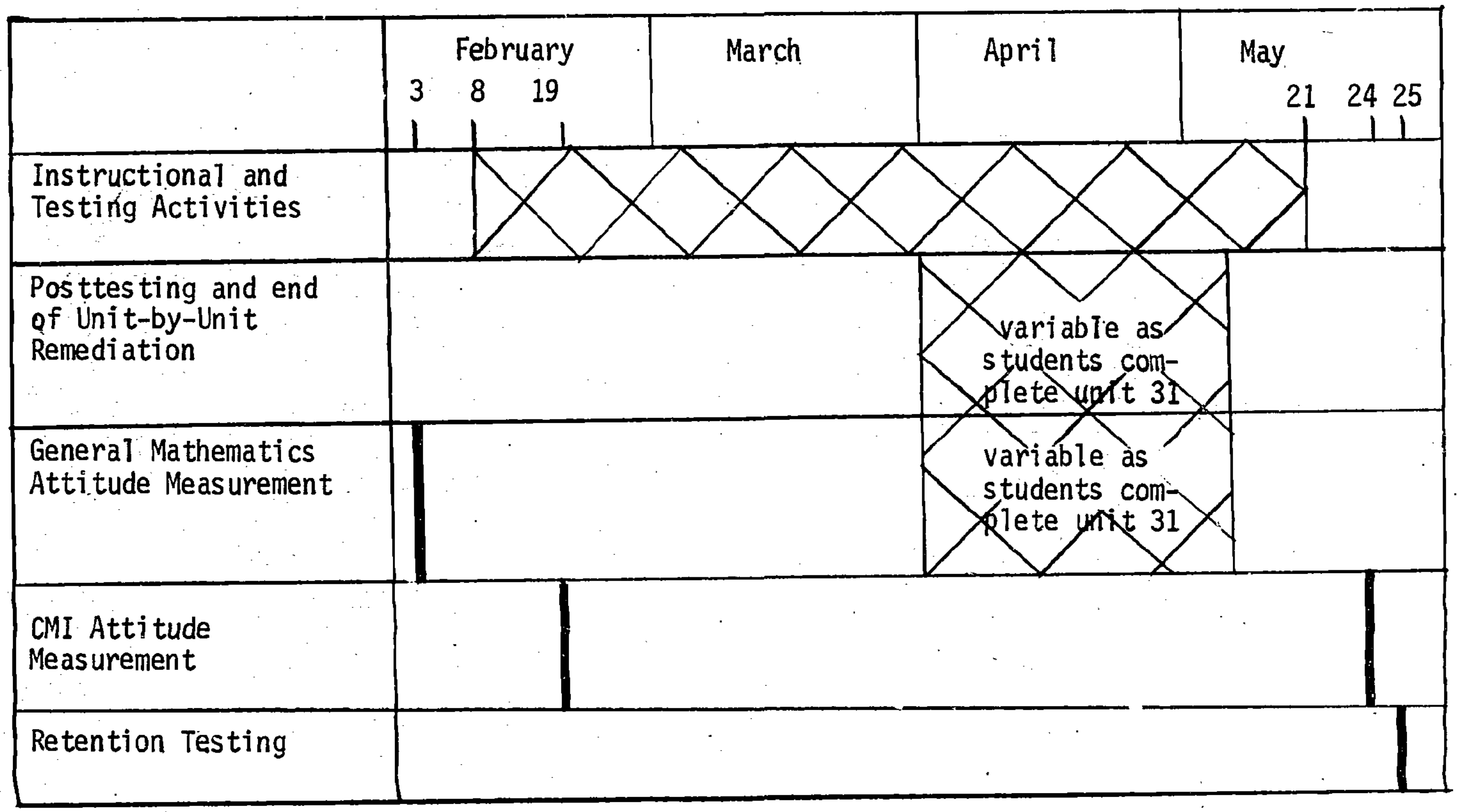

Figure 2.-- Procedural Schedule

Wednesday, February 3, 1971 -- administration of the general mathematics attitude questionnaire.

Monday, February 8 through Friday, May 21 -- students received instruction from the individualized booklets and were tested on the computer terminal.

Friday, February 19 (end of second week) -- administration of CMI attitude questionnaire to obtain initial student reaction.

Thursday, April 1 (eighth week) -- students began moving through Unit 31 and the post-testing began. The general mathematics attitude questionnaire was readministered upon completion of the posttest. As the students worked through units above number 31, the unit-by-unit remediation ended. Instead of a computer-administered test over each unit, the students took a written test which they checked themselves, and received a computer test only at the end of five-unit segments. This change served three primary purposes:

1. Reduced the use of the terminals by the faster-moving students and provided more time for the slower-moving students to use the terminals.
2. Provided an opportunity to compare weekly testing with daily testing in order to determine an optimum routine.
3. Reduced the time the students were on line and thus facilitated movement to and from the terminals.

The post-testing and attitude measurement occurred continuously throughout April and May as the students finished Unit 31.

Friday, May 21 -- completion of the instructional portion of the study.

Monday, May 24 -- administration of the CMI attitude questionnaire.

Tuesday, May 25 -- administration of the retention test over the material in the first 31 units.

Wednesday, May 26 -- last day of school.

IV. ANALYSIS OF RESULTS

In this chapter each research question will have its statistical findings presented in the order reflecting the activity of the experiment. Because this is a feasibility study as opposed to theoretical research, many of the statistical analyses are posed in descriptive form. Where inferential statistics are used, the null hypothesis of no difference between remediation modes is implied, all statistical tests are two-tailed, and no specific rejection level of probability is adhered to. The calculated probabilities are reported and the reader is allowed to determine feasibility relative to his own situation.

Throughout the remainder of this document the four groups involved in the study will be identified by the following codes:

CR = Computer-remediated

TR = Teacher-remediated

HCR = High ability computer-remediated

LCR = Low ability computer-remediated

HTR = High ability teacher-remediated

LTR = Low ability teacher-remediated

Question 1: Student Performance

Do students who receive computer remediation perform as well as students who receive remediation from their teacher?

<u>Unit tests.</u> The forced criterion level of 80% for each of the individual unit tests precluded the use of traditional norm-referenced statistical analyses on these scores. The most valuable information, therefore, would seem to involve the number of students in each remediation mode who attained criterion on the individual unit tests. Since there were unequal numbers of students in the remediation modes and all students did not complete the same number of units, percentages of units successfully completed by each group compared to the total number of units completed were calculated for each group. These figures are presented in Table 1 and concern only those units among the first 31 units in which remediation was received (this excludes review test units 10, 19, 26, and 31).

Within each group shown in Table 1, the top row of numbers in columns B through G are numbers of units, and the second row of numbers indicate the units in terms of percentages. For example, in the HCR group a total of 513 units was completed. Columns B and C show that of those 513 units, 457 (89.1%) of the units were passed and 56 (10.9%) were failed on the first trial. Columns D and E show that of the 56 units failed in Column C, 42 (75%) were passed on the second trial while 14 (25%) were failed. Columns F and G give the totals for both 1 and 2 trials.

TABLE 1

Number and percentage of students who passed and failed unit tests. Criterion = 80%.

	Total Units A		1st Trial Passed B	1st Trial Failed C	2nd Trial Passed D	2nd Trial Failed E	Total 1 or 2 Trials Passed F	Total 1 or 2 Trials Failed G
HCR (n=19)	513		457	56	42	14	499	14
		%	89.1	10.9	75.0	25.0	97.3	2.7
LCR (n=17)	456		340	116	72	44	412	44
		%	74.6	25.4	62.1	37.9	90.4	9.6
HTR (n=18)	486		411	75	60	15	471	15
		%	84.6	15.4	80.0	20.0	96.9	3.1
LTR (n=16)	432		338	94	65	29	403	29
		%	78.2	21.8	69.1	30.9	93.3	6.7
All CR	969		797	172	114	58	911	58
		%	82.2	17.8	66.3	33.7	94.0	6.0
All TR	918		749	169	135	44	874	44
		%	81.6	18.4	74.0	26.0	95.2	4.8
All Hi	999		868	131	102	29	970	29
		%	86.9	13.1	77.9	22.1	97.1	2.9
All Lo	888		678	210	137	73	815	73
		%	76.4	23.6	65.2	34.8	91.8	8.2
All	1887		1546	341	239	102	1785	102
		%	81.9	18.1	70.1	29.9	94.6	5.4

To determine if a significant difference existed between the unit test performance of the CR and TR students, a Chi-square test was applied to the data in columns F and G. The following comparisons were made: HCR versus HTR, LCR versus LTR, and All CR versus All TR. The probability of a significant difference was greater than .20 for the HCR-HTR and All CR-All TR comparisons, and greater than .10 for the

LCR-LTR comparison. These results indicate that the performance of the CR and TR students did not differ significantly on the unit tests.

Column D provides a direct measure of the efficiency of the remediation provided to the students. Among the high ability students, the teacher remediation was 80% effective compared to 75% effectiveness for the computer remediation. The differential between lower ability students was 69% to 62% in favor of teacher remediation, and the total for each remediation mode was 74% to 66%, also favoring teacher remediation. A Chi-square test indicated the probability of a significant difference in the All CR-All TR distributions was greater than the .05 level, and that the probability of a significant difference in the HCR-HTR and LCR-LTR distributions was greater than the .20 level. These results are encouraging in that even though the teacher remediation was more efficient, the performance of the students within each ability group on the computer remediation was within acceptable levels.

Review tests. A second measurement of the performance of the CR groups as compared to the TR groups is the score achieved by each group on the review tests which occurred at units 10, 19, 26, and 31. The analysis of the review test scores is presented in Table 2.

TABLE 2

Group Mean Scores on Review Tests

	Ability Level		
	High	Low	
Remediation Mode			
Computer	92.1 (n=19)	75.2 (n=17)	84.1
Teacher	90.7 (n=18)	82.5 (n=16)	86.8
	91.4	78.8	85.4

Analysis of Variance Table

Source	d.f.	MS	F Ratio	
Remediation Mode	1	503.31	1.252	p>.25
Ability Level	1	10691.43	26.597	p<.01
Remediation Mode X Ability Level	1	1291.92	3.214	.10>p>.05
Error	64	401.97		

The analysis indicates no statistically significant difference between high ability students across remediation modes, but a difference favoring the TR students between the lower ability students. The probability of a significant interaction was greater than the .05 level, primarily due to the seven point difference between the means of the LTR and LCR students.

Table 3 reports the performance of the students on the review tests relative to the criterion of 80%.

TABLE 3

Percentages of students who attained criterion of 80% on review tests

	Review Test Units				
	10	19	26	31	Total
HCR(n=19)	94.7	89.4	89.4	84.2	89.5
LCR(n=17)	88.2	41.2	76.5	56.3	71.3
All CR	91.7	66.7	83.3	71.4	80.1
HTR(n=18)	94.4	77.8	94.4	88.9	88.9
LTR(n=16)	87.5	68.8	87.5	68.8	78.1
All TR	91.2	73.5	91.2	79.4	83.8

In general, higher percentages of TR students attained criterion on the review tests than did CR students. There are somewhat small differences between the higher ability groups, with the total being slightly in favor of the HCR group. However, with the exception of the unit 10 test, there were large differences in favor of the LTR group over the LCR group, indicating that the teacher remediation had a more positive effect for the lower ability students.

Posttest. As the students completed unit 31, the 25 question posttest was administered. The results of the analysis of the scores are presented in Table 4.

TABLE 4

Group mean scores on posttest

	Ability Level High	Low	
Remediation Mode			
Computer	86.5(n=19)	60.3(n=16)	73.4
Teacher	83.3(n=17)	69.9(n=14)	76.6
	84.9	65.1	75.7

Analysis of Variance Table

Source	d.f.	MS	F Ratio	
Remediation Mode	1	180.669	.7043	p=.59
Ability Level	1	6876.622	26.8086	p<.001
Remediation Mode X Ability Level	1	716.695	2.7941	p=.096
Error	66	256.508		

As in the review test results, a nonsignificant difference is observed between the high ability groups along with a larger difference, in favor of the LTR group, between the lower ability students. In relation to the 80% level, 84% of the HCR group attained that level compared to 61% of the HTR group. Among the lower ability students, 38% of the HTR group scored 80% or higher compared to 13% of the LCR group. The total for each remediation mode shows that 54% of the CR students attained the criterion compared to 50% of the TR students.

Retention test. Slightly different results were obtained in the retention testing than were obtained in the review test and posttest situations. These results are presented in Table 5.

TABLE 5

Group mean scores on retention test

	Ability Level High	Low	
Remediation Mode Computer	79.8(n=19)	58.1(n=16)	69.0
Teacher	81.4(n=17)	68.3(n=14)	74.8
	80.6	63.2	72.7

Analysis of Variance Table

Source	d.f.	MS	F Ratio	
Remediation Mode	1	555.571	2.8185	p=.09
Ability Level	1	4847.923	24.5947	p<.001
Remediation Mode X Ability Level	1	291.574	1.4792	p=.23
Error	61	197.113		

The analysis again fails to reveal a significant difference between the high ability groups, but the observed difference was in favor of the HTR group. Once again, however, the LTR group outperformed the LCR group, and the probability of a significant difference between remediation modes was .09.

In relation to the 80% criterion, 59% of the HTR group attained criterion compared to 58% of the HCR group, while 36% of the LTR group reached criterion compared to 13% of the LCR group. The total between remediation modes was 48% to 38% favoring the TR students.

Comprehensive Tests of Basic Skills. The Wakulla County School system, as part of their evaluation program, administered the CTBS in the fall of 1970 and again in the spring of 1971. This provided an opportunity to examine the performance of the experimental groups on a test which was of other than local origin. It must be emphasized that the pretest and posttest were administered approximately eight months apart and the period of this study accounted for only three of those eight months. Nevertheless, if the assumption is made that all students received comparable instruction in the traditional classroom during the five months prior to this study, the results of the CTBS achievement testing deserve consideration. Tables 6 through 8 present the results of the pre- and posttests on the CTBS mathematics subtest.

TABLE 6

CTBS mean mathematics grade equivalents for each group

	Pretest Mean	Posttest Mean	Adjusted Mean
HCR (n=15)	7.9	9.2	8.4
LCR (n=12)	5.0	6.1	7.2
All CR	6.7	7.9	7.8
HTR (n=17)	7.4	8.3	7.7
LTR (n=16)	5.4	6.0	6.9
All TR	6.4	7.2	7.3

Because of the differences which existed between the groups on the pretest, an analysis of covariance with the pretest as covariate was performed on the posttest scores. The adjusted means are shown in the last column of Table 6 and the ANCOVA summaries are presented in Tables 7 and 8.

TABLE 7

ANCOVA summary table of CR and TR groups:
variate = posttest score and covariate = pretest score (CTBS)

Source	df	MS	F	P
Total	58			
Error	57	1.8321		
Treatments	1	3.6244	1.978	>.10

TABLE 8

ANCOVA summary table for all 4 groups:
variate = posttest score and covariate = pretest score (CTBS)

Source	df	MS	F	P
Total	58			
Error	55	1.7019		
Treatments	3	4.8162	2.83	.05

Table 6 shows that the CR groups exhibited greater gains than the TR group of similar ability, providing results which are somewhat different from the outcomes of the previously described testing situations. Where the previous tests showed mixed results, the CTBS tests indicate the CR students performed better than the TR students at both ability levels. This is particularly evident among the lower ability students where the LCR students began the year .4 grades behind the LTR students but were .1 grades ahead on the unadjusted posttest mean and .3 grades ahead on the adjusted mean. The probability of a significant difference between the HCR and HTR groups, in favor of the HCR group, was slightly greater than the .10 level on both the unadjusted and the adjusted means.

Question 2: Movement Through the Instructional Materials

Does the mode of remediation received affect the rate at which students progress through the instructional materials?

Number of units completed. The rate at which the four groups moved through the instructional materials was closely monitored. Table 9 shows the mean number of units completed by each group at three week intervals throughout the 15 week study.

The figures in Table 9 can be considered accurate only through the ninth week. At that time, the higher ability students were moving into the portion of the materials where no remediation was provided. This freed the terminals for more extensive use by the lower ability students during class time, which partly accounts for the anomalous situation at the end of 12 weeks in which the HTR and LTR groups had completed the same mean number of units.

The data at the end of nine weeks, when analyzed by the Mann-Whitney U Test, show no significant differences in mean number of units completed between all CR and TR students or between LCR and LTR students.

TABLE 9

Mean number of units completed by each group

Time (Weeks)	Remed. Mode	Ability Level High	Low	Total
3	CR	10.2(n=19)	8.1(n=17)	9.2
	TR	9.6(n=18)	8.3(n=16)	9.0
6	CR	17.6	13.2	15.5
	TR	15.3	13.6	14.5
9	CR	25.4	18.4	22.1
	TR	21.2	19.9	20.5
12	CR	31.4	24.4	28.0
	TR	27.8	27.8	27.8
15	CR	40.9	34.5	37.3
	TR	37.1	34.6	35.9

However, the probability of a significant difference in favor of the HCR group over the HTR group was between the .05 and .10 levels.

Rate of Movement. A closer examination of the rate of movement through the materials is graphically presented in Figure 3. Calculation of average movement rates indicated that very high rates at the beginning and end of the study tended to obscure rate measurements in other time segments. Therefore, the rate of movement was calculated for each separate three-week time period.

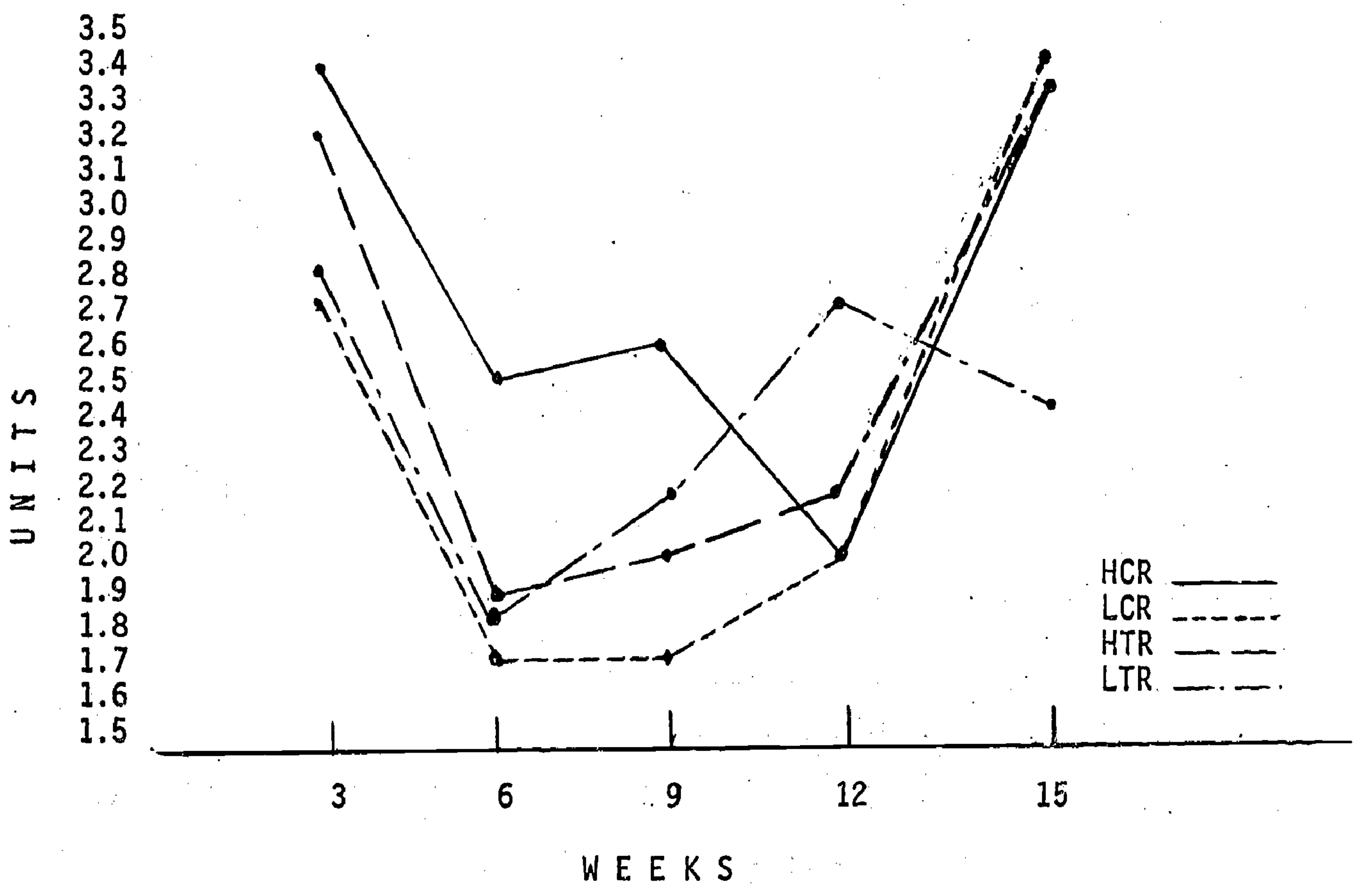

Figure 3.--Mean number of units completed per week during each three week period.

When it became apparent at about the twelfth week that most of the students were going to reach the 31 unit plateau, the two lower ability groups reacted in startlingly different manners. The LTR group, upon completion of the minimum amount of work required of them, did very little more. The LCR group, on the average approximately 3.5 units behind the LTR group at the end of 12 weeks, continued working at a high rate, reached the 31 unit plateau, and pushed beyond it. In the high ability class, it had become a contest and a matter of prestige to see who could complete the greatest number of units. These factors are reflected in the varying rates of movement observed in Figure 3.

The figures in the last column of Table 9 indicate that the CR groups completed a greater number of units throughout the study than did the TR groups. However, since this difference was not statistically significant, it would appear that mode of remediation had no effect on the rate of movement through the instructional materials.

Question 3: Student Attitudes

Does the presence of computer-managed individualized instruction have an effect on the student's attitude toward mathematics?

In investigating the feasibility of a new instructional program, it would seem to be wise not to ignore the effect of the new program on the attitudes of the students toward the program and toward the subject matter involved. This would seem to be especially true in mathematics where research has shown an extremely close relationship between attitude and achievement (Aiken, 1970).

To investigate the attitudes of the Wakulla students toward the computer-managed individualized instruction program, attitudes were assessed in three areas: mathematics in general, computer-managed instruction, and individualized instruction.

General mathematics attitudes. The median score on the Dutton questionnaire on both the pretest and posttest was 84. On the pretest, 35 students scored above the median and 36 below. On the posttest, 31 students scored above the median and 33 below. The Median Test of these data indicated ($p>.90$) that the two sets of scores came from the same population, leading to the conclusion that the students' attitudes toward mathematics in general were not affected by the computer-managed individualized instructional program. In addition, no significant differences in attitudes were observed when the students within each remediation mode were divided according to ability.

CMI/individualized instruction attitudes. On the Brown questionnaire incorporating both subscales, the initial testing provided a median score of 138.5 and the median score on the posttest was 141. On the initial testing, 34 students scored above the median and 34 were below. On the posttest, 35 students exceeded 138.5 and 30 fell below. Even though the median increased between measurements, the Median Test indicated ($p>.50$) that the change in distribution was not statistically significant.

On the CMI subscale, the initial testing demonstrated a median score of 79.5, with 34 students' scores falling on each side of that figure. The posttest median was 80.5, with 33 scores above the initial median and 32 below, resulting in a minimal change. When the posttest data for this subscale were divided and analyzed according to remediation mode, it was found that 19 CR students scored above the initial median and 12 were below. In contrast, 14 of the TR scores were above the same figure and 20 scored below. The probability of a significant difference between these score distributions was between the .05 and .10 levels, indicating that the CR students' attitudes toward CMI became more positive while the TR students' attitudes toward CMI became more negative.

Somewhat different results for the entire group were obtained on the individualized instruction subscale. The median score on the initial testing was 59 and the posttest median was 61. On the initial test, 30 students scored above 59 and a large number of ties resulted in 38 scores below 59. On the posttest, however, 38 students scored above 59 while 27 were below. The probability of a significant difference between these score distributions was slightly greater than the .10 level, indicating that even though the attitudes toward mathematics in general and CMI did not change, the students' attitudes toward individualized instruction per se tended to become more positive during the study.

A further indication of this positive shift in attitudes is seen in the responses to a question which was asked at the end of the study. When asked "Compared to how you felt about mathematics before we started the CMI program, how do you feel now?", 49 of the students (71%) responded to the choice "much better", 15 (21.7%) replied "better", four (5.7%) replied they felt the same, and one student (1.4%) indicated she felt worse about mathematics. This evidence indicates the merit of a program of individualized instruction, whether it be automated or nonautomated.

Question 4: Impact on the Teacher

What effect does the presence of computer-managed instruction have upon the functions and daily actions of the teacher?

The introduction of the CMI program created a significant change in the day to day activities performed by the teacher, both in and out of the classroom.

In-class activities. Prior to the study, the teacher's in-class activities consisted primarily of the activities normally associated with a traditional mathematics classroom. The majority of the class period was spent in the mass dissemination of information through lecture and demonstration, and a short period of time was allowed for the students to work on the assignment. During that time the teacher usually worked with some students individually, but this individual contact was extremely limited due to class enrollments in excess of 30 students. Periodically, an entire class period was devoted to testing, during which the teacher usually graded papers or began preparations for the next set of lessons.

While the CMI program was in progress, the teacher spent all his time in individual contact with the students. Some students were calling on him for help with the material in the booklets while others were requiring remediation after failure of a test. Thus, he was constantly in demand. If he moved about the room helping students, there were always several hands up where students were waiting for him to come to their desk next. If he remained seated at his desk, a minimum of six or eight students quickly gathered around him.

The teacher found this opportunity to engage in activities of a more interactive, tutorial nature to be a stimulating experience, both personally and professionally. In the personal context, it allowed him to become better acquainted with his students and their unique characteristics as individuals in a learning situation. Professionally, rather than being merely a dispenser of information, he was provided an opportunity to perform at a higher level of professional competence.

Out-of-class activities. With the exception of assigning grades and filling out grade cards every six weeks, the teacher had no duties to perform outside the classroom. It was not necessary to do any planning for the two CMI classes since the booklets had already been developed and sequenced. The most significant factor in the reduced workload, however, came from being freed from the clerical duties which consume so much of a teacher's time outside of the classroom. He had no papers to grade and record and no tests to generate, score, and record.

Since two of his four classes had been converted to CMI, his outside workload was effectively cut in half. This extra time gained was utilized in additional planning for the two lower ability classes on his schedule.

Question 5: Economic Factors

What are the costs of a terminal-oriented CMI system?

Program costs. The costs of the development and operation of the CMI course for 70 students for 15 weeks are presented in Table 10.

TABLE 10

Cost Data

Developmental	
1. One graduate student spent approximately 180 hours on 57 units, 20 hours/week @ $138.80 biweekly	$625.00
2. Materials and duplication	100.00
3. Computer Coding Time 50 hours @ $3.33/hr.	167.00
4. 57 instructional units @ $110.00/unit	6,270.00
	$7,162.00
$7,162.00 / 1 hour per day X 75 days X 70 Students (5,250 hrs.) =	$1.36 per Student hour
Operational	
1. Teacher. $6,500/36 weeks X 15 weeks X 1/2 Time	1,354.00
2. Two terminal room proctors	1,500.00
3. Computer time 375 hours/$3.33/hr.	1,248.00
	$4,102.00
$4,102.00 / 5,250 hours = $.78 per student hour	
Total Hourly Cost = $2.14 per student hour.	

Since only 70 students were involved in these calculations, the developmental costs comprised an inordinate proportion of the total instructional costs.

Computer time. It would seem that the presentation of remediation to one group of students would cause that group to spend more time in direct (on-line) computer contact. This in turn would make computer remediation more expensive than teacher remediation within a CMI format. Analysis of the on-line time by remediation mode and ability level, as presented in Table 11, indicates that in this particular study the above assumption was not valid.

TABLE 11

Average amount of time (in minutes) spent on line during the 15 weeks.

Remediation Mode	Ability Level High	Low	Total
Computer	298.8	346.8	322.8
Teacher	300.5	345.7	323.1
Total	299.7	346.2	

It is obvious that the only significant difference appearing in Table 11 is the difference between ability levels. The median on-line time was 312.5 minutes. Twelve high ability students were on line longer than that and 25 less. Of the lower ability students, 23 were on line longer than the median figure and 11 less than that. The Median Test indicated this difference was significant at less than the .01 level of probability. Since communications costs represent a substantial portion of the cost of terminal-oriented CMI, these data indicate that ability level could be a more crucial economic factor than remediation mode.

V. DISCUSSION AND CONCLUSIONS

The primary purpose for conducting this study was to investigate the feasibility of a terminal-oriented CMI program in a public school setting. One of the capabilities of terminal-oriented CMI is the provision of remedial assistance to the student in the event a test is failed. The effectiveness of computer-presented remedial assistance and its viability as an alternative to teacher-presented remedial assistance was the specific factor under investigation.

The five questions which this study attempted to answer can be grouped into three major areas that should be considered in determining the feasibility of an instructional system. They are the program's: (a) effect on the students; (b) effect on the teacher; and (c) economic factors. The purpose of this chapter is to summarize the findings of this study in each of these areas.

Effect on the Students

Measurements of the effect of the experimental instructional system on the students were taken in both the cognitive and affective domains. In the cognitive domain, performance data were gathered through both criterion-referenced assessment instruments and norm-referenced achievement tests. From the affective domain student attitudes toward mathematics and the CAI/CMI system were sampled.

Student performance. The data from the primary focus of this investigation, teacher remediation compared to computer remediation, indicate no statistically significant differences in student performance between remediation modes. Differences which existed between lower ability groups tended to favor teacher remediation, and could have been due to the possibility that the teacher remediation was more supportive in nature or that the teacher might have provided more than two examples to some students. However, a concerted effort was made to maintain uniformity between remediation modes. The more efficient teacher remediation for lower ability students also could be due to characteristics of the computer remediation provided in this particular program, and should not be a condemnation of all efforts to provide remediation via computer.

It should also be noted that the remediation was considerably more efficient in the higher ability groups than in the lower ability groups, a factor which could be related to the ability of the LCR group to read the remediation and to the possibility that more than two examples may be required for proper remediation.

In general, the criterion-referenced performance indicators show nonsignificant differences between CR and TR students. When the CR and TR students were subdivided according to ability, nonsignificant differences again appeared between the high ability groups, but larger differences became apparent between the lower ability groups. These differences favored the LTR students and the majority of the differences were statistically significant.

With the exception of the CTBS achievement test, the LTR students demonstrated performance superior to that of the LCR students. This difference was most noticeable in the testing situations. Both lower ability groups demonstrated relatively high success rates on the individual units, with the LCR performance level within 3% of the level of the LTR students. Unfortunately, this success rate did not carry over to the review, post-, and retention testing situations. Both groups performed less well on these tests, and the LCR group means fell seven to ten points below that of the LTR group. It appears that allowing a student to progress at his own rate through the instructional materials had a positive effect on performance in the day-to-day situation, but did not carry over to the testing situation. The higher test performance of the LTR group would indicate that interaction with a teacher during remediation had a more positive effect on lower ability students than computer remediation, placing great importance on the nature of student-teacher relationships for lower ability students.

The indication that teacher interaction is more important for lower ability students is further reinforced by the nonsignificant differences in performance between HCR and HTR students. The high ability students in this study apparently were able to work independently without heavy reliance upon the teacher and to maintain a high performance level. This would indicate that the provision of remedial assistance via computer would not have an adverse effect on the course performance or overall achievement of higher ability students.

The norm-referenced CTBS achievement testing yielded data which only partially agreed with the data from the criterion-referenced tests developed in conjunction with the program. On the CTBS the CR students performed better than the TR students at both ability levels. A possible explanation might be that through personal characteristics, inadvertent actions, or subtle voice inflections which could pervade the student-teacher interaction, the teacher might unintentionally focus upon the immediate objectives of the program. In other words, the "teach to the test" phenomenon could enter into the teacher-presented remedial activity. In contrast, the computer treated all students equally and provided exactly the same remediation to all students regardless of ability. These factors may have reduced the tendency to focus on immediate objectives, allow better generalization to occur, and resulted in better performance by the CR students on the norm-referenced, broader-based achievement test.

Rate of movement. The data regarding the rate at which the different groups progressed through the instructional materials indicate that ability level was the primary determinant, not the mode of remediation. The CR students completed a greater mean number of units than the TR students, but this difference was not statistically significant. Thus, remediation mode had little effect on the students' rate of movement through the learning materials.

Student attitudes. Perhaps the most important aspect of the attitude measurements is not the small magnitude of the pre-post gain, but the high level of the posttest scores. Regardless of the scores obtained on the pretest, which were obviously positively skewed, it is apparent that at the end of the 15 week period the students exhibited highly positive attitudes toward both mathematics in general and CMI/individualized instruction in particular. These high positive attitudes toward the CMI program are especially noteworthy in light of the fact they were measured on the next-to-last day of the academic year.

Closer examination of the CMI and individualized instruction subscales of the Brown questionnaire indicates that all median scores increased from the initial testing to the final testing except for the TR students on the CMI subscale. Their median score decreased. All the students indicated that the use of the computer terminals was the most exciting part of the program. Evidently, then, the less extensive use of the terminals by the TR students led to a reduction in their attitude toward the CMI program. Another factor which may have contributed to this situation is that when the TR students failed a test, they were required to tear the paper off of the teletype and take it back to the classroom to get help from the teacher. Therefore, when a student walked into the room with a long piece of teletype paper in his hand, everyone in the class knew he had failed a test. The CR students were able to fail in privacy.

Effect on the Teacher

In this study, the HCR and HTR students demonstrated equivalent performance levels which were significantly higher than the performance levels of the LCR and LTR students. Within the lower ability groups, teacher remediation appears to have had a more positive effect on student achievement, indicating that the presence of a teacher is an important factor in the provision of learning experiences for lower ability students.

These observations offer implications for the recent movement within the schools toward a more flexible use of the time and talents of classroom teachers. Since high ability students apparently can work independently, receive remediation from a computer if necessary, and maintain an acceptable level of performance, it would seem that an aide or intern could supervise the learning activities of those students in the kind of program offered in this study. This would free the more highly-skilled teacher to work individually with the lower ability students who seem to need their attention more. The teacher could focus more closely on identifying the particular learning difficulties of the individual students and the prescription of learning experiences which could alleviate those difficulties.

The teacher who participated in this study was not operating under typical conditions which would be present in the usual CMI classroom application. The experimental teacher was only minimally involved in the preparation of the instructional materials and remedial exercises for the study. In the usual situation the teacher would be involved in the developmental activities, the implementation procedures, and the evaluation and revision methods. Thus, the usual teacher would not find his work load cut in half as did the experimental teacher. However, the usual teacher, relieved of the mind-numbing clerical duties which consume so much evening and weekend time, would be involved in the professionally higher level developmental, prescriptive, and diagnostic tasks for which he was trained. The teacher would be equally as busy in a CMI situation as in a traditional program, but his energies would be directed toward those more professionally satisfying tasks he is most competent to perform.

Economic Factors

Table 10 indicates that the cost per student instructional hour of this study was $2.14. The immediate impression is that this is an exorbitant cost and that such a terminal-oriented program is far from feasible in a typical school system. It must be remembered, however, that this was an "add-on" to the normal school program, and since it involved only 70 students, the cost is indeed exorbitant. However, because this research was designed to investigate an instructional system which might exist in the future, it will be necessary to discuss the economic factors surrounding the study in terms of the future. To provide a more reasonable level of analysis, the calculations will be based on 700 students rather than 70.

Two major assumptions underlie this cost analysis. The first is that schools will continue present trends and implement programs of individualized instruction based on differing student needs and learning capabilities. The second assumption is that the two remediation modes are equally effective in bringing about student learning.

In regard to the first assumption, the provision of a program of individualized instruction should tend to increase the cost of traditionally administered instruction (TAI). The teachers and all the school facilities would need to be provided to the students for the same number of hours as at present, but to these fixed costs must be added the cost of developing the instructional materials needed to support a program of individualized instruction. The costs incurred by Palm Beach County in developing the materials used in this study amounted to $110 per unit. When multiplied by the 57 units used in the study, this cost amounts to nearly $6300.

In a normal situation, as opposed to a short program like this one, these costs would be amortized over a period of time. Using the standard five year life span of a textbook as the amorization period and adding additional printing charges, an annual cost of approximately $1300 is realized. Dividing by 52,500 instructional hours provided the 700 students during the study, it is found that an additional $.03 per hours must be added to the base cost of TAI in order to provide a nonautomated individualized instruction program.

Recent U.S. Office of Education estimates place the cost of elementary and secondary education during the 1970-71 school year at $.38 per student hour (Kopstein & Seidel, 1969). Thus, the cost of basic services plus the software necessary for a nonautomated individualized instruction program for 700 students would be $.41 per student hour.

Using the $.41 per hour as the basic cost of the teacher, facilities, and software, it is now possible to calculate the cost of providing an individualized instruction program supported by a terminal-oriented CMI system. It should be noted that the figure of $3.33 per hour charged by the FSU CAI Center for the use of the IBM 1500 CAI system is somewhat inflated due to a nonutilization charge. Stolurow (1967) estimates that with student use of the terminals for two normal school-day shifts per day, the cost of the IBM 1500 could be reduced to $1.95 per hour. At that rate, the 3,750 hours required for the program would result in computer charges of $7,312. Adding this figure to the costs for eight part-time proctors results in an operational expenditure of $13,312, yielding an hourly cost of $.25. The remaining developmental costs, when amortized over five years and divided by 52,500 hours, amount to less than one-half cent per hour, and may be disregarded. Thus, the cost of providing terminal-oriented CMI in addition to the individualized program would total $.66 per hour.

This increase in cost can only be justified by an increase in student performance. Since the CR students in this study demonstrated equivalent, but not superior, performance, this cost overage of 60% cannot be considered feasible at the present time. However, projections of present economic trends into the future indicate that a changing picture may be emerging.

It is generally acknowledged that computing hardware costs are decreasing due to mass production methods and technological advances. At the same time, moreover, personnel costs are rising. For the purpose of these projections, it will be assumed that hardware cost decreases will be balanced by personnel cost increases and the cost of an individualized program with terminal-oriented CMI capabilities will remain constant at $.66 per hour.

USOE estimates indicate the $.38 per hour cost of 1970-71 will increase to $.42 by 1974-75, a four-year increase of 10.5%. Assuming this rate of increase to be constant and beginning with a 1970-71 cost of $.41 per hour, projected costs of teacher administered individualized instruction should reach $.66 at about 1988. This is a conservative date, however, due primarily to two factors. First, the figure of $.41 per hour for a nonautomated individualized instruction program assumes that the teacher is the entire information management system, an impossible assignment. No individual teacher could possibly cope with the mountain of prescriptive, diagnostic, and evaluative data generated by an individualized program. Clerical or mechanical assistance will be needed to provide a management system, thereby increasing the costs of TAI at a rate greater than 10.5%. Secondly, if a terminal-oriented CMI program was present in a school, an aide or intern (two or three of whom can be obtained for the money allocated for one teacher unit) could supervise the learning activities of many of the students, leaving the master teacher free to work with individual learning difficulties. An example: a typical classroom adult/pupil ratio of 1 to 30 would require eight teachers (not counting teachers for special areas such as art and music) to accommodate 240 students. If four teacher units were traded for eight trained paraprofessionals, an adult/pupil ratio of 1 to 20 could be achieved with no increase in expenditure. A net reduction in the cost of instruction should result due to more efficient use of the higher-paid teacher's time, increased frequency of pupil contact with adult assistance, and provision of remediation by computer.

If the assumptions which have been made are true, and if the projections made herein, based on 1970-71 dollars and not considering inflation, are accurate, the cost of a teacher administered individualized program and the cost of an individualized program supported by a terminal-oriented CMI system should become equal near the year 1980.

The projections just presented are based on the very important second assumption of equal effectiveness of teacher and computer remediation, and if the data from this study are applied in terms of the performance of the TR students compared to the CR students, the assumption appears valid. However, when the students in the two remediation modes are subdivided according to ability, the data do not meet the assumption. Therefore, it will be necessary to modify the above projections with the phrase "for high ability students." The performance differential between the LTR and LCR students would indicate the provision of computer remediation to students performing below grade level would not be feasible.

The lower ability students in this study averaged .7 grades below grade level on the CTBS achievement test. It is obvious that further research is needed to determine at what ability level the computer remediation would become feasible. Replication of this research in other academic areas with other students is needed to determine if these results are related only to these students and to mathematics.

Conclusions

Considering both quantitative data and information of an observational nature, the following conclusions arise from this study:

1. Computer remediation allowed higher ability students to maintain acceptable performance standards, but teacher remediation had a more positive effect on the lower ability students.
2. The students exhibited greater pleasure with their mathematics class due to the absence of daily lectures and homework.
3. The students developed closer relationships with the teacher.
4. Mode of remediation had no effect on the rate at which the students moved through the instructional materials. The determining factor here was ability level.
5. Due to extremely high pretest levels, the students did not exhibit significant attitude gains. However, highly positive attitudes toward mathematics in general, CMI, and individualized instruction were exhibited at the end of the study. The CR students demonstrated more positive attitudes toward the CMI program in particular than did the TR students.
6. The teacher developed a better rapport with his students and was able to work more easily with them in the dissolution of their learning difficulties with the instructional materials.
7. The teacher found more personal satisfaction with the individualized situation than in the traditional lecture and demonstration setting.

8. Freed from clerical tasks and with the needed assistance in managing the individualized program, the teacher was able to perform at a higher level professionally.
9. A terminal-oriented CMI system is not economically feasible at present in a typical public school system. Barring a significant breakthrough in terminal and communication costs, the earliest date of feasibility for high ability students appears to be about 1980.
10. Until educational research discovers better methods of alleviating the learning difficulties of students performing below grade level, the economic utility of providing computer remediation for such students is questionable.

REFERENCES

Aiken, L.R. Jr. Attitudes toward mathematics. Review of Educational Research, 1970, 40(4), 551-596.

Atkinson, R. Computerized instruction and the learning process. In R. Atkinson & H. Wilson (Eds.), Computer-assisted instruction: A book of readings. New York: Academic Press, 1969. Pp. 3-14.

Brown, B.R. An instrument for the measurement of expressed attitude toward computer-assisted instruction. In Semi-Annual Progress Report, Experimentation with Computer-Assisted Instruction, Project No. 5-85-074, prepared by H.E. Mitzel, et al., December 31, 1966.

Bundy, R.F. Computer-assisted instruction--where are we? Phi Delta Kappan, 1968, 49, 424-429.

Bushnell, D.D. Applications of computer technology to the improvement of learning. In D. Bushnell & D. Allen (Eds.), The computer in American Education. New York: John Wiley & Sons, 1967. Pp. 59-76.

California Test Bureau. Comprehensive Tests of Basic Skills, Form Q3. Monterey, California: McGraw Hill Book Company, 1968.

Campbell, D. & Stanley, J. Experimental and quasi-experimental designs for research. Chicago: Rand McNally & Company, 1963.

Cooley, W. & Glaser, R. An information and management system for individually prescribed instruction. In R. Atkinson & H. Wilson (Eds.), Computer-assisted instruction: A book of readings. New York: Academic Press, 1969. Pp. 95-117.

Dutton, W.H., & Blum, M.P. The measurement of attitudes toward arithmetic with a Likert -type test. Elementary School Journal, 1968, 68, 259-264.

Ferguson, R.L. Computer-assisted criterion-referenced testing. Working paper, Learning Research and Development Center, University of Pittsburgh, 1970.

Flanagan, J. The role of the computer in PLAN. Journal of Educational Data Processing, February, 1970, 7, 1-10.

Geddes, C. & Kooi, B. An instructional management system for classroom teachers. Elementary School Journal, 1969, 69, 337-345.

Hansen, D. The role of computers in education in the 70's. Technical Memorandum Number 15, CAI Center, Florida State University, 1970a.

Hansen, D. Current research development in computer-assisted instruction. Technical Memorandum Number 17, CAI Center, Florida State University 1970b.

Hansen, D., Johnson, B., Durall, E., Lavin, B., & McKune, L. End of Project Report, July 1, 1968-June 30, 1971: A rural county computer-related instructional technology project. CAI Center, Florida State University, 1971.

Hansen, D., O'Neil, H., Brown, B., King, A., & Rivers, L. Annual Report: January 1, 1969 through December 31, 1969, CAI Center, Florida State University, 1970.

Hansen, D., Brown, B., O'Neil, H., Merrill, P., & Johnson, B. Annual Report: January 1, 1970 through December 31, 1970, CAI Center, Florida State University, 1971.

Kennedy, W. A follow-up normative study of Negro intelligence and achievement. Monographs of the Society for Research in Child Development, 1969, 34, (2, Whole Number 126).

Kopstein, F., & Seidel, R. Computer-administered instruction versus traditionally administered instruction: Economics. In R. Atkinson & H. Wilson (Eds.), Computer-assisted instruction: A book of readings. New York: Academic Press, 1969. Pp. 327-362.

Lawler, R.M. An investigation of selected instructional strategies in an undergraduate computer-managed instruction course. Technical Report Number 19, CAI Center, Florida State University, 1971.

Palm Beach County Board of Public Instruction. Mathematics Curriculum EIE Project, Secondary Curriculum Development, Frank Miller, Director, 1969.

Rogers, J. Dear computer, how am I doing? PARADE: The Sunday Newspaper Magazine, February 7, 1971, 10-13.

Silberman, H. Computer-managed instruction: Use of a computer to monitor student performance. Engineering Education, 1969, 59, 484-486.

Stolurow, L. "Computer-assisted instruction (CAI)" Unpublished paper, Harvard University, 1967, 56, as quoted in Oettinger, A. Run, computer, run: The mythology of educational innovation. Cambridge, Mass.: Harvard University Press, 1969, Pp. 191.

Suppes, P. On using computers to individualize instruction. In D. Bushnell & D. Allen (Eds.), The computer in American education New York: John Wiley & Sons, 1967. Pp. 11-24.

Suppes, P. & Jerman, M. CAI at Stanford. Educational Television International, 1969, 3, 176-179.

Tuttle, J. The historical development of computer capabilities which permitted the use of the computer as an educational medium in the United States from 1958 to 1968, with implications of trends. Unpublished doctoral dissertation, New York University, 1970.