UNIVERSITY OF ALBERTA

STRATEGIES FOR IMPROVING THE MATHEMATICS 30^{CAI} COURSE

by

Leona D. Bjarnason ©

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF EDUCATION

DEPARTMENT OF EDUCATIONAL POLICY STUDIES

EDMONTON, ALBERTA

FALL 1995

ISBN 0-612-06385-2

UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR:	Leona D. Bjarnason
TITLE OF THESIS:	Strategies for Improving the Mathematics 30^{CAI} Course
DEGREE:	Master of Education
YEAR THIS DEGREE GRANTED:	1995

Leona Bjarnason

10511 - 17 Avenue

Edmonton, Alberta

Date September 25, 1995

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for the acceptance, a thesis entitled Strategies for Improving the Mathematics 30^{CAI} Course submitted by Leona D. Bjarnason in partial fulfillment of the requirements for the degree of Master of Education.

Dr. Milton Petruk

Dr. Dave Collett

Dr. Steven Hunka

Date September 25, 1995

Abstract

The purpose of this study was to devise strategies for the improvement of Computer-Assisted Instruction (CAI). The Alberta Education Mathematics 30 *CAI* materials were used by the Urban, Full-year (UF) and Rural, Semestered (RS) classes included in this study.

The strategies focused on the areas of students'; time on task, subjective feedback, and achievement scores. The time-on-task and subjective feedback data gathered came from computer-generated student audit trails. The CAI teachers supplied the students' achievement scores. Additional data came from observation of the (UF) students.

The strategies for the improvement of the CAI stemmed from the findings that in both classes there was a high percentage (48.8%) of Low-scoring (below 40%) and High-scoring (above 79%) students, on two different diploma examinations. A further analysis of the (UF) students' time-on-task, subjective feedback and researcher's observations of them, served to initiate other strategies.

Acknowledgments

I would like to thank Dr. Milton Petruk, Dr. Dave Collett, and Dr. Steven Hunka for their advice, guidance, and support throughout the research and writing phases of this thesis. A special thanks to all staff and students in the Centre for Research and Applied Measurement and Evaluation (C.R.A.M.E.) for their dialogue and support.

I would like to express my appreciation to all the students, teachers, school and district personnel without whose participation made this research possible.

To my husband, Richard, and my two sons, Jared and Brendon, my gratitude for their understanding, patience and support throughout my university education.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I: INTRODUCTION

Background

"Computer-Assisted Instruction (CAI) encompasses a wide variety of activities that attempt to apply the results of learning theory to practical classroom instruction" (Mis, 1990, p. 71). The most common forms of CAI are tutorials, drill and practice, simulations and games. CAI seems to be useful for individualizing instruction. "Individualized instruction demands varied applications of different objectives, curricula, learning tasks, materials, and learning / instruction methods; so that learning / instruction work that is organized within the frame of the classroom means individualized sequence, level, speed of learning, and choice of the learning task" (Sovik, 1981, p. 14). Technological advances in speed and capabilities of the computer are evolutionizing CAI instruction.

Some of the benefits of CAI, as stated in numerous studies, has been the improvement of students' achievement scores and attitudes towards the computer and instruction. The meta-analysis of 42 controlled evaluations on the effectiveness of Computer-Based Education (CBE) in secondary schools done by Bangert-Drowns, Kulik and Kulik (1985) suggested that CBE had a positive effect both on achievement scores and student attitudes. "Programs of computer-assisted and computer-managed instruction were generally quite effective, raising student examination scores by approximately 0.4 standard deviations" from the 50th to 60th percentile. (Bangert-Drowns, Kulik & Kulik, 1985, p. 59). At the computer management level, according to Bangert-Drowns, Kulik and Kulik (1985), the benefits of computer-managed instruction (CMI) seemed to profit the older students more, possibly due to the independence and choice that it provided. These studies seem to indicate that CAI has a place in the individualized classroom of today.

Many feel that by exploring new or improved methods of instruction, through the use of computer technology, other discoveries may be made that will enhance the learning process. "The amount of information required to be proficient in any field is increasing at rates that challenge the abilities of professionals in a field to learn it. Therefore, information scientists are increasing their efforts to find better ways to organize that information and to provide better, easier-to-use tools to access it" (Johnson & Foa, 1989, p. 187). The computer has allowed connectivity to vast amounts of information, making it accessible to individual learners, but the "principal role of any technology in education is to help improve the overall efficiency of the teaching/learning process" (Percival & Ellington 1988, as cited by Murray, 1990, p. 15). Research is continuing to investigate whether technology will improve overall efficiency in the learning environment.

Preliminary steps that address what strategies will improve instruction to make it more efficient, might lead in turn to strategies that may improve overall efficiency in learning. Common themes addressed in the literature for instruction and learning are the student's factors of time, achievement and preference. By analyzing these factors in the context of Computer-Assisted Instruction, some strategies may be developed to improve CAI.

Since 1988, a Computer-Assisted Instruction package entitled Mathematics 30^{CAI} is being developed at the University of Alberta under the sponsorship of Alberta Education. The 1990/91 version of this Mathematics 30^{CAI} course consisted of six units and forty-nine topics in total and included all of the content of the traditional Alberta grade 12 Mathematics 30 course. The Mathematics 30^{CAI} course contained unit tutorials and test banks in the form of drill and practice. The CAI was available on computer diskettes. The Mathematics 30^{CAI} course includes the means for monitoring and recording extensive information concerning the interaction between students and the CAI in real time. At the inception of this study, there was very little in the literature that addressed how such interactions should be analyzed or how strategies could be devised to improve Computer-Assisted Instruction (CAI) based on this information.

While the majority of the research in CAI suggests that this form of instruction typically leads to improvement in student learning, one of the frequently overlooked benefits of CAI is the ability to closely monitor the interactions that are taking place between the student and the CAI. Such information becomes invaluable as the basis for improving or optimizing CAI. Optimization of CAI becomes increasingly important at a time when there is increased emphasis on the use of computer-assisted or computer-based instructional resources for teaching and learning.

Definitions and Descriptions

Mathematics 30 course. In Alberta, the Mathematics 30 course represents a grade 12 level, matriculation course. At the time of this study, the Mathematics 30 course consisted of 6 units. The six units were: "Unit 1 Polynomial Functions, Unit 2 Logarithms, Unit 3 Sequences, Series and Limits, Unit 4 Trigonometry, Unit 5 Quadratic Relations, and Unit 6 Statistics" (Alberta Education, Mathematics 30 Learning Facilitator's Manual, 1990, p. 3). The student's Mathematics 30 course mark was weighted at fifty percent for their classroom work and fifty percent for their departmental examination. The Mathematics 30 course contributes 5 credits towards a required 100 credits for a student's high school diploma. The course could be semestered (5 months) or full year (10 months). The course consisted of 125 hours (7500 minutes) of instruction.

Mathematics 30 ^{CAI} course In 1988, Alberta Distance Learning Center (ADLC) funded the work done by the Apple Innovation Support Center (AISC) at the University of Alberta to create the Mathematics 30^{CAI} course. The (AISC) used an authoring software program called "Course of Action" or known today as "Authorware Professional" (Authorware, 1990). The Mathematics 30^{CAI} course was developed on computer, using the Alberta Education Mathematics 30 printed materials and guidelines (Alberta Education, 1988). The Mathematics 30^{CAI} course consisted of 6 units and 49 topics. The Mathematics 30^{CAI} course was divided into three sections for each unit; the introduction and objectives, the tutorial and the test bank. The tutorial contained student interactions usually in the form of typed, text student response(s) to CAI text prompt(s) and text feedback as to correctness of those response(s). The test bank contained approximately ten questions selected randomly from a pool of questions for the topic with a percentage correct displayed at completion. Many graphical displays of the mathematical content were also included, with many being animated to show progressive stages of graphing. Computerized sounds and movies were included in one unit, in May of 1991, and experimented with by students in this study. The teacher in the Mathematics 30^{CAI} classroom setting served as a coach or tutor, with the student interacting primarily with the CAI.

Traditional Mathematics 30 course. The Mathematics 30 course, that the researcher referred to as the "traditional Mathematics 30 course" in this study, was primarily a teacher-directed course. In this environment the teacher interacted, interpreted and presented the Mathematics 30 course curriculum to a class of students.

Audit trails. The term "audit trails" was used in this study instead of "on-line monitoring" for capturing and recording the student-computer interactions in real time on the computer. "On-line monitoring goes by various names including keystroke records, audit trails, and logging data" (Flagg, 1990, p. 177). The computer automatically wrote to a file time-stamped data that contained information on location in a unit, time and completion of a unit. The student could type comments at any location throughout the course. These typed comments were written automatically to the audit trails and will be referred to as "subjective feedback" in this study. These audit trails could be viewed by electronic spreadsheet or word processor.

Time-on-task. Time-on-task was a measure of the computer-recorded time that the student was connected with the Mathematics 30^{CAI} course. The CAI was designed to be logged onto by name and password at the beginning of each session, which opened the audit trail. On completion of the session, the student logged out and the students' audit trail file recorded the sum of time that the student was connected.

Scope

Two of the seven Alberta Mathematics 30^{CAI} pilot classes for the 1990-91 school year were chosen for inclusion in this study. One was a Rural, Semestered class (RS), in which a self-selected sample of students took the Mathematics 30^{CAI} course for one semester or 5 months. The other was an Urban, Full-year class (UF), in which a sample of students were randomly selected by computer to take the Mathematics 30^{CAI} course for the full school year or 10 months.

The students' data collected for this study consisted of the audit trails (time-on-task and subjective feedback) and achievement scores. At the onset of this study, forty-nine students in the two Mathematics 30^{CAI} classes were included. The number of students dropped to forty-three from the forty-nine before the Mathematics 30^{CAI} course completion, therefore the researcher chose not to include the six students with incomplete course data in this study. In the (RS) class, one student out of twenty-one moved to a new school at the beginning of the term. In the (UF) class, five students out of the twenty-eight did not complete the CAI. Three students of those five had timetable conflicts and had to be moved to another class within the first two weeks of the term. Another one moved to another school in the first month and the other chose to drop the course midway through the term for unknown reasons. The students used in this study were believed to be a fair sample of the Alberta Mathematics 30^{CAI} course population.

The Statement of the Problem

The main problem was to develop strategies which could be used for improving Computer-Assisted Instruction. The strategies were developed by analyzing data gathered from the available sample of students as they interacted with the Mathematics 30^{CAI} course.

The Statement of Sub Problems

The First Sub Problem. What was the distribution of time-on-task for students recorded across each unit of the Mathematics 30^{CAI} course? Did the students complete the units, as shown by the computer-generated audit trails?

The Second Sub Problem. What was the learning level attained as indicated by the student's achievement scores for each unit of the Mathematics 30^{CAI} course, the diploma examination mark and the final Mathematics 30^{CAI} course combined mark?

The Third Sub Problem. What was the distribution and direction of the student's subjective feedback as recorded by the computer-generated audit trails during the Mathematics 30^{CAI} course? What were the observations noted by the researcher from the Urban Full-year class?

The Fourth Sub Problem. What are the strategies that can be developed from the analysis of the student's time-on-task, the student's achievement scores, the student's subjective feedback, and the researcher's observations and their inter-relationships to improve the Mathematics 30^{CAI} course?

Assumptions

The First Assumption was that the Mathematics 30^{CAI} course was a valid representation of the Alberta Mathematics 30 course curriculum.

The Second Assumption was that the sample of students' achievement scores are a representative sample of students taking the Mathematics 30^{CAI} course.

Limitations

The First Limitation. The Mathematics 30^{CAI} course included a test bank, but because this test bank was undergoing major revisions for validity at the time of this study, the student achievement scores collected were based on teacher-administered pen and paper unit assignments and examinations. The Alberta Provincial Diploma examinations were standardized tests while, but the teacher-administered were different examinations for each class of students.

The Second Limitation. Student audit trails, which formed the basis for this study, were generated by the Mathematics 30^{CAI} course. In one instance, an equipment failure caused student audit trails to be over-written, therefore only remaining (UF) students' audit trails from Unit 4 were included in this study.

Significance of the Study

The benefits of Computer-Assisted Instruction (CAI) are evident in diverse areas and levels of education as shown in numerous studies. Specifically in the area of mathematics, CAI programs have been widely utilized. According to Bangert-Drowns, Kulik and Kulik (1985), the degree of the effectiveness of the Computer-Based Education (CBE) instruction were related to student attitude, aptitude level of the group, and a positive correlation between study effects and study year. The student attitude categories examined were attitudes towards the computer, the instruction and the subject area. In all the studies examined there were positive attitude changes noted by the CBE classes, as compared to the traditional classes.

"Computer-based teaching had its clearest" positive "effects in studies of disadvantaged and low aptitude students" (Bangert-Drowns, Kulik & Kulik, 1985, p. 66). No statistical proof of the link between aptitude and instruction had been documented at that time. The factor of study year seemed due to the improvement of the hardware and software in recent years, and teachers finding more effective ways of utilizing the computer technology. The summative evaluations described in these studies give credence to the use of CAI in the learning environment from the standpoint of improving student achievement scores and student attitude towards both the computer and the instruction.

One of the benefits of individualized CAI purports to be the flex-time available to the learner to progress through the materials. Time is important to learning in a variety of ways. "Engaged time, or time on task, is that portion of the allocated time that students spend actually studying a subject or completing assigned learning activities" (American Association of School Administrators, 1982, p. 16). "Academic learning time (ALT) takes time on task one step further by postulating that the task in which a student is engaged must be at an appropriate level of difficulty so that the student can complete it successfully" (American Association of School Administrators, 1982, p. 16). An indicator such as achievement scores might be used with engaged time to define appropriate levels of difficulty. "Carroll's formula, simply stated, illustrates that the degree of learning equals the time actually spent learning" that she termed; perseverance and opportunity, would then be "divided by the amount of time needed to learn", which is related to the aptitude, quality of instruction and ability (Carroll (1963), as cited in American Association of School Administrators, 1982, p. 11-2). Time-on-task seemed an important element to examine to improve the instruction for learning to occur. It may be noted that time-on-task is not usually isolated from other components such as aptitude, quality of instruction and ability.

Formative evaluation provides information to improve a product or process. The process or product is revised and implemented in a continuous cycle. Improvement to CAI may suggest the use of formative evaluation techniques. "Information about variables, such as the scope and accuracy of content, quality of instructional interactions, and the sequencing and pacing of instructional events in instructional products, should be collected by formative evaluation methods and used to guide decisions that will increase the effectiveness and efficiency of the products" (Johnson & Foa, 1989, p. 165). The common sources of the data collected are from the participants directly involved in the field testing stage or the evaluator/observer. Using the student audit trails recorded by the computer during student interactions with the CAI suggests a possible source of data by which the CAI may be improved. The evaluator/observer could be the teacher within the classroom that collects data for inclusion in the formative evaluation.

While the majority of research in CAI suggests that this form of instruction typically leads to improvements in student learning, one of the frequently overlooked benefits of CAI is the ability to closely monitor the interactions that are taking place between the student and the CAI. Such information could be invaluable as the basis for improving the instruction and possibly the optimization of student learning. "Computer technology, with its potential for interactivity and individualization, may yet allow us to create powerful instructional designs capable of optimizing learning" (Williams & Brown, 1990, p. 105). Strategies to improve CAI becomes increasingly important in an educational environment where high student achievement standards are expected.

Computer-Assisted Instruction has benefited education in the following ways. The use of CAI in the classroom has shown improved students' achievement scores and attitudes towards instruction. CAI has been associated with the individualization of instruction, so that student's time-on-task can be self-paced. Students' subjective feedback about the instruction and materials may be a useful strategy to improve CAI. A closer analysis of the students' time-on-task, subjective feedback, achievement scores, and the researcher's observations may provide important information to make improvements to the CAI. The literature also suggests an analysis of the relationships between these variables may also reveal suggested areas for improvement. Most CAI courses use computer-recorded student audit trails that allow the possibility and/or simplification of this analysis to occur within the CAI automatically. This captures in real time the students' times, routes, interactions, responses, and feedback. This could be an invaluable source of information about the instruction and the learning process.

Little was known about what type of data needed to be analyzed, or how to analyze it to improve CAI. There was even less known about what strategies could be developed from the analysis that would provide a preliminary platform for the improvement of CAI. This study attempted to develop strategies for improving CAI through an analysis of the students' time-on-task, subjective feedback, achievement scores and the researchers observations in the Mathematics 30^{CAI} course. "Technology is obviously going to make it easier to do things in the future (calculators a decade ago, spreadsheets today; dynamic economic models and who knows what else tomorrow?); its amplifier potential is clear. However, it is also important to think in terms of its transformational potential, to think about the ways in which technology will enable us, either as individuals or as a society, to do things differently or do new things altogether" (Nickerson & Zodhiates, 1988, p.77)

Outline of the Thesis

Chapter I provided a conceptual framework for this thesis by including an introduction, definitions, scope, problem and sub problem statements, assumptions, limitations, significance of the study and outline of the thesis. Chapter II contains a review of literature on the topics of; methodology (summative and formative evaluation, observation, and attitude questionnaires), monitoring the instructional process (time-on-task, learning outcomes, attitudes, and instructional strategies. The summary provides a framework for this study. Chapter III provides a description of the methodology consisting of; the research design, the data source and collection process, the study environment, the data analysis, the data presentation and the summary. Chapter IV documents, reported on, and analyzed the data gathered from the students' achievement scores, the students' audit trails (time-on-task and subjective feedback), and researcher's observation. The data gathered is compared both independently and inter-relationally. Chapter V provides a summary of the study, states the conclusions and strategies for the improvement of Mathematics 30^{CAI} course, and provides suggestions for further research.

CHAPTER II: REVIEW OF THE LITERATURE

Overview

This chapter contains literature on the methodology for monitoring of the instructional process, and instructional strategies. This chapter focuses on literature in the area of secondary education, specifically mathematics. The methodologies reviewed in the literature were summative and formative evaluations, which could use observation and/or attitude questionnaires to gather the data. The monitoring of the instructional process contains variables on time-on-task (time and mastery), learner outcomes (achievement), and attitude (subjective feedback). This chapter will conclude with specific directions taken by this study.

Methodology

The main methodologies to consider when conducting a study in the area of evaluation are summative and formative. Summative evaluation is conducted at the completion of the instructional process or development of a product. Formative evaluation is a cyclic process that is used to evaluate and revise the instruction or product throughout the testing phase.

Summative. Two common forms of summative evaluation are "meta-review" and "meta-analysis". The meta-review, on the factors affecting learning, conducted by Wang, Haertek and Walberg (1990) gathered, selected and synthesized authoritative papers and articles. The researcher constructed a conceptual framework of six categories around common variables. The six categories of variables prioritized, in order of importance from most to least, were; program design, out-of-school contextual, classroom instruction and climate, student, school-level, and State and district variables. Wang, Haertek and Walberg in 1990 found that:

> Thirty scales within the six categories were identified. The most important proximal psychological variables shown by mean ratings scales of 2.00 or greater

> are: metacognition (X = 2.08), classroom management (X = 2.07), quantity of instruction (X = 2.02), student/teacher interactions: social (X = 2.02), classroom climate (X = 2.01), and peer group influences (X = 2.00) (p. 34).

This study reaffirmed the "importance of the quality of schooling for learning outcomes" (Wang, Haertek & Walberg, 1990, p. 35). This infers that a study to improve the Mathematics 30^{CAI} course could include summative evaluation on any of the six related categories.

The meta-analysis of 42 controlled evaluations, by Bangert-Drowns, Kulik and Kulik (1985) suggested that Computer-Based Education (CBE) had a positive effect both on achievement scores and student attitudes. The student examination scores improved by 0.4 standard deviations. The student attitude categories examined were attitudes towards the computer, the instruction and the subject area. In all the studies examined there were positive attitude changes noted by the CBE classes, compared to the traditional classes.

According to Taylor (1981), most studies prior to 1981 dealt with evaluation of the product in a summative role. In 1981, there was a move towards more meaningful tasks, with the emphasis on making these tasks more realistic in context and complexity. Another change was the recognition of the individual differences in "learning style, strategies, pace, preference, interest and ability" (Taylor, 1981, p. 51). When more complex variables are introduced, other forms of evaluation may be considered in place of, or included with summative evaluation.

According to Bangert-Drowns, Kulik and Kulik (1985), the summative evaluations have given credence to the use of CBE and CMI in the learning environment from the viewpoint of improving student achievement scores and student attitude towards both the computer and the instruction. However, the limitations of over-generalizing the results from these studies of the meta-analytical method are to be emphasized. The limitations are that predictions are made to future outcomes, the location and type of the study may be of a very specific nature and therefore not generalizable to the total population, and most studies do not examine the full range of a subject area. Therefore, strategies for the improvement of the Mathematics 30^{CAI} course, must also include formative evaluation.

Formative. "Formative evaluation refers to the process of gathering information to advise design, production, and implementation decisions" (Flagg, 1990, p. 14). The information received is then revised and implemented in a continuous cycle. Formative evaluation can be used throughout the development of a process or product. "Formative evaluation is the essence of good instructional design, and it should be carried out with respect to all aspects of the project - the processes as well as the products" (Johnson & Foa, 1989, p. 164). Formative evaluation is used most in the initial design stages when the most feasible opportunity for revisions can occur due to time and cost factors.

Formative evaluation involves choosing appropriate, effective indicators. The effective indicators chosen, by Skilling and Sutton (1990), are most likely to have the following characteristics: They must be directly related to the targets, be acceptable to the users, be realistic in number, be written in clear simple language, be both quantitative and qualitative, be identified for the process as well as the outcome stage, and it should be possible to provide evidence in support of the indicator.

> The following studies support the effectiveness of formative evaluation. Studies cited in review by Baker and Alkin (1973) on the effects of formative evaluation indicate that programmed print instruction and televised instruction revised using empirical data yield better student performance than unrevised versions (as cited in Flagg, 1990, p. 25).

Since 1973, studies by; Baghdadi, 1981; Kandaswamy, Stolovitch, & Thiagarajan, 1976; Nathenson & Henderson, 1980; Scanlon, 1981; Wager, 1983, as cited by Flagg (1990), have supported this conclusion. These studies show support for the use of formative evaluation, in the instructional process.

A preliminary formative evaluation study done by Barnes (1990) on the Polynomial Functions, Unit 1, of the Mathematics 30^{CAI} course gave evidence of positive opinions of students and teachers to the course. Designers were able to gain insights as to where problematic areas in the mechanics of the program existed and to make revisions. The study identified the following factors:

- teacher intervention during the use of the CAI materials is important,
- the CAI materials include inadequate feedback and insufficient numbers of questions and examples, and
- students were positive about the CAI experience and indicated a desire to try another unit in the course, despite identifying some areas where improvements in the CAI materials could be made (Barnes, 1990, p. 88).

Indications from this study, suggested the need for a formative evaluation of the entire Mathematics 30^{CAI} course.

Data Collection

Two forms of gathering data for summative or formative evaluation are observation and attitude questionnaires.

Observation. One way of collecting the data for either summative or formative evaluation is through observation. According to the American Association of School Administrators in 1982, the participants directly involved in the field testing stage or the evaluator is used to make the observation. The data can be collected by the evaluator through questionnaires, interviews, and/or observation from the participants. The evaluator/observer may choose to simply observe the small groups or individuals using the instructional prototype. Classroom observation has been an important part of formative evaluation. It helps to examine the product or process in context, sometimes leading to other possible explanations for success or failure of the product. The "classroom observation gives teachers and administrators an accurate assessment of the causes of decreased time on task" (American Association of School Administrators, 1982, p. 64). The observations may lead to other contributing variables that must be considered in the improvement of the product.

Individualized instruction has been stressed by a number of authors, but the picture depicted is usually of a one-on-one learning environment.

> Since the assumed benefits of CAI have centered on individualized instruction, much research has focused on one-to-one instructional methods. However, extensive research suggests that separation from peers during instruction often may be undesirable and less effective than many small-group instructional methods (Johnson, Maruyama, Johson, Nelson, & Skon, 1981; Moskowitz, Malvin, Schaeffer, & Schaps, 1983; Peterson & Janicki, 1979; Peterson, Janicki, & Swing, 1981; Slavin, 1980; Swing & Peterson, 1982; Webb, 1980; 1982a; 1982b, as cited in Dalton, Hannafin & Hooper, 1989, p. 15-6).

This research seems to suggest that individualized CAI may be effective in a group classroom environment.

Another form of observation could be the examination of computer-recorded and stored information about the user's interaction with the CAI or CMI. On-line monitoring can capture the human-computer interaction automatically and in real time by the CAI program. As advances in the computer's capabilities and uses increase, so do the capabilities of accurate, individualized recordings of quantitative data about the student's interactions and chosen learning route. In the school project by Hawkins, Bosworth, Chewning, Day, & Gustafson in 1985, online monitoring was used to record adolescents interactions with a series of health information and behavior change, computer programs. Student surveys and intermittent computer data were collected and assessed on the age, sex, number of users, and topics viewed. "The researchers found that online monitoring of topics viewed was 'most useful in discovering which program segments were or not [sic] being used heavily (and adjusting new versions accordingly)'" (Hawkins, Bosworth, Chewning, Day, & Gustafson (1985), as cited in Flagg, 1990, p. 177). According to Flagg (1990), two types of data can be defined, both of which can be found in online monitoring.

> Transactional data refer to the interactions between the user and the system; for example, what segments of the program were accessed in what sequence, which commands and features were used, what decisions were made in response to program queries, what performance was achieved in task and test situations, which

error messages appeared, what kind of assistance was requested. Temporal data supply the time and duration of the transactions. (Flagg, 1990, p. 177).

In the case of the Mathematics 30^{CAI} course, the audit trails recorded many of the transactional data listed, as well as, student-typed comments. Data that can be collected either by evaluator observation and/or by computer interactive observation can act as useful tools in the evaluation of the complex instructional environments of process or product evaluation.

Attitude Questionnaires. Participant attitudes or opinions give evaluators valuable answers as to problem areas, suggestions for improvement or sometimes just an idea of what characteristics the learner has that constitute a meshing of the user and the materials. According to Dick & Carey (1985), the attitudinal questionnaire helped to focus the evaluation on important components in the materials. These type of questionnaires have been common forms of data collection. The disadvantages of questionnaires as stated by Flagg (1990) are:

- First, that the intended meaning of questions cannot be clarified for respondents and follow-up probing in a questionnaire is limited to pre-defined directions.
- Second, when filling out the questionnaire after using the program, respondents may not clearly remember their specific difficulties with respect to user-machine interactions, especially if they adapted their behavior to cope with the difficulty (Flagg, 1990, p. 187).

It is suggested practice to cross-check other data with questionnaire results to help establish validity and consistency of the findings. This cross-check would lead to a detailed analysis of other contributing factors, that may render the questionnaire invalid. Due to these disadvantages the researcher chose not to use a questionnaire, in this study.

Monitoring the Instructional Process

There are many contributing factors for the success or failure of the instruction. By monitoring the instructional process, some of these variables can be analyzed. Improved students' performance and attitudes have been the main factors behind the implementation of CAI. The factors that were reviewed in the literature were time-on-task (time and mastery), learner outcomes (achievement), and attitudes (towards mathematics, computers and CAI).

Time-on-Task (Time). The "educators must realize that these concepts of time and learning constitute a tool for analyzing instructional problems - not a rulebook for the 'right' instruction" (American Association of School Administrators, 1982, p. 19). Three aspects to consider for time-on-task are the time available, the student's time spent on task, and the time needed to master the task.

> Teachers and school administrators who seek to influence learning outcomes by controlling the important variable of time must take into account not only how much time is actually spent on learning, but also how much time is made available and finally, the nature of the tasks on which students spend their time (American Association of School Administrators, 1982, p. 19).

Engaged time in both the traditional and the CAI classroom is difficult to monitor or assess. The researcher would have to ""find out how time is actually used - or wasted - during the school day, and then increase the amount of time the students spend actively learning" (American Association of School Administrators, 1982, p. 49).

Tables 33 and 34 in the Appendix, show examples of manually calculated time-on-task rating forms. These forms are usually recorded and tabulated by an evaluator observing a student or small group of students. To reduce the chance of error in recording the data, multiple evaluators would observe the same student and compare data. A similar form could be constructed as part of a CAI program to record each time-engaged student interaction with the computer, while recording this data simultaneously for each student in the group. As students proceed on different paths through the materials, the length of the paths and therefore the time-on-task will vary. The nature of the task and direction of the instruction could be varied according to responses made by the learner, thereby adjusting the time-on-task appropriate for the learner.

> The computer can record; the responses of learning and, in many cases. judge whether they are correct or not. In all cases the computer can store information

about the progress of the learner and make preplanned decisions as to the sequence of presentation of materials. ... The computer can far more efficiently perform this function and can do so on a continual basis so as to indicate to the teacher exactly how much each student has learned (Slack, 1971, p. 94).

The advancement of computer technology allows the computer to record, tabulate and analyze the data in real time for multiple students, simultaneously, with less chance of error.

The "Carnegie Unit" has placed learning into a time frame with hours of instruction equated to a credit value. The total time to complete a course only becomes a problem for the student, if the scheduled learning time is less than required by the student to complete the course. Time guidelines set from evaluation of actual time-on-task for a given program may give a more realistic idea of course completion time.

The assumed benefit of individualized CAI is that the learner is engaged with the materials. Studies such as those by "Jane Stallings of the Stallings Teaching and Learning Institute in Palo Alto, California, show that increasing time on task in secondary schools does lead to improved learning, especially for low-achieving students" (Stallings, as cited in American Association of School Administrators, 1982, p. 16).

> The amount of time a student is willing to devote to a task depends to a great extent on ability and aptitude. Some studies indicate that students in the lower five percent of their class take at least five times longer to learn a subject than do students in the top five percent (American Association of School Administrators, 1982, p. 32).

These studies identify ability and aptitude as being factors that contribute to time-on-task.

Time-on-Task (Mastery). "A task is a goal-oriented set of activities specifically intended to produce a particular learning outcome" (American Association of School Administrators, 1982, p. 8). Mastery level is achieved when the goal is achieved or the task has been learned. The many studies cited below have shown that increased time-on-task is a contributing factor in mastery learning.

> The mastery learning studies show that when students are given extra time and appropriate help, and when they are motivated to learn, 80 percent or more can finally attain the preset mastery level on each learning unit. One of the more striking and consistent results of these studies is the pattern of learning of mastery groups versus control groups (Anderson, 1973, 1976; Arlin, 1973; Block, 1970; Levin, 1975; Ozcelik, 1973). As learning progresses, it is apparent that the mean performance level of the mastery groups becomes significantly higher than that of the control group (Anderson, 1973, 1976; Arlin, 1973; Block, 1970; Levin, 1975; Ozcelik, 1973, as cited in Levin & Long, 1981, p. 7).

In order to evaluate learning time for a component of a program, appropriate levels of difficulty of the complexity of the content and of the ability-level of the student should be considered. Academic Learning Time or (ALT) "refers to the amount of time students are actually engaged in, and experiencing success in learning. Success, in these researchers' view, is more likely when learning tasks are at appropriate levels of difficulty for students" (American Association of School Administrators, 1982, p. 15). The assumption is that if the students' engaged time with the instruction is at the appropriate level and the student masters the instruction, the quality of the instruction is rated high. Dinkheller, Gaffney & Vockell, in 1989, suggested that good instructional software enhance the mathematics ALT in two ways:

1. by permitting learners to acquire specific information and practice specific skills,
2. by helping students develop basic tools of learning that they can apply in a wide variety of settings (Dinkheller, Gaffney & Vockell, 1989, P.9).

Carroll and Spearitt (1967) found that when the "instructional materials were clear and organized, students were more likely to be actively involved in their learning. They tended to lose interest and to spend less time actively involved in learning when the instructional materials were unclear" (Carroll and Spearitt, 1967, as cited in Levin & Long, 1981, p. 5). When this is applied to CAI, careful attention to clarity of instruction is important so that students remain on task.

The CAI could route the student into tasks based on the student responses or interactions with the materials. "A computer can run quickly through the consequences of a given guess and provide the student with feedback about whether s/he is on the right track. ... The focus will be on the problem-solving methods, not on the mechanics of arithmetic" (Heiman, Narode, Slomianko, & Lochhead, 1987, p. 41-2).

> Instruction itself, according to Bloom, has a profound effect on student learning time, which in turn can affect student achievement. In his view, the quality of instruction depends on four main factors: Instructional cues, Reinforcement, Participation, and Feedback and correctives (Bloom (1974), as cited in American Association of School Administrators, 1982, p. 12-3).

The time-related success of the instruction depends on the completion of the instruction within the given time frame, the engaged time spent on task, and the time needed to learn the task. If the appropriate factors are present in the instruction, the learner will stay on task and complete the task learned.

Learner Outcomes (Achievement). In the study done by Akbari-Zarin & Gray (1990), software was designed for students to apply critical thinking skills to mathematics topics.

> The variables used to evaluate the effectiveness of the software was the difference between the scores of the students of the control group and the experimental group on an in-class test consisting of five questions, where some questions had several parts. The experimental group did better than the control group, particularly on questions requiring more analysis. ... Thus the critical thinking techniques employed in the software seem to have impacted the performance of the students on the more complex topics (Akbari-Zarin & Gray, 1990, p. 71).

This study used achievement scores as indicators of the success of the software.

Many studies have found that students who are involved in the learning process attain higher achievement scores. Studies involving the observations of select groups of students "generally demonstrate that, within a classroom, students who are more involved in their learning have higher achievement than students who are less involved in classroom learning activities" (Good and Beckerman, 1978; Perkins, 1965, as cited in Levin & Long, 1981, p. 2).

> Numerous studies have used an overt measure of student involvement. They typically found a correlation between student involvement and achievement (Attwell and others, 1967; Berliner, 1979; Cobb, 1970, 1972; Edminston and Rhoades, 1959; Gaver and Richards, 1979; Lahaderne, 1968; Morsh, 1956; Olson, 1931;

Samuels and Turnure, 1974; Stallings, 1976; Stallings and Kaskowitz, 1974; Turnure and Samuels, 1972, as cited in Levin & Long, 1981, p. 2-3).

The purpose of the study by Liedtke in 1970, was to examine the relationship between certain pupil characteristics and mathematics learning. The three distinct settings used were: self-directed, partially teacher-directed and teacher-directed. "The characteristics studied included intellectual ability, reading ability, reflectiveness, impulsiveness, socio-economic status, ability to make personal adjustment, ability to make social adjustment and sex" (Liedtke, 1970, p. iii). The results showed no significant differences for any of the characteristics examined in the self-directed setting. For the partially teacher-directed setting,

> there existed significant relationships between the criterion variables initial learning and retention, and the following factors: intelligence, personal adjustment, social adjustment and reading ability. Of these factors, only intelligence showed a significant relationship with the pretest scores. The mean for the reflective subjects on the Retention Test was significantly higher than the mean for the impulsive subjects. The means for the boys and girls did not differ (Liedtke, 1970, p. iii-iv).

"The learning outcomes for the teacher-directed subjects could be predicted on the basis of intellectual ability only" (Liedtke, 1970, p. iv).

In a study by Englert (1972), first year algebra high school students were given two different teaching approaches; the "traditional group-oriented" teaching approach and the individualized approach. Students could work on their own, with another student, with the teacher or listen to pre-recorded tapes on instruction. He "reported that there where no significant differences either in attitude nor achievement" between the two different teaching approaches. (Englert, 1972, p. 1076).

In the early study, by Steinberg in 1977, learner control over the CAI resulted in higher achievement only for high performing students within the subject area.

> When allowed to control course flow, students demonstrated two major deficiencies. First, they failed to employ adequate review strategies. Second, they did not know how to manage their time and frequently did not complete a course

> during the allotted time. ... High performers were most likely to be skillful instructional managers (Steinberg, 1991, p.126-7).

Steinberg also stated that a "few studies of motivation and attitude in CAI revealed that learner control sometimes resulted in greater task engagement and better attitudes, but not necessarily in greater achievement" (p.127). "Students with low pretest scores made poor sequencing decisions. In addition they practiced too little, emphasized topics with which they were familiar, and avoided topics that were difficult for them" (p.129). This suggests that learner-control may not be useful for all students to help them attain high achievement scores.

The CAI could target certain types of learners to help focus on and provide appropriate instruction.

> Unlike group instructional methods, where teachers are forced to target their instruction at various 'steering groups' (Slavin, 1987), CAI enables individual learning needs to be identified and appropriate instruction provided. The consistent nature and quality of the individually differentiated feedback and reinforcement of well-designed CAI lessons has also been credited with improved performance and attitudes (Clement, 1981; Dalton & Hannafin, 1985, as cited in Dalton, Hannafin & Hooper, 1989, p. 15).

When achievement scores or performance improve, the instruction is usually well-designed for the intended learner.

Attitude (Subjective Feedback). Students can be a valuable source of information for formative evaluation of an instructional prototype. "William James (1890) made one of the earliest attempts to explain the great variation in participation. He identified student interest as the chief determinant influencing the degree of active learning" (James, 1890, as cited in Levin & Long, 1981, p. 3). "Recent studies demonstrate the correlation between such affective measures as self-concept or attitudes toward schools and student involvement (Anderson, 1973; Ozcelik, 1973; Block, 1970; Lahaderne, 1968; Hecht, 1977, as cited in Levin & Long, 1981, p. 3-4).

One of the goals of individualized education is to teach the student how to learn. Many computer programs have been developed to individualize education. Learning to Learn (LTL) which has been developed over a twenty-year period and:

teaches students to actively question the material they are learning, to break up complex ideas and tasks into manageable components, to obtain ongoing feedback on their learning progress, and to direct their learning toward their teachers' instructional objectives (Heiman, Narode, Slomianko, & Lochhead, 1987, p. 34).

Improvements to the design of the CAI depend on the response of the learner to the CAI.

McMahon (1979) administered the "Aiken Attitude Toward Mathematics Scale and the Pupil Control Ideology Form developed by Willower, Eidell, and Hoy to over 1800 grade nine mathematics students and 53 teachers" (McMahon, 1979, p. 2525). The results of this study concluded that the relationship between the mathematics teachers' pupil control ideology was significantly correlated at the .018 level with the students' attitudes towards mathematics. The conclusions drawn by McMahon were that "teachers of mathematics who tend to be more humanistic in their relationships with students create an atmosphere in the classroom which not only improves attitudes toward mathematics but also improves achievement in mathematics" (McMahon, 1979, p. 2525). The low correlation level does not support this conclusion.

Tschofen (1973), developed a unit in the Mathematics 10 program using the 'mathematizing mode', then implemented it and examined some general principles regarding its implementation. The mathematizing mode described by Johnston in 1968 "refers to a specific type of discovery learning" (as cited in Tschofen, 1973, p. 70). Some positive comments made by students after experiencing the unit were:

- made us think so that we had to know what we were talking about,
- it wasn't a boring class,
- you can learn more and remember it,
- you could talk freely to your friends about the problems,
- we were left to discover for ourselves what methods were correct and useful,
- math was more of a challenge,
- I think I learned a lot more from this program than some years of the book learning of math,
- the anticipation of finding the correct solution to a problem thrilled me, and got me interested in math as a challenge instead of a chore,

- you can at least state your views and methods of attacking a problem without being shot down or laughed at for not following the methods you had been given years before, and
- I liked working with friends (Tschofen, 1973, p. 127-8).

The negative comments were:

- Because I am generally slow in becoming to understand something in Math, the whole two weeks was not enough for me to learn anything. I was not yet too sure about doing one thing and we went on to another. I think this is a good way to teach people who do really good in Math but for someone who doesn't pick things up so fast it leads to greater confusion, and
- the persons who aren't as progressed in math, and I consider myself among them, are better off with the regular class (Tschofen, 1973, p. 128).

McGivney states that "software, together with well-designed lab experiments, can make the learning of mathematics more effective and more enjoyable. When students work together using material and equipment that allow them to use their imagination, mathematics can be discovered and remembered (and even enjoyed)" (McGivney, 1990, p. 57).

In 1990, McGivney taught three contemporary mathematics classes to over 60 students and asked the students to write anonymous evaluations of their experiences. Their negative comments focused on the lack of:

- space in the computer lab,
- help in the labs and outside of class,
- software demonstrations before going to the lab, and
- answers to the assignments.

The positive comments included:

- Four months ago I was afraid of math and computers. Now I feel more comfortable with both;
- It was interesting to see computers used for something other than word-processing or games;
- They ought to teach all math courses with a computer;
- I liked the change of pace in each class -- some lecture, then some work on our own;

- I like working in teams. When one of us was stuck, the other always seemed to have a good idea; and
- The teacher and the lab assistant were great in the labs. That's where I really learned things (McGivney, 1990, p. 57).

In a study carried out by Shirey (1976), students from three high school mathematics classes were randomly assigned to receive the inquiry exercises of a portion of a Home Mortgage Unit by the use of a computer-augmented instruction method or the use of tables and hand-held calculators.

> Computer-augmented instruction and the low-cost method were equally effective across both experiments on the Home Mortgage Test, three of the Attitudes Toward Computers scales and Attitudes Toward the Home Mortgage Unit. However, the computer group scored significantly higher on attitudes towards using a computer themselves (Shirley, 1976, p. 3386-87).

Surprisingly the computer-augmented instruction group did significantly less inquiry than the low-cost alternative, due in part, the student interviews revealed, to the time consumed by the running of the program.

In summary, due to the students' positive attitudes towards the instruction and the computer, as cited in the studies above, their attitudes are a valuable source of information for improvement of the CAI.

Attitudes Towards Computer-Assisted Instruction. "Probably the most significant uses of the computer in simulation, game, or tutorial modes are represented by the Chicago City Schools Project (using Suppes and Atkinson's materials), the PLATO project, and the TICCIT" (Time-Shared Computer-Controlled Information Television) project. (Walker & Hess, 1984, p.11).

> In the one major situation of primary CAI in which entire mathematics and English courses were taught through the TICCIT system and evaluated in a controlled manner, completion rates for the mathematics course dropped considerably below the traditional classroom, and student attitudes toward the CAI mathematics course were not positive. The opposite was true for the English course, as indicated earlier. ... Thus, by implication, primary CAI, and distance learning in general, may achieve results similar to those for adjunct CAI as long as there is sufficient

> human interaction accompanying the use of the CAI materials (Walker & Hess, 1984, p.12).

In the TICCIT "mathematics classes managed by unfamiliar instructors, the completion rate was 16% compared to an average of 50% for lecture sections" (Alderman, Appel, & Murphy, 1978; as cited by Steinberg, 1991, p.66). "In order for full course instruction to be successful, instructors have to understand the system and be willing to serve as nurturants, advisors, and moderators between machine and student" (Wyles, 1984, as cited by Steinberg, 1991, p.66).

> Avner and associates (Avner, 1981; Jones, Kane, Sherwood, & Avner, 1983) in a series of evaluations found that University of Illinois' students favored PLATO over other instructional media. For two semesters, Chemistry 100 students were asked to rate several different media with regard to helpfulness in learning the class materials. These media were PLATO, the textbook, lecture, labs, and quiz sections. For both semesters, the system received the highest ratings of 4.5 on a 5-point scale (Avner, 1981; Jones, Kane, Sherwood, & Avner, 1983, as cited by Schlechter, 1991, p.11).

The literature states that students' attitudes towards the CAI may also help the CAI developers.

> When implementing the evolutionary approach in developing a CAI system, a large community of users in direct and instantaneous communication with systems developers is vital to identify problems, correct deficiencies, and expand capabilities to meet unforeseen needs (Avner, 1987). Consider, for example, the addition of extensive answer judging capabilities to Tutor, PLATO's programming language (Steinberg, 1991, p.71).

In a study to evaluate the distance learning program carried out by Murray in 1990 found that:

> the instructors within the nine program categories were satisfied with the technologies they used if a comparison of positive versus negative responses is made. For the entire group, the means for satisfaction with technologies used within the four course segments were: Course Content 3.4, Student/Teacher Interaction 3.4, Student/Student Interaction 2.9, Student Evaluation 3.5. These means are based on a four point scale with 4 being very satisfied (Murray, 1990, p. 105).

These studies indicated that students' attitudes were generally positive towards the CAI instruction.

Instructional Strategies for CAI

"More has been written about the strategies employed by planners and agents of change than perhaps any other topic in the literature on planned organizational change. Three such strategies can be discerned in the literature: top-down or mandated strategies, bottom-up or grass roots strategies, and collaborative or participatory strategies" (Giacquinta, Bauer & Levin, 1993, p.158). The more participatory the strategy is the more effective the quality of innovation and its implementation. "A change strategy that involves the participation of all interested parties in the decision-making process surrounding an innovative effort is the surest way of gaining individual cooperation, ownership, and receptivity to an innovation" (Giacquinta, Bauer & Levin, 1993, p.159). The involvement from the bottom-up of the students, teachers and CAI developers may contribute to the improvement of the CAI.

> As cited by Schlechter in 1991, Derry and Hawkes describe a tutoring system that: not only design and present problem-solving tasks compatible with a student's prior knowledge, motivational history, and current instructional goals, but that also can analyze task performance online while the student is solving problems, providing

maximally effective guidance, correction, and encouragements directed at improving the problem solving process (p.151)

This may go beyond CAI into intelligent tutoring systems (ITSs). The tutoring system they described must "possess all of the following subsystems:

1. An intelligent problem-solving expert that recognizes all feasible plans and strategies possible for any given problem.
2. A sophisticated problem-generation system that can create whatever type of problem the system needs to tutor the student and that matches the student on characteristics such as age, world knowledge, gender, and interests.
3. A multipurpose interface that provides concept-enhancing problem-solving tools for the student to use in solving problems and that also helps make explicit the student's strategies, plans, and misunderstandings.
4. A coaching expert that can recognize and respond not only to correct moves, but also to errors and indicators of motivational breakdowns.
5. A lesson planner that selects problems and instructional routines and assembles them into lessons designed to accomplish instructional goals.
6. A sophisticated student record system for developing and storing student knowledge models and for establishing instructional goals for students (Derry & Hawkes, as cited by Schlechter, 1991, p.151-2).

Laurillard described the importance of student controlled learning strategies in the tutorial program design in the "sequence of presentation of content, and the sequence of learning activities" (Laurillard, 1990, as cited in Boyd-Barrett & Scanlon. p.66). The strategies she associated with the sequence of presentation of content are "student control over provided facilities such as:

1. index of content;
2. content map;
3. escape at any time to index or map;
4. skip forward or back a chosen amount; and
5. retrace chosen route through the material (Laurilla, 1990, as cited in Boyd-Barrett & Scanlon. p.66).

The learner controlled strategies she associated with sequence of learning activities were when and whether to:

1. see examples;

2. do exercises;
3. receive information;
4. consult glossary;
5. ask for explanation; and
6. take test (Laurilla, 1990, as cited in Boyd-Barrett & Scanlon. p.66-7).

More difficult to implement than the student control of learning strategy, she claims is the student's manipulation of the subject matter. She states that the pedagogically desirable features a Computer-Assisted Learning (CAL) or CAI program should have are the following:

1. The student should have direct access to the object domain - the object domain is an algorithmic description of how the domain behaves, such as a mathematical model of a physical system.
2. The program should have operational knowledge of how the domain behaves, such as a mathematical model of a physical system.
3. The program should be able to give intrinsic feedback - intrinsic feedback refers to results of the student's operations in terms of the system's behaviour, that is, the program can operationalize the match to the present goal.
4. The program should make the goals of the exercise explicit - these goals may be defined either by the student or by the program (Laurilla, 1990, as cited in Boyd-Barrett & Scanlon. p.68).

"When we considered child receptivity to educational software, we found that most children were not motivated by educational software; the excitement of computer games may very well have affected their perception of the educational programs they used" (Giancquinta, Bauer & Levin, 1993, p.123). Hasselerharm and Leemkuil in their experiment to test the relation between strategies and performance and attitudes in CBI (Computer-Based Instruction) on secondary technical school students, used three types of control strategies; the learner control (LC), the non-adaptive program control (PC) and the adaptive program control (APC). They concluded that

> there are no significant differences in performance between the three control strategies and because of the positive attitude towards LC, it must be considered to give students a certain degree of freedom to control their own learning process in

computer-assisted instruction. However, the results indicated that LC was not an effective strategy for low achievers with regard to the transfer of learning. This could be due to the lack of practicing. In particular to the transfer of learning, an adequate number of exercises is important. In the LC condition low achievers have done fewer exercises than low achievers in the PC condition. In the PC condition there was no difference in test scores between low and high achievers (Hasselerharm & Leemkuil, as cited in Pieters, Simons & Leeuw, 1990, p.78).

The literature is inconclusive in this area and more research seems to be needed. Ridgeway stated that ICAI (Intelligent Computer-Assisted Instruction) or CAI systems have a valuable role to play in making:

> the pupils and teachers aware of epistemological issues, and to reflect on their own knowledge and ways of acquiring knowledge. ICAI usually possess, either explicitly or implicitly:
>
> - A specification of the knowledge to be acquired (with some implicit epistemology).
> - A set of teaching techniques (with some implicit theory of teaching).
> - Rules to structure teaching sequences (with some implicit pedagogy).
> - Descriptions of possible user states (with some implicit development theory).
> - Beliefs about the current state of the user (Ridgway, 1988, as cited in Boyd-Barrett & Scanlon. p.143).

These strategies apply to the CAI developers.

Papert, in 1993, used the term "Knowledge Machine" as being synonymous with a computer program not unlike CAI.

> The entire point of the Knowledge Machine would be lost if it were conceived solely as a device for teaching children to read. Similarly, the point of developing nonformalized ways of knowing in mathematics is entirely subverted if these are conceived as a scaffolding for learning the formal way or as a trick to lure children into formalized instruction. They have to be valued for themselves and genuinely useful to the learner in and of themselves (Papert, 1993, p.17).

Papert is addressing subject specific CAI, as well as, using appropriate presentation tools. Rieber, in 1994, portrays some useful strategies to incorporate graphics into CAI.

Ample contexts (the ground rules used by Levin and Lesgold (1978) for example) exist where pictures appear very useful in facilitating reading achievement.

Dominant conclusions drawn from this research are:

1. pictures are superior to words for memory tasks;
2. adding pictures (external and internal) to prose learning facilitates learning, assuming that the pictures are congruent to the learning task;
3. children up to about the age of 9 or 10 rely more heavily on externally provided pictures than do older children;
4. children do not automatically or spontaneously form mental images when reading (Rieber, 1994, p.141).

This research suggests alternate forms of presentation, other than textual. Dugdale stated the following suggestions for the design of instructional materials in general:

1. Design instruction around the subject matter.
2. Exhibit a genuine enthusiasm for both the subject matter and the students. ... It is important to recognize insights of students and all ability levels and to encourage investigation of ideas which students consider their own. Extensive work with students during the development of materials can be beneficial in achieving this goal.
3. Give careful attention to the student's experience beyond the immediate content objectives. Learning takes place on many levels. Instructional methods impact not only students' mastery of information and skills, but also their attitudes and perspectives (Dugdale, as cited by Larkin & Chabay, 1992, p.43-4).

The strategies stated by Dugdale summarize some of the strategies cited in this literature, with the emphasis on the subject matter and the learner.

According to Fabricant (1986), some problematic areas with computer software have been the lack of coordination in terms of vocabulary and pedagogical approach with the textbooks used in the class, the uncoordinated assortment of software with a great variety of directions for using the programs, and "to use software effectively, it is important to understand what each type of software purports to do and how well it carries through on its goals" (Fabricant, 1986 p. 137). This attests to some form of standardized requirements attached to instructional software. The software discussed by Fabricant, was of the supplementary type. If the entire course was on CAI many of these same areas would no longer be problematic.

Software for use in microcomputers needs to:

1. Acquire interests of students,
2. Develop purpose or reasons for learning,
3. Provide sequential content for learners,
4. Give students appropriate feedback for each step in learning, and
5. Have relevant, vital content for learners (Ediger, 1989, p. 50).

Evaluation of software needs to address some of these issues. The answers to the questions many seek may be both developed by the computer and evaluated by the computer.

Summary

The review of the literature on the methodology, suggest the appropriateness of formative evaluation to build strategies to improve the Mathematics 30^{CAI} course. The audit trails were formative in nature and a form of detailed computer observation of the interaction of the student with the Mathematics 30^{CAI} course. The audit trails contained students' subjective feedback or typed comments. The researcher observed the Urban, Full-year students to gain added insights into the learning process. Summative evaluation was used in relation to students' achievement scores, that were collected from the Rural, Semestered and Urban, Full-Year teachers.

The variables included in the literature review for monitoring the instruction process were the time-on-task, learner outcomes and attitude. Most researchers agree that having increased time on task leads to improved learning of the task. However, spending appropriate time-on-task and mastery of the task were emphasized. Most positive aspects for the use of CAI are its positive effects on improving student achievement and attitude.

The instructional strategies for CAI were the most recent research included in this literature review. These strategies are either of an instructional programming design or an instructional learning design. The strategies to improve the CAI in this study contains both types.

CHAPTER III: METHODOLOGY

Introduction

This chapter provides a description of the methodology. The research design, the data source and collection process are explained in the study environment. The data presentation and analysis and the summary of this study are reported.

Research Design

In the literature, the evaluation of CAI has been accomplished using formative and/or summative evaluation. This study lends itself mainly towards formative evaluation. The researcher gathered data throughout this study and made suggestions to the CAI developers for improvements. Most suggestions were incorporated into the CAI. Summative evaluation included the collection of the students' achievement scores for this study. Some common themes apparent in the literature that have been selected for focus in this study were students' time-on-task, their subjective feedback about the CAI, and their achievement scores. The literature suggests a relevant relationship of each of these components, so these were examined. There was evidence in the literature that observation may provide added insights, so the researcher frequently observed the (UF) students as they interacted with the Mathematics 30^{CAI} course.

A descriptive statistical analysis was conducted of the students' audit trails (time-on-task and subjective feedback) and of their achievement scores. The teachers provided the audit trails on computer diskette and the summative students' achievement scores on paper, as requested by the researcher.

The students' summative achievement scores were comprised of the six unit scores, the class mark and the provincial diploma examination mark. The Mathematics 30^{CAI} course was comprised of 6 units of 49 topics. Alberta Education's grade weightings on each of the six units, out of 100%, are as follows: Unit 1 (Polynomial Functions) constituted 10%, Unit 2 (Logarithms) constituted 10%, Unit 3 (Sequences, Series, and

Limits) constituted 19%, Unit 4 (Trigonometry) constituted 24%, Unit 5 (Quadratic Relations) constituted 22%, and Unit 6 (Statistics) constituted 15%. These grade weightings were used to determine time-on-task weightings for each of the six unit by the researcher.

The Mathematics 30^{CAI} course was a 125 hour or 7500 minute course. The students' class mark comprised 50%, with the other 50% derived from the Alberta Education Diploma Examination, and compiled for the students' final Mathematics 30^{CAI} course mark. The Alberta Education Diploma Examinations were standardized tests for all students in the province, compiled and administered twice a year. The Alberta Education Diploma Examination student results were reported by unit and were displayed in this study for some of the (UF) students. The class achievement scores were unit specific, teacher selected and administered, pen and paper examinations.

The relationships between the student's time-on-task, the subjective feedback and the achievement scores were analyzed. The teachers were consulted on points of clarification about any data or about corrections or suggestions for the CAI. The researcher's observations are reported in the conclusions in this study. The conclusions drawn from the analysis of this data will provide the basis for the design of the strategies for improving CAI.

The Data Source

A sample of approximately one hundred students had been identified in the seven Alberta Mathematics 30^{CAI} pilot classes/schools for the 1990-91 school year, for possible inclusion in this study. The criteria for being a CAI pilot class was that some Apple Macintosh computers had to be made available for student use that could access a storage device for the Mathematics 30^{CAI} course to reside on and a place for audit trails to be written to, such as a hard disk drive. Only two easily accessible and available classes were chosen for this study by the researcher. One of these two classes of students was an Urban, Full-year (UF) Mathematics 30^{CAI} class with twenty-eight students that started in

September of 1990 and ended in June of 1991. The other was a Rural, Semestered class (RS) Mathematics 30^{CAI} class with twenty-one students that started in September of 1990 and ended in January of 1991. Consent by the mathematics' teachers of these two classes for inclusion in this study was granted. For these two classes agreeing to participate with the study, additional individual student/parent permission letters were distributed and collected. At the conclusion of this study, a total of 43 Mathematics 30^{CAI} students completed the course. This study did not examine the data from the six students, who dropped the course prior to completion. All but one of these six students withdrew prior to completion of one month of the course. One of the (UF) High-scoring students, chose not to participate, so was excluded in the results displayed for their audit trails and unit achievement scores.

The Data Collection Process

The audit trails were written automatically from the CAI software to diskette or later to a hard drive, while the student interacted with the Mathematics 30^{CAI} course. These audit trails consisted of detailed data collected on the students' time-on-task as spent connected to the Mathematics 30^{CAI} course and the students' subjective feedback (typed comments) as recorded at any designated screen displays. The comments section in the audit trails was an optional feature of the CAI program to allow the student to express subjective feedback in context. The students were encouraged to express themselves whenever possible through this method.

A session, as recorded by the audit trails, was the period of time the student was logged-in to the Mathematics 30^{CAI} course. A class for the (RS) was usually 80 minutes long and for the (UF) 64 minutes, but both classes of students could log-in at other times during the day or could choose not to be logged-in to the CAI for the whole class. The students had to turn on their computers, double click with the computer mouse to start up the Mathematics 30^{CAI} course, and then sign in with a computer I.D. or start-up diskette and a password. The audit trails were recorded from the log-in until the students logged-out. The students' time-on-task audit trails recorded; the date, topic and unit text information for each start or ending of the session or change of topic, each interaction per topic, the time spent on each interaction, the ending date and time per topic per unit, the number of sessions as depicted by the number of log-ins made, the accumulated time spent on each session, and the time spent per topic in the test bank. The students' subjective feedback was interspersed throughout the time-on-task data showing the topic and unit location. These audit trails were collected, summarized, and categorized by the researcher.

The interactions were recorded keystrokes. Throughout the introduction and objectives section of the CAI, single keystrokes were used to advance the textual screen displays as they were read. In the tutorial section, the topics in each unit were selected from a menu. The interactions in the tutorial section consisted of mainly textual question and answer format. Animated graphical displays were interspersed throughout the unit tutorials. The randomized feedback was specific as to the correctness of the student's answer. The feedback was usually textual, although graphs and sound were sometimes incorporated. The students received three tries on most questions before the correct answer was displayed. Hints and optional help screens were available to the students after most incorrect responses. The test bank could be accessed at any time, through the menu. The unit tests consisted of usually ten questions, with a percentage correct displayed upon completion. The student was given a chance to change their answers in the test bank before the next question, but no feedback as to the correctness of the answer was received. The audit trails did not tabulate the number of trials or number of correct answers for the students' interactions and only through location from the menu did it date and time stamp the location of the student in the CAI. All interactions were computed by the researcher after summarized data were gathered.

From September 1990 to the beginning of January 1991 the students were mainly "computer-controlled" through the Mathematics 30*CAI* course. The students were lock-stepped into completing each topic before moving to the next. The (RS) students were almost finished the course before the "learner-controlled" or navigational changes were made by the CAI developers in January 1991. The interactions were therefore linear for the (RS) students. After January 1991, the (UF) students had the choice to navigate anywhere in the CAI through the menu or navigational bar displayed on each screen.

The Unit 1 and Unit 4 bench marks developed by the researcher determined minimum time-on-task for each interaction and topic. The bench marks were created in the audit trails by taking the shortest possible time for each interaction through the two Mathematics 30^{CAI} units. The researcher typed the correct answers into the computer, taking the quickest and most direct route through the screen displays. This set a minimum time-on-task for each of the topics to help the researcher validate the data collected. The Unit 1, Polynomials, topics 0 through 4 section of the Mathematics 30^{CAI} course was the first bench mark. Another bench mark was developed for Unit 4, Trigonometry, topics 1 through 18. Unit 1 was the shortest unit, while Unit 4 was the longest. These bench marks served as guides to identify any extreme outliers in the audit trails for further analysis. An outlier would be identified by a time below the bench mark for an interaction or a topic. This time would be analyzed to determine whether the student took the time required to read the screen displays or did not complete a topic in the unit.

The researcher received from the teachers the students' achievement scores on the following variables: the students' six final unit scores, the final classroom marks which are compiled from the six weighted units, the diploma examination results, and the aggregate students' final mark for the course. Although the CAI had a test bank that students could opt to use in different units, it was undergoing major revisions and was not a source of student achievement scores in this study. The unit marks were determined by teacher-administered written assignments and tests. The researcher collected the students' unit scores from the teachers throughout the study. Visual comparisons were made using samples from both the (RS) and (UF) students' audit trails and achievement scores for Unit 1. The Unit 1 Bench Mark and (UF) class researcher observations were compared with these audit trails and achievement scores, to summarize the data from the audit trails. Informal interviews were carried out between the teachers and the researcher on points of clarification about the students' data and Mathematics 30^{CAI} course. The researcher and teachers communicated preferences or difficulties to the CAI developers throughout this study for the improvement of the next version of the CAI. The researcher's frequent observation of the Urban, Full-year (UF) Mathematics 30^{CAI} class were used to gain further insights reported in this study.

The Study Environment

The researcher conducted a detailed study on the accessible sample of the Urban Full-year (UF) students of the pilot Mathematics 30^{CAI} class. The researcher's direct observations of this Mathematics 30^{CAI} course environment started in September 1990 and finished in June 1991. The Rural, Semestered (RS) students began in September 1990 and concluded in January 1991. The researcher relied on teachers of both (UF) and (RS) classes for the audit trails and achievement scores.

The audit trails from the (RS) class were difficult to use due to the duplication of diskettes given to the researcher to update the student data. Each (RS) computer had it's own hard drive of which the Mathematics 30^{CAI} course was accessed. The audit trails were written to diskette. These hard drives were not big enough to contain all the Mathematics 30^{CAI} course. This meant that the teacher had to load and unload one to four units at a time from each computer, depending on the student's progress. The problem with an insufficiently large hard drive was that, the students could not go back to the some previous unit to review or jump ahead, if they so chose, because the unit may have been removed or not yet loaded. The audit trails were automatically written to the student's computer diskette on a per session basis. The audit trails were at risk of being over-written or deleted, due to insufficient diskette space in the larger units, so multiple diskettes were used. The (RS) teacher chose to present the units in sequential order from 1 to 6. This may have helped the students and the teacher ease into the Mathematics 30^{CAI} course, because Unit 1 (Polynomials) was not only the easiest mathematically, according to the teachers, but also the most tested (Barnes, 1990). Most of the (RS) students had previous computer experience, which meant that the amount of time required to learn how to use the technology was reduced. The (RS) teacher had previewed the Mathematics 30^{CAI} course and had pre-set timelines and deadlines for the students to complete each unit. This made the students more aware of time restraints.

The (UF) class had some difficulties. The (UF) teacher had not seemed familiar with the Mathematics 30^{CAI} course, until its introduction to the students, in September 1990. The school, along with its other traditional Mathematics 30 classes, chose Unit 4 (Trigonometry) as their first unit. They then continued with Units 1, 2, 3, 5, and 6. Unit 4 turned out to be a very difficult unit. Not only were the students learning mathematics, but at the same time they were learning how to use the computer. Most (UF) students had no previous computer experience. The CAI computer lab in this school had individual computer workstations with hard drives that were also attached to a central hard drive or server through a network. At the outset, this was an untested environment, both for the CAI developers and the Mathematics 30^{CAI} class. Two things happened: 1) some files were accidentally over-written on the start-up diskette, and 2) the students became frustrated with the linear or "computer-controlled" presentation of the CAI materials. The students verbally berated the loss of time and lock-step progression through the materials of the CAI. The CAI developers had set the route of the audit trails to write to the student's diskette for both schools. This worked well for Unit 1, because of the relatively small amount of data written. However, with Unit 4, by the third and fourth weeks the computer diskette, that contained the system and log-in instructions and the audit trails caused the system to crash when the diskette capacity was reached. The CAI was developed with a lock-step approach in mind, therefore the student audit trails checked off which screens had been previously viewed and did not allow the student to jump ahead beyond this location. When the diskettes crashed, the students received new diskettes with limited systems.

Some audit trails were copied back onto the diskettes to enable the student to get back closer to their current location in the topic or unit. Most of the time, unfortunately, students were forced to redo the material from the start of their last topic. This meant lost data which caused a bias towards the time measures in this study. The lost time frustrated the students and teachers. The audit trails displayed data that was incomplete for some students and duplicated for others.

The CAI developers started to work on the problem immediately and a solution was put into place for January 1991. The solution was to take out the lock-step or linear aspect of the Mathematics 30^{CAI} course and in its place allow the student to navigate freely to any topic or unit in the CAI. As well, this learner-controlled strategy allowed the student to place a bookmark or comment at any point in the course and be able to jump ahead and back to those areas. This did not help the faster mathematics students who were already through the Unit 4 materials, but it did help the slower students. In the end, all students benefited with the change of approach the CAI developers produced.

The second improvement was the redirection of the audit trails to any hard drive the teacher specified. For the (RS) class this meant the frequent copying from the individual hard drives to diskettes or frequent changes of student start-up diskettes to back-up their audit trails for the researcher. For the (UF) class this meant the audit trails were written to the biggest central hard drive on the computer server accessed through the network. This eliminated the use of computer diskettes, completely automating the process of writing to the students' audit trails, as well as, having enough available space to store both the CAI course and complete students' audit trails. The audit trails were written into student folders and saved on a class folder to be copied and analyzed at any time by the teacher and researcher. The one drawback was that some speed was sacrificed at the beginning and end of each class session while the network was used to open and save the audit trails from each computer workstation, the average time was 3 to 5 minutes, as recorded by the researcher. The (RS) teacher recorded a comparable time spent with the diskette exchange and copy procedure of the (RS) class.

Small samples of the audit trails of selected students had been collected to familiarize the researcher with the specific data that could be collected. These audit trails were previewed in an electronic spreadsheet or word processor and in print-out form in an attempt to identify specific components for analysis. The researcher experimented with the selection and organization of the data to ensure that the data would answer the problems addressed by this study. The researcher became familiar with a new program designed to retrieve and summarize the audit trails in the most efficient manner for the preliminary analysis of the students' time-on-task and subjective feedback. The Unit 1 and 4 bench marks were made by the researcher to help understand the tracking of the audit trails, how they worked and what the data meant. These bench marks helped to depict minimum time-on-task per topic and unit. The bench marks became a useful tool for the validation of the audit trails. The researcher having gone through the materials in detail could recognize components in the student audit trails and depict that those components existed both in the original and summarized students' audit trails.

Some data from the students' completed final Unit 1 and 4 scores had been collected to carry out some preliminary statistical analysis. From this exposure and comparison with samples of students' audit trails, the researcher determined what data was collected and organized. The researcher had also identified a need for a computer program to be made or modified to summarize data into a usable format for further analysis using a more conventional statistical analysis program. Initial computer programs proved time consuming due to the slow speed of the computers, and the huge audit trail files. No existing program proved useful for summarizing the data into usable formats. Specific details of how to handle the data or the process to be used was not known at the time of this study. Some speculation on the relationship of these components in the literature helped to confirm the choices of data selected. Many discussions with university professors and programmers, led the researcher to devise a program to extract and summarize the data from the audit trails into a usable format.

Previous to the onset of this study, the Mathematics 30^{CAI} course had undergone its third round of extensive revisions from verbal and written suggestions gathered from various mathematics master teachers and the CAI developers. The major revisions, for the most part, were to fix programming or content errors and computer management problems. Minor revisions by the CAI designers were ongoing throughout the piloting period, from September 1990 until the end of June 1991. This study helped to familiarize and clarify some of the types of data to collect, what instruments to use, and how to analyze and present the data.

The Data Presentation and Analysis

The audit trails formed the basis of a formative evaluation. The audit trails of the students' time-on-task and their subjective feedback could be viewed on an electronic spread sheet program or any word processor and printed out for the initial analysis. This preliminary view of the audit trails was used to identify patterns and themes in the data. Initially, a few samples of (RS) and (UF) students' Unit 1 and Unit 4 audit trails were used. The researcher completed the time bench marks for Unit 1 and 4. Comparing the bench marks, with data of a sample of students' audit trails, identified the data to be extracted for inclusion in this study. Once a (RS) student completed audit trail sample was available, the researcher tried to extract the data using known statistical analysis programs. The audit trails needed to be summarized to extract the data chosen for this study i.e., student time-on-task, unit completion and subjective feedback into a shorter, more usable format for statistical computations. The known available programs could not be used, so one was devised for the researcher by a computer programmer. This new program summarized data so that the interactions were extracted and written to a computer file for further analysis. An interaction was the keystrokes recorded in the students' audit trails.

One of the shortest audit trails in summarized format was 9,193 interactions. The researcher chose fourteen (UF) students' audit trails for detailed analysis in June 1991.

Computer technical and (UF) student preference CAI problems were being dealt with throughout Unit 4 and Unit 1 from September 1990 to January 1991. The CAI developers worked closely with the (UF) and (RS) classes to solve these problems. The start-up diskette over-write problems encountered from Unit 4, owing to insufficient diskette space, were solved by redirecting the audit trails to write to a hard drive of the teacher's choice. The linear or "computer-controlled" presentation of the materials was changed to a "learner-controlled" or student navigation presentation that was the (UF) students and teacher preference. The CAI developers received suggestions for topographical changes from the students, teachers and researcher, through the print-outs of the student subjective feedback and a teacher-compiled written list by topic and unit of possible errors.

The students' achievement scores were analyzed at the completion of the Mathematics 30^{CAI} courses. In January 1991, the (RS) students finished the Mathematics 30^{CAI} course and the achievement scores were tabulated. The (RS) class mean on the January 1991 Alberta Diploma examination was 65.1% or 4.1% higher than the provincial mean of 61.0%. The (UF) class mean on the June 1991 Alberta Diploma examination was 65.9% or 6.5% higher than the provincial mean of 59.4%. These scores suggested further analysis.

Some students in both classes scored extremely high, above 80%, and some extremely low, below 40%, on the provincial diploma examinations. The researcher decided further analysis of these, High-scoring (HS) or Low-scoring (LS) students' achievement scores may prove useful. The fourteen (UF) audit trails of the (HS) and (LS) students were analyzed in detail. The validity of this data could be backed up, in part, by the researcher's observations. The researcher analyzed this data in search of more specific strategies to enhance the Mathematics 30^{CAI} course.

Descriptive statistical analysis was used for the major analysis for the students achievement scores and time-on-task. The main components of this analysis were the means and ranges (minimums and maximums). The relationships between the (UF) students' time-on-task, the two bench marks and the Alberta Education guidelines were displayed. The fourteen (UF) students' audit trails were used to calculate students' time per interaction and unit completion.

The (UF) students' subjective feedback was collected by topic and unit. The researcher interpreted and categorized the feedback. The frequency of subjective feedback interactions per topic and per unit was noted. Most subjective feedback was recorded during the first units, Units 4 and 1, from the (UF) students' audit trails. Most of the subjective feedback tended to identify typographical errors. The errors noted by the students, teachers and researcher were corrected by the CAI developers for inclusion in their next version of the course. Updated versions of the Mathematics 30^{CAI} course were available from the CAI developers throughout this study upon request. The subjective feedback in the form of comments tended to be infrequent, therefore the researcher categorized them based on context. The researcher frequently observed the (UF) class and noted interactions or comments made by the students and teacher throughout the course.

The relationships between the students' time-on-task, the subjective feedback and the achievement scores were analyzed both individually and collectively, to develop the strategies for the improvement of the Mathematics 30^{CAI} course.

Summary

This chapter has identified the research methodology using the analysis of the students' time-on-task, students' subjective feedback and students' achievement scores of the Mathematics 30^{CAI} course to develop strategies to aid developers and educators in the improvement of CAI. Chapter IV will discuss and describe the results of the analysis of the data.

CHAPTER IV: RESULTS

Overview

This chapter documented, reported on and analyzed the following data: the students' achievement scores, the students' audit trails (time-on-task, unit completion, and subjective feedback), and researcher's observation. The researcher began this study with a broad over-view of two Mathematics 30^{CAI} classes; the Rural, Semestered (RS) and the Urban, Full-year (UF) class, and narrowed to an in-depth study of the fourteen (UF) Low and High-scoring students.

The (RS) and (UF) students' achievement scores from their class unit scores, class final mark and diploma examination marks were categorized into Low-scoring (LS), Medium-scoring (MS), and High-scoring (HS) students. A further report analyzed the combined (LS) and (HS) students' marks; class final mark and diploma examination marks for the six (RS) and fourteen (UF) students. The six (RS) students' consisted of; three, Low-scoring (LS) students and three, High-scoring (HS) students. The fourteen (UF) students consisted of; five Low-scoring (LS) students and nine High-scoring (HS) students. The fourteen (LS) and (HS) students' audit trails for the (UF) class of (time-on-task, unit completion, and subjective feedback), were summarized along with the researcher's observation of the (UF) students. The data was compared both independently and collectively to develop strategies for the improvement of CAI.

Achievement Scores

The two classes of students' achievement scores were collected from the teachers. Table 1 shows the unit marks, class total marks and the January 1991 Diploma Examination marks for the Rural, Semestered (RS) students. Table 2 shows the unit marks, class total marks and the June 1991 Diploma Examination marks for the Urban, Full-year (UF) students. The students were divided into 3 groups: LOW, MEDIUM, and HIGH, based on their Diploma Examination scores. In the (RS) and the (UF) classes

TABLE 1

(RS) Students' Achievement Scores in Percentages

September 1990 - January 1991

Weight	UNIT 1 (10)	UNIT 2 (10)	UNIT 3 (19)	UNIT 4 (24)	UNIT 5 (22)	UNIT 6 (15)	CLASS MARK (100)	DIPLOMA MARK (100)
LOW 1	63	50	0	44	69	38	39	29
LOW 2	63	56	28	44	38	59	40	38
LOW 3	63	41	38	54	46	81	56	38
MEDIUM 1	43	47	56	55	64	59	57	48
MEDIUM 2	97	50	84	96	90	53	73	55
MEDIUM 3	73	56	84	64	78	84	65	57
MEDIUM 4	87	63	63	61	80	75	66	62
MEDIUM 5	80	63	56	67	72	69	68	62
MEDIUM 6	80	72	81	77	88	69	72	62
MEDIUM 7	50	47	53	67	72	78	62	68
MEDIUM 8	63	50	63	69	70	75	68	71
MEDIUM 9	83	50	88	80	85	81	78	71
MEDIUM 10	90	59	66	54	77	75	66	72
MEDIUM 11	73	72	47	74	68	75	66	74
MEDIUM 12	80	72	69	75	85	94	79	74
MEDIUM 13	67	66	59	69	81	81	68	75
MEDIUM 14	97	69	75	83	83	78	75	77
HIGH 1	87	81	84	77	86	97	84	82
HIGH 2	97	100	91	94	100	91	95	92
HIGH 3	80	97	88	88	97	94	92	94
Mean	76	63	64	70	76	75	68	65.1
Maximum	97	100	91	96	100	97	95	94
Minimum	43	41	0	44	46	38	39	29
Range	54	59	91	52	54	59	56	65

JANUARY PROVINCIAL DIPLOMA EXAMINATION MEAN = 61.0

combined, there were eight (LS) students below 40% (LOW), twenty-two (MS) students between 40% and 79% (MEDIUM) , and twelve (HS) students above 79% (HIGH). The achievement scores and statistics were rounded to the nearest percent, in both tables. The class means, and ranges for each category are also shown in the tables. The researcher noted in Table 1 and Table 2 that the two classes scored comparatively higher than the rest of the province's Mathematics 30 students on the two different diploma examinations. These examinations were two standardized provincial tests written in January and June of 1991. The (RS) class scored 65.1% or 4.1% higher than the mean of 61.0% on the January 1991 Diploma Examination. The standard deviation was 17.2. The (UF) class scored 65.9% or 6.5% higher than the mean of 59.4% on the June 1991 Diploma Examination. The standard deviation was 23.8. The Alberta Education guidelines were used by the teachers to weight the units according to the emphasis the instruction was to be given. These weightings are also shown in the tables.

As shown in Table 1, the Rural, Semestered (RS) class had three of the twenty students scoring in the Low-scoring (LS) category with marks of below 40% on the January 1991 Alberta Diploma Examination. Fourteen of the twenty were in the Medium-scoring (MS) category with marks of 40% to 79% on the January 1991 Alberta Diploma Examination. Three of the twenty were in the High-Scoring (HS) category with marks of 80% to 100% on the January 1991 Alberta Diploma Examination. The students' class achievement scores are shown categorized by unit with their percentage weightings. The units and class mark was derived by the teacher using teacher-administered class assignments and tests. The units from highest class means to lowest were; Unit 1 and 5, 6, 4, 3, and 2. The largest range was 91 in unit 3, where Low-scoring student 1 received a mark of 0% for not handing in any assignments or writing any tests. The other unit ranges were between 52% to 59%. The class mean was 68%. The ranges were 56% on the class final mark and 65% on the diploma examination mark. In Table 1, the (HS) students had the most inconsistent marks with Unit 2, as shown in their achievement score ranges of

TABLE 2

(UF) Students' CAI Achievement Scores September 1990 - June 1991

Weight	UNIT 1 (10)	UNIT 2 (10)	UNIT 3 (19)	UNIT 4 (24)	UNIT 5 (22)	UNIT 6 (15)	CLASS MARK (100)	DIPLOMA MARK (100)
LOW 1	65	14	30	52	7	35	37	22
LOW 2	70	60	50	52	26	80	51	25
LOW 3	50	20	60	54	32	65	50	33
LOW 4	0	58	30	58	32	50	48	36
LOW 5	80	93	75	79	55	70	74	38
MEDIUM 1	90	10	90	79	33	80	68	42
MEDIUM 2	85	40	60	69	39	55	60	49
MEDIUM 3	85	75	68	90	67	95	81	49
MEDIUM 4	95	85	70	77	91	80	80	61
MEDIUM 5	60	60	65	43	71	70	56	62
MEDIUM 6	80	99	63	77	88	60	77	64
MEDIUM 7	95	40	80	84	78	80	78	75
MEDIUM 8	88	88	55	74	82	70	74	78
HIGH 1	85	100	80	69	77	75	76	83
HIGH 2	90	90	85	70	76	90	78	83
HIGH 3	98	95	90	94	84	85	91	83
HIGH 4	90	98	95	90	97	85	92	83
HIGH 5	83	94	85	87	88	75	86	84
HIGH 6	100	99	95	85	85	80	88	88
OMIT	-----	-----	-----	-----	-----	-----	82	89
HIGH 7	85	90	90	88	75	90	86	94
HIGH 8	85	99	95	93	72	95	90	94
HIGH 9	88	100	95	95	100	85	95	100
Mean	80	74	74	76	66	75	74	65.9
Maximum	100	100	95	95	100	95	95	100
Minimum	0	10	30	43	7	35	37	22
Range	100	90	65	52	93	60	58	78

JUNE PROVINCIAL DIPLOMA EXAMINATION MEAN = 59.4

between 81% and 100%, and the most consistent marks with Unit 6 with ranges of between 91% and 97%.

As shown in Table 2, the Urban, Full-year (UF) class had five of the twenty-three students scoring in the Low-scoring (LS) category with marks of below 40% (LOW) on the June 1991 Alberta Diploma Examination. Eight of the twenty-three were in the Medium-scoring (MS) category with marks between 40% and 79% (MEDIUM). Ten of the twenty-three were in the High-Scoring (HS) category with marks of 80% to 100% (HIGH) on the June 1991 Alberta Diploma Examination. One of the ten (HS) students chose not to participate in this study, therefore class data is shown as an "OMIT". The units from highest class means to lowest were; Unit 1,4, 6, 2 and 3, and 5. Units 1, 6, and 3 were ranked in the same order for the (RS) and (UF) classes. Unit 1 was the easiest unit for both classes, with means of 76% for the (RS) and 80% for the (UF) class. For the (UF) students, the largest range was 100% in Unit 1, where Low-scoring student 4 received a mark of 0% for not handing in any assignments and being absent for all the tests. The range for Unit 4 of 52% was the same for both the (RS) and (UF) classes. This suggested that students from both classes had a similar degree of difficulty with this unit. This was in line with the teachers' opinions of Unit 4 being the most difficult for all students and that Unit 1 was the easiest. The class mean was 74% and the diploma examination mark mean was 65.9%.

Owing to the large variability of diploma examination achievement scores, the researcher decided to examine the data for the Low-scoring (LS) students and the High-scoring (HS) students to note the differences of these groups. The students' Mathematics 30^{CAI} combined mark or achievement scores were weighted at 50% for the students' class mark and 50% for the Provincial Diploma Examination mark, as shown in Tables 3, 4, 5 and 6.

The (RS) students' achievement scores are shown in Table 3 for the (LS) students and in Table 4 for the (HS) students. Low-scoring student 3 had the largest range with a

TABLE 3

(RS) Low-scoring Students' January 1991 Combined

Weight	Class Mark (50)	Diploma Mark (50)	Combined Mark (100)
LOW 1	39	29	34
LOW 2	40	38	39
LOW 3	56	38	47
Mean	45	35	40
Maximum	56	38	47
Minimum	39	29	34
Range	17	9	13

TABLE 4

(RS) High-scoring Students' January 1991 Combined

Weight	Class Mark (50)	Diploma Mark (50)	Combined Mark (100)
HIGH 1	84	82	83
HIGH 2	95	92	94
HIGH 3	92	94	93
Mean	90	89	90
Maximum	95	94	94
Minimum	84	82	83
Range	11	12	11

score of 56% in their class mark and 38% on the diploma examination. In Table 1, the (LS) students had the most difficulty with Unit 3, as shown in their achievement scores of less than 40%, and the most consistent achievement with Unit 1 with achievement scores of 63%.

The (RS) High-scoring students' achievement scores are shown in Table 4. The range was 11% for the final class mark and 12% for the diploma examination. The means were 90% and 89% respectively.

Even though the students' final class mark and diploma examination mark seemed similar, they were not comparable. The achievement scores were the result of two different standards of testing. The final class mark was achieved by the student's completion of a series of paper and pencil, teacher-administered tests and assignments throughout the course, while the diploma examination marks were achieved by writing a one-day cumulative, provincial standardized examination. The provincial examinations were different examinations written in January and June of 1991. Within each class, each students' achievement scores are comparable.

At this point in the study, both (RS) and (UF) students had completed the Mathematics 30^{CAI} course. The (RS) students had concluded with the January 1991 Diploma Examination. The (UF) students had concluded with the June 1991 Diploma Examination. In this study, the results of the diploma examinations scores for both classes of students, showed that all students did not achieve the high standards of achievement expected. In fact, eight students out of the forty-three or 18.6%, achieved scores of below 40%. Another thirteen students out of the forty-three or 30.2%, achieved scores of above 80%. In the review of the literature in Chapter 2, CAI results usually showed an improvement in achievement, with low achievers benefiting more due to the CAI instruction. A closer examination of other contributing factors of the Low-scoring and High-scoring students seemed to be in order to discover strategies to improve the Mathematics 30^{CAI} course. The researcher had the additional factor of observation of the

(UF) students throughout the course to aid in analysis of the (LS) and (HS) students, therefore a detailed analysis was carried out on these groups. The contributing factors analyzed for the (UF) Low-scoring and High-scoring groups were their achievement scores, time-on-task, unit completion, subjective feedback and researcher's observation.

In Tables 5 and 6, the (UF) Low-scoring students' class and diploma examination, unit scores are displayed. In Tables 7 and 8, the (UF) High-scoring students' class and diploma examination, unit scores are displayed. The (UF) class unit scores in Table 6 are consistent with the diploma examination unit scores in Table 5, with (LS) student 1 scoring lowest in Units 2, 3, and 5 and (LS) student 5 scoring highest in Units 2, 1, and 4. In Table 5, the (LS) students scored highest on the diploma examination Unit 6 with a mean of 58% and Unit 4 with a mean of 37%. Unit 6 was the last unit the students did in class before the diploma examination.

On the diploma examination in Table 5, Unit 1 was the lowest achievement score mean at 18%, while Unit 6 was the highest mean of 58%. Units 2, 3 and 5 were consistently low at 28%, 22% and 21% means respectively.

The (UF) High-scoring students examination unit scores in Table 7 showed that more students scored higher than their class unit scores in Table 8, with the exception of Unit 2. In Table 7, for Unit 2, no students scored above 80% on the diploma examination, as compared to the two students that scored 100% and seven that scored over 80% of the nine students on the class unit marks, as shown in Table 8. In Tables 7 and 8, for Unit 1, five students scored 100% and three more scored above 80%, as compared to one student that scored 100% and eight students that scored above 80% in Table 8. On Unit 3, two students scored 100% and six scored over 80% on the diploma, as compared to nine over 80% on the class unit marks, as shown in Tables 7 and 8. On Unit 4, Table 7, two students scored 100% and seven scored over 80%, as compared to seven over 80% in Table 8. On Unit 5, two students scored 100% and four scored over 80% on the diploma examination, as compared to one over 100% and four over 80% on the class unit marks.

TABLE 5

(UF) Low-scoring Students' Diploma Achievement Scores

	UNIT 1	UNIT 2	UNIT 3	UNIT 4	UNIT 5	UNIT 6	DIPLOMA
LOW 1	13	25	8	13	29	50	22
LOW 2	25	25	0	33	21	50	25
LOW 3	13	25	31	40	14	75	33
LOW 4	25	25	31	47	29	50	36
LOW 5	13	38	38	53	14	63	38
Mean	18	28	22	37	21	58	31
Maximum	25	38	38	53	29	75	38
Minimum	13	25	0	13	14	50	22
Range	12	13	38	40	15	25	16

TABLE 6

(UF) Low-scoring Students' Class Achievement Scores

	UNIT 1	UNIT 2	UNIT 3	UNIT 4	UNIT 5	UNIT 6	CLASS MARK
Weight	(10)	(10)	(19)	(24)	(22)	(15)	(100)
LOW 1	65	14	30	52	7	35	37
LOW 2	70	60	50	52	26	80	51
LOW 3	50	20	60	54	32	65	50
LOW 4	0	58	30	58	32	50	48
LOW 5	80	93	75	79	55	70	74
Mean	66	49	49	59	30	60	52
Maximum	80	93	75	79	55	80	74
Minimum	50	14	30	52	7	35	37
Range	30	79	45	27	48	45	37

TABLE 7

(UF) High-scoring Students' Diploma Achievement Scores

	UNIT 1	UNIT 2	UNIT 3	UNIT 4	UNIT 5	UNIT 6	DIPLOMA MARK
HIGH 1	88	38	92	93	86	63	83
HIGH 2	75	75	69	93	86	75	83
HIGH 3	88	75	85	93	86	38	83
HIGH 4	88	75	85	87	64	88	83
HIGH 5	100	75	100	87	57	75	84
HIGH 6	100	75	92	87	79	75	88
HIGH 7	100	50	92	100	100	88	94
HIGH 8	100	75	85	93	93	100	94
HIGH 9	100	75	100	100	100	100	100
Mean	93	68	89	93	83	78	88
Maximum	100	75	100	100	100	100	100
Minimum	75	38	69	87	57	38	83
Range	25	37	31	13	43	62	17

TABLE 8

(UF) High-scoring Students' June 1991 Class Achievement Scores

Weight	UNIT 1 (10)	UNIT 2 (10)	UNIT 3 (19)	UNIT 4 (24)	UNIT 5 (22)	UNIT 6 (15)	CLASS MARK (100)
HIGH 1	85	100	80	69	77	75	76
HIGH 2	90	90	85	70	76	90	78
HIGH 3	98	95	90	94	84	85	91
HIGH 4	90	98	95	90	97	85	92
HIGH 5	83	94	85	87	88	75	86
HIGH 6	100	99	95	85	85	80	88
HIGH 7	85	90	90	88	75	90	86
HIGH 8	85	99	95	93	72	95	90
HIGH 9	88	100	95	95	100	85	95
Mean	89	96	90	86	84	84	87
Maximum	100	100	95	95	100	94	95
Minimum	83	90	80	69	72	75	76
Range	17	10	15	26	28	19	19

In Table 7, Unit 6, two students scored 100% and two scored over 80% of the nine students, as compared to seven over 80% in Table 8. Unit means in Table 8 for the class unit marks ranged from 76% to 95% for the (HS) students and diploma units from 83% to 100% in Table 7. Units 2 and 6 were the lowest means with 68% and 78% on the diploma examinations, while Unit 5 and 6 were the lowest means with 84% on both for the class. High-scoring student 1 scored 38% on Unit 2, as shown in Table 7. High-scoring student 3 scored 38% on Unit 6, as shown in Table 7.

The Low-Scoring (UF) students' combined achievement scores are in Table 9. The High-Scoring (UF) students' combined achievement scores are in Table 10. The (UF) Low-scoring students all achieved scores of between 33% and 74% on their class final mark, and all achieved scores below 40% on the diploma examination. In Table 10, the (UF) High-scoring students all achieved scores between 76% and 95% on their class final mark and between 83% and 100% on the diploma examination.

For both the (RS) and (UF) class, in Table 1 and 2, the students' class achievement scores showed only one student each below 40% i.e., one student out of twenty in the (RS) class and one out of twenty-three in the(UF) class. While eight out of forty-three students from both (RS) and (UF) scored below 40% on the diploma examination, which was 18.6% of this sample were in the Low-scoring group. The High-scoring group had three out of the twenty for the (RS) class and ten out of the twenty-three for the (UF) class, which was 30.2% of this sample were in the High-scoring group on the diploma examination. Forty-eight percent of the two CAI classes scored in either the (LS) or the (HS) group on the two standardize diploma examination scores.

In both classes, the same students that scored low for the class mark, also scored low for the diploma examinations, with the exception of (RS) Low-scoring student 2 who scored 56% and (UF) Low-scoring student 5 who scored 74% on the class mark. Both students scored 38% on the two different diploma examinations. In both classes the same students that scored high for the class mark also scored high, with two exceptions. The

TABLE 9

(UF) Low-scoring Students' Combined Achievement Scores

Weight	Class Mark (50)	Diploma Mark (50)	Combined Mark (100)
LOW 1	37	22	30
LOW 2	51	25	38
LOW 3	50	33	42
LOW 4	48	36	42
LOW 5	74	38	56
Mean	51	31	42
Maximum	74	38	56
Minimum	33	22	30
Range	41	16	26

TABLE 10

(UF) High-scoring Students' Combined Achievement Scores

Weight	Class Mark (50)	Diploma Mark (50)	Combined Mark (100)
HIGH 1	76	83	80
HIGH 2	78	83	81
HIGH 3	91	83	87
HIGH 4	92	83	88
HIGH 5	86	84	85
HIGH 6	88	88	88
HIGH 7	86	94	90
HIGH 8	90	94	92
HIGH 9	95	100	98
Mean	87	88	88
Maximum	95	100	98
Minimum	76	83	80
Range	19	17	18

(UF) High-scoring student 2 with 78% and (UF) High-scoring student 4 with 76% on the class mark, both improved their scores to 83% on the diploma examination. In Table 10 the High-scoring student 9 scored 100% on the diploma examination and received a class mark of 95%.

Audit Trails: Time-on-Task

During the Mathematics 30^{CAI} students' class time, the primary mode of instruction was their interaction with the CAI. The students' other resources were the teacher, the other students and the Mathematics 30 textbook.

The students' audit trails were written to computer diskette, in the initial four months and then to the hard drive. A variety of the students' audit trails were sampled by the researcher throughout this study from both the Rural, Semestered (RS) and Urban, Full-year (UF) class. The researcher visually compared these audit trails in an electronic spreadsheet and print-outs to note similarities in format and content. Both class samples were similar in format and content. However, the samples of students' completed audit trails varied in size and students' choice of route through the CAI. The completed audit trail for Low-scoring student 1 was 9,384 interactions and showed a sequential route through the CAI. Owing to the nature of the data, a special program had to be designed to summarize and extract the variables from the original audit trails to a summarized computer file for this study. The summarized student's audit trail file was reduced to approximately one-tenth the size.

The audit trails were collected for the (RS) and (UF) classes by the teachers on computer diskette to give to the researcher. A number of factors led the researcher to use only the (UF) class audit trails. The (RS) Mathematics 30^{CAI} class used single computers with smaller hard drives to store the CAI course and the audit trails. The students could not review from the beginning units or preview the last units of the CAI course, because those units may have been removed or not placed on the hard drive by the teacher. The hard drive could store two to four units at a time, therefore the students could not make use of the CAI navigator to its potential, thereby limiting the "learner-control" through the Mathematics 30^{CAI} course. Another problem was the audit trails had been over-written by at least one student on the computer diskette and the data lost. The researcher received multiple computer diskettes that had duplicate information from one time to the next from the (RS) class and it was difficult to track the students' audit trails. The summarized student's audit trail file recorded duplicated information and as the audit trails grew, the researcher had a greater chance of eliminating review data, along with the redundant data.

In the (UF) class, the students' audit trails were stored on the large central computer or server hard drive, after the initial diskette use, the students were required to use a computer sign-on identification code and password. That area of the hard drive was not given public access, so data could be written to but not deleted. The server's hard drive was large enough to contain the CAI course and the audit trails allowing the use of the navigational tools and routing features throughout the Mathematics 30^{CAI} course. The researcher had the added benefit of observing this class frequently throughout the Mathematics 30^{CAI} course. The student audit trails were easily accessible to the researcher at any time during the course. Any duplication in the data meant the student had reviewed that topic in the unit. The researcher narrowed the analysis to the (UF) Low-scoring and High-scoring students, after viewing the diploma examination results.

The audit trails for the Urban, Full-year Low-scoring and High-scoring students were analyzed. The audit trails displayed data on the time-on-task spent for each of the fourteen students in each of the 49 topics across the 6 units of the Mathematics 30^{CAI} course. The six units were; Unit 1 (Polynomials), Unit 2 (Logarithms), Unit 3 (Sequence, Series, and Limits), Unit 4 (Trigonometry), Unit 5 (Quadratic Relations) and Unit 6 (Statistics). The summarized student's audit trail file contained recorded data on: time-on-task, unit trial and completion, the number of interactions, the number of sessions, the route taken by the student and typed comments (subjective feedback). Visual crosschecking to ensure accuracy was done between the original audit trails and the summarized audit trails, by the researcher in an electronic spreadsheet and print-outs.

The descriptive statistics contained in Tables 12, 13, 26 and 27 are the means and the ranges (maximums and minimums). Some tables contain the bench mark times (Bench) and times suggested by Alberta Education (AB Ed.) guidelines for each unit.

The order in which these students viewed the units may have had some bearing on these statistics. For the (UF) class of students, Unit 4 was the first unit attempted, with Unit 1 next, followed in order to Unit 6. Due to problems encountered when the student audit trails were saved at the beginning of this study, the statistics for Unit 4 are inaccurate and show less time than students actually spent in the unit. The faster students, the (UF) High-scoring students 8 and 9, spent considerably more time than was shown, due to their participation in the testing and re-testing of the route changes made by the CAI developers to Unit 4. Due to time-table pressures imposed for completion of the course, most (UF) students did not have much, if any time in Unit 6 on the CAI. The (UF) students had the option of receiving traditional class instruction from the teacher for Unit 6.

The five (UF) Low-scoring and nine (UF) High-scoring students' summarized audit trail data are summarized and displayed Tables 12 and 13. The audit trail time-on-task data was identified by text titles to show the students location in the topic and unit. The date and time were automatically recorded at the beginning and end of each session. A session was recorded from the time the student started the CAI, until the student quit the CAI session. The interactions were key-strokes recorded from the students interaction with the CAI. The interactions or icons on the tables, were numerically recorded with some text labels. A running total for each interaction was recorded to the end of each session. The interactions were not judged or categorized as to type or correctness of the student's responses.

Alberta Education set a standardized time of 125 hours (7500 minutes) for a five-credit course. The Mathematics 30^{CAI} course was a five-credit class timetabled as a full year course, which requires approximately 195 minutes per week, or semestered, which is usually 390 minutes per week, for a total of 7500 minutes to completion. Alberta Education set guidelines for unit weightings, according to the amount of emphasis placed on each unit. The guidelines used in this study were taken from the Mathematics 30 - Learning Facilitator's Manuals (Alberta Education, 1990). The researcher used these percentages to establish time-guidelines for each unit. In Table 11, these percentages have been converted to the number of minutes out of a total of 7500.

In examining the students' audit trails to calculate their time-on-task, the researcher found it useful to have a minimum guideline for completion of two of the units; Unit 1, the shortest and most mathematically simplistic, and Unit 4, the longest and most mathematically difficult for the students, based on the opinions of the teachers and CAI developers at the beginning of this study. These time-on-task "bench marks" were derived from the researcher using the correct answers to interact with the CAI units. A single computer with a hard drive was used that would be faster than a computer used on the labs' network. These bench marks allowed the researcher to devise the fastest route through the Mathematics 30*CAI* units. This allowed the familiarization of the researcher with the audit trail data, the identification of abnormalities in the data, and a basis for comparison with the student and Alberta Education data. In Table 11, the bench marks times are compared with the times recommended by Alberta Education.

The bench mark gave the minimum time required to complete the unit based on the most direct route through the CAI. In the tutorial section of the CAI, if the student answered incorrectly, the program would either make the student respond again, route them to a graph or chart to show how to get the answer or give the student the correct answer. After three trials by the student the correct answer was given. Usually textual feedback was used in the CAI course, with textual and graphical screen displays. The return or enter key was used to move from one screen to the next and was recorded as an interaction. All keystrokes including student answers were recorded as interactions.

TABLE 11

Bench vs. Alberta Education Time-on-Task per Unit

	UNITS	BENCH MARK	ALBERTA EDUCATION
UNIT 1	Polynomials	59	750
UNIT 2	Logarithms		750
UNIT 3	Sequence, Series & Limits		1425
UNIT 4	Trigonometry	331	1800
UNIT 5	Quadratic Relations		1650
UNIT 6	Statistics		1125
SUM			7500

TIME-ON-TASK (MINUTES)

The Unit 1 bench mark was completed in 59 minutes compared to 10% of the 7500 minutes or 750 minutes as a suggested Alberta Education Unit 1 time. The Unit 4 bench mark was 331 minutes compared to 24% of the 7500 minutes or 1800 minutes as a suggested Alberta Education Unit 4 time. The bench marks for Unit 1 and 4 served the purpose of verifying the reasonableness of the recorded data. Students must have taken the time to read the screens displays and interact with the CAI course for the times to be well above the bench marks. Any students' time-on-task below the bench mark values would be due to: an error in the summarized students' audit trails, an incomplete unit, or the student responding with a return or enter key without reading the contents of the screen displays. The researcher would cross-checked the data to find the cause for any inconsistency in either the bench mark or the original students' audit trails.

All the (UF) students spent time in the Test Banks, as shown in Tables 12 and 13, therefore the students found some value in using them, despite the errors in answers and the incompleteness of the Test Banks. The Mathematics 30^{CAI} Test Banks were undergoing major revisions, throughout this study. Each unit Test Bank presented approximately ten randomized questions, each time the student selected it. Some Test Banks had a total of 40 questions for each topic. Because of these revisions the Test Banks were not expected to be [illegible] extensively, so were tabulated as time-on-task only by the summarized audit trails program. In Table 12, the (UF) Low-scoring students spent a mean of 245 minutes on the Test Banks in the CAI out of the Alberta Education 7500 minutes or approximately 3.3% of the time. The (LS) Test Bank ranges showed a maximum of 620 minutes by (LS) student 4 and a minimum of 47 minutes by (LS) students 1 and 5.

In Unit 4, the students' time-on-task calculations are inaccurate, because many of the audit trails were accidentally over-written, due to the inadequate size of storage for the file on the computer diskette. All (UF) students spent more time-on-task in Unit 4 than the tables show. The Low-scoring students 1, 4, and 5 received mostly traditional teacher's instruction for Unit 4, due to their audit trail over-write problems with the CAI. All (LS) students chose to spend very little or no time in at least one unit, as shown in Table 12. All (LS) students chose to spend some time in Units 2, 3, and 4. In Unit 2, the mean was 297. The maximum ranges across Unit 2, 3, and 4 varied from 543 to 863 minutes and minimum ranges of 109 to 456 minutes, as shown in Table 12. In Unit 1, (LS) students 2 and 4, spent 2 and zero (0) minutes respectively. In Unit 4, (LS) students 1, 4, and 5, spent zero, zero, and nine minutes respectively, as recorded by the audit trails. These were the first two units in the Mathematics 30^{CAI} class. In Unit 6, (LS) students 2 and 3, spent 18 and zero (0) minutes respectively. Unit 6 was the last unit to be done in the CAI and the slower students had not monitored their time as effectively as two of the faster (UF) High-scoring students. At least one (HS) student finished the course unit work with six weeks or eighteen classes for review. The teacher offered traditional, optional instruction for Unit 6, due to the insufficient time left to complete the course on schedule for use of the CAI. In Units 2, 3, and 5, where all (LS) students spent considerable time, with a (LS) mean of 297, 662 and 525 minutes respectively, the students each spent less than 46% of the recommended Alberta Education time. The Alberta Education guidelines for Units 2, 3, and 5, were 750, 1425, and 1650 respectively, as shown in Table 11.

In Table 13, the (UF) High-scoring students spent a mean of 225 minutes on the Test Banks in the CAI out of the Alberta Education 7500 minutes or approximately 3% of

TABLE 12

(UF) Low-scoring Students' Time-on-Task

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Test Bank	Sum	Mean	Max.	Min.	Range
Low 1	108	412	856	0	778	124	47	2325	332	856	0	856
Low 2	2	216	655	581	366	18	232	2082	297	667	2	665
Low 3	128	109	456	557	436	0	278	1964	281	557	0	557
Low 4	0	543	666	0	863	100	620	2792	399	863	0	863
Low 5	341	203	666	9	182	126	47	1573	225	665	9	656
Mean	116	297	660	229	525	74	245	2147				
Max.	341	543	856	581	863	126	620	2792	399	863	9	863
Min.	0	109	456	0	182	0	47	1573	225	557	0	557
Range	341	434	400	581	681	126	573	1219	174	306	9	306
BENCH	59			331								
AB Ed.	750	750	1425	1800	1650	1125		7500	1250	1800	750	1050

Time-on Task (Rounded to the minute)

Key: Max. (Maximum)
Min. (Minimum)
AB. Ed. (Alberta Education)

TABLE 13

(UF) High-scoring Students' Time-on-Task

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	TEST BANK	SUM	Mean	Max.	Min.	Range
High 1	126	0	884	0	407	0	633	2050	293	884	0	884
High 2	254	662	766	193	982	57	127	3041	434	982	57	925
High 3	0	522	469	197	605	95	58	1946	278	605	0	605
High 4	232	419	676	849	532	51	227	2986	427	849	51	798
High 5	96	295	623	0	741	183	427	2365	338	741	0	741
High 6	0	806	415	1762	1107	0	368	4458	637	1762	0	1762
High 7	0	295	10	0	0	68	37	410	59	295	0	295
High 8	123	24	455	568	280	0	144	1594	228	568	0	568
High 9	5	0	1053	429	863	158	7	2515	359	1053	0	1053
Mean	93	336	595	444	613	68	225	2374				
Max.	254	806	1053	1762	1107	183	633	4458	637	1762	57	1762
Min.	0	0	10	0	0	0	7	410	59	295	0	295
Range	254	806	1043	1762	1107	183	626	4048	578	1467	57	1467
BENCH	59			331								
AB Ed.	750	750	1425	1800	1650	1125		7500	1250	1800	750	1050

Time-on Task (Rounded to the minute)

Key: Max. (Maximum)
Min. (Minimum)
AB. Ed. (Alberta Education)

the time. This was comparable to the 245 minutes or 3.3% by the (LS) students. The (HS) Test Bank ranges showed a maximum of 633 minutes by (HS) student 4 and a minimum of 7 minutes by (HS) students 9.

In Table 13, seven of the nine, (HS) students chose to spend no time in at least one unit. The (HS) students 1 and 7 chose to spend no time in three out of the six units, as depicted by the audit trails. All (HS) students chose to spend some time in Unit 3, with a maximum range of 1053 and a minimum of 10 minutes, as shown in Table 13. The (HS) students' maximum of 1762 minutes was spent on Unit 4, as compared with a (LS) students' maximum of 863 minutes was spent on Unit 5, a difference of 49% more time for the highest time-on-task of the (HS) student 6 from the (LS) student 4. In Unit 1, (HS) students 1, 6, and 7, spent zero (0) minutes respectively, with (HS) student 9 only spending 5 minutes. In Unit 2, (HS) students 4, and 9, spent zero (0) minutes. In Unit 3 (HS) students 7 spent only 10 minutes. In Unit 4, (HS) students 4, 5, and 7, spent zero (0) minutes respectively. In Unit 5, (HS) student 7, spent zero (0) minutes. In Unit 6, (HS) students 4, 6, and 8, spent zero (0) minutes respectively. The highest mean of 637 minutes, was by (HS) student 6 for four out of the six units. The lowest mean of 59 minutes, was by (HS) student 7 for three out of the six units. Only (HS) students 1 and 2 spent time-on-task in all six units with means of 427 and 434 minutes respectively.

The other (HS) students tended to be very selective with the units chosen to spend time-on-task in the CAI. The (HS) student 7 chose mainly the text book and some teacher interaction over the CAI. The (HS) students' mean of 2374 minutes was less than 32% of the recommended Alberta Education (AB. Ed.) time. The students spent the remaining time with the other classroom resources: the other students, their textbook and the teacher. In Tables 12 the (LS) students' means ranged between 225 and 399, which was comparable to (HS) students' mean ranges of 228 and 434, in Table 13, with two (HS) student exceptions. One of the exceptions was (HS) student 6 that spent a mean of 637 minutes, some of this time was spent during the students' spare time and noon hours. The other was (HS) student 7 that spent a mean of 59 minutes in total on the CAI course. This meant that this student did not use the CAI course or that they shared a computer whereby their audit trails were recorded to their partner's audit trails. The latter was more likely, since the researcher observed all students interacting with the CAI for at least part of each class session.

The summarized student audit trails were analyzed to select and extract the data on the number of interactions and topics each of the (LS) and (HS) students tried and completed for each unit. The compilation and computations of the data are shown in the tables. Tables 14 to 19 show this data by unit for the (LS) students. Table 20 to 25 show this data by unit for the (HS) students. The time in seconds was recorded and rounded to the nearest tenth of a second. The time in minutes was calculated by dividing the time in seconds by sixty and rounding to the nearest minute. The number of interactions (icons) were counted, then the time per icon was calculated in seconds by dividing the time in seconds by the number of icons. The topics identified as completed in the audit trails were counted and placed over the number of topics tried to give the topics completed. The total number of topics in the unit to complete is displayed in the "Topics Complete" column. The "Complete Units %" column was calculated by dividing the number of topics the student completed divided by the total number of topics in the unit. The "Tried Units %" column was calculated by the number of topics the student tried divided by the total number of topics in the unit. The "Sum" row displays the number of students that spent time-on-task in the unit by the total number of students, as well as, the sums for each column. The "Mean" row displays the percentage of students that spent time-on-task in the unit, as well as, the means for each column. The Unit 1 bench mark (U1 Bench) is displayed for comparison in Tables 14 and 20 . The Unit 4 bench mark (U4 Bench) is displayed for comparison in Tables 17 and 23.

In Tables 14 to 19, the (LS) students time-on-task for Unit 1 through 6 completed and tried units are displayed. In Table 14, 80% of the students tried Unit 1. The (LS)

TABLE 14

(UF) Low-scoring Students' Time-on-Task (Unit 1 Completed/Tried)

UNIT 1	Time (Min)	Time (Sec)	No. of Icons	Time Per Icon	No. of Sess.	4 Topics Complete	Complete Unit	Tried Unit
U1 BENCH	**59**	**3559.0**	**1396**	**2.55**	**4**	**(4/4)**	**100**	**100**
LOW 1	108	6459.4	507	12.7	2	(0/1)	0	25
LOW 2	2	120.0	16	7.5	1	(0/1)	0	25
LOW 3	128	7654.2	664	11.5	5	(0/2)	0	50
LOW 4	0	0.0	0	0.0	0	(0/0)	0	0
LOW 5	341	20443.7	411	49.7	7	(2/4)	50	100
Sum (4/5)	578	34677.3	1598	21.7	15	(2/8)		
Mean(80)	116	6935.5	320	16.3	3	25	10	40

KEY:

- Min (minutes) rounded to nearest minute
- Sec (seconds). rounded to nearest tenth
- No. (Number)
- Icons (interactions)
- Time Per Icon in seconds
- Sess. (Sessions)
- Min. (Minimum)
- Max (Maximum)

TABLE 15

(UF) Low-scoring Students' Time-on-Task (Unit 2 Completed/Tried)

UNIT 2	Time (Min)	Time (Sec)	No. of Icons	Time Per Icon	No. of Sess.	7 Topics Complete	Complete Unit	Tried Unit
LOW 1	412	24729.5	2091	11.8	11	(3/4)	43	57
LOW 2	216	12984.2	905	14.3	8	(1/3)	14	43
LOW 3	109	6548.4	675	9.7	5	(0/3)	0	43
LOW 4	543	32607.5	3000	10.9	16	(4/6)	57	86
LOW 5	203	12171.5	1254	9.7	7	(1/3)	14	43
Sum (5/5)	1484	89041.1	7925	11.2	47	(9/19)		
Mean(100)	297	17808.2	1585	6.5	9	47	26	54

KEY:

- Min (minutes) rounded to nearest minute
- Sec (seconds). rounded to nearest tenth
- No. (Number)
- Icons (interactions)
- Time Per Icon in seconds
- Sess. (Sessions)
- Min. (Minimum)
- Max (Maximum)

TABLE 16

(UF) Low-scoring Students' Time-on-Task (Unit 3 Completed/Tried)

UNIT 3	Time (Min)	Time (Sec)	No. of Icons	Time Per Icon	No. of Sess.	7 Topics Complete	Complete Unit	Tried Unit
LOW 1	856	51336.7	2091	24.6	22	(4/7)	57	100
LOW 2	655	39299.2	1942	20.2	21	(0/7)	0	100
LOW 3	456	27363.4	1246	22.0	18	(3/6)	43	86
LOW 4	666	39980.8	2171	18.4	19	(5/7)	71	100
LOW 5	666	39972.5	1946	20.5	17	(4/7)	57	100
Sum(5/5)	3299	197952.6	9396	21.1	97	(16/34)		
Mean(100)	660	39570.5	1876	13.1	19	47	46	97

KEY:

- Min (minutes) rounded to nearest minute
- Sec (seconds). rounded to nearest tenth
- No. (Number)
- Icons (interactions)
- Time Per Icon in seconds
- Sess. (Sessions)
- Min. (Minimum)
- Max (Maximum)

TABLE 17

(UF) Low-scoring Students' Time-on-Task (Unit 4 Completed/Tried)

UNIT 4	Time (Min)	Time (Sec)	No. of Icons	Time Per Icon	No. of Sess.	18 Topics Complete	Complete Unit	Tried Unit
U4 BENCH	**331**	**19864.9**	**3752**	**5.29**	**18**	**(18/18)**	**100**	**100**
LOW 1	0	0.0	0	0.0	0	(0/0)	0	0
LOW 2	581	34887.2	2114	16.5	18	(0/5)	0	28
LOW 3	557	33409.4	2099	15.9	23	(0/7)	0	39
LOW 4	0	1.1	2	0.5	1	(0/1)	0	6
LOW 5	9	527.2	39	13.5	2	(0/1)	0	6
Sum (4/5)	1147	68824.9	4254.0	16.2	44	(0/14)		
Mean(80)	229	13765.0	851	9.3	9	0	0	16

KEY:

- Min (minutes) rounded to nearest minute
- Sec (seconds). rounded to nearest tenth
- No. (Number)
- Icons (interactions)
- Time Per Icon in seconds
- Sess. (Sessions)
- Min. (Minimum)
- Max (Maximum)

TABLE 18

(UF) Low-scoring Students' Time-on-Task (Unit 5 Completed/Tried)

UNIT 5	Time (Min)	Time (Sec)	No. of Icons	Time Per Icon	No. of Sess.	9 Topics Complete	Complete Unit	Tried Unit
LOW 1	778	46665.9	2951	15.8	21	(8/9)	89	100
LOW 2	366	21934.6	983	22.3	14	(0/6)	0	67
LOW 3	436	26154.4	'104	23.7	16	(3/6)	33	67
LOW 4	863	51793.5	2892	17.9	19	(8/9)	89	100
LOW 5	182	10919.5	666	16.4	7	(2/3)	22	33
Sum(5/5)	2624	157467.9	8596.0	18.3	77	(21/33)		
Mean(100)	525	31493.6	17.9	11.6	15	64	47	73

KEY:

- Min (minutes)
- Sec (seconds).
- No. (Number)
- Icons (interactions)
- Time Per Icon in seconds

rounded to nearest minute
rounded to nearest tenth

- Sess. (Sessions)
- Min. (Minimum)
- Max (Maximum)

TABLE 19

(UF) Low-scoring Students' Time-on-Task (Unit 6 Completed/Tried)

UNIT 6	Time (Min)	Time (Sec)	No. of Icons	Time Per Icon	No. of Sess.	4 Topics Complete	Complete Unit	Tried Unit
LOW 1	124	7419.7	736	10.1	8	(2/3)	50	75
LOW 2	18	1074.2	273	3.9	5	(0/4)	0	100
LOW 3	0	0.0	0	0.0	0	(0/0)	0	0
LOW 4	100	6022.9	560	10.8	2	(0/2)	0	50
LOW 5	126	7540.6	508	14.8	3	(2/3)	50	75
Sum (4/5)	368	22057.4	2077.0	10.6	18	(4/12)		
Mean(80)	74	4411.5	415	4.2	4	33	20	60

KEY:

- Min (minutes)
- Sec (seconds).
- No. (Number)
- Icons (interactions)
- Time Per Icon in seconds

rounded to nearest minute
rounded to nearest tenth

- Sess. (Sessions)
- Min. (Minimum)
- Max (Maximum)

student 5 was the only student to try all four topics, but only completed 50%. The (LS) student 4 did not spend any time in Unit 1. The other (LS) students tried at least 25% of the unit. The (LS) students spent between 0.0 seconds and 49.7 seconds per icon (interaction). The (LS) student 1 spent 108 minutes in 2 sessions and (LS) student 3 spent 128 minutes in 5 sessions respectively. The (LS) student 5 spent 341 minutes in sessions on Unit 1.

In Table 15, all or 100% of the (LS) students tried some part of Unit 2. The (LS) student 3 tried 43% of the unit, but completed 0% of the unit. The (LS) student 4 completed and tried the most of Unit 2 with 56% completed and 86% tried. The (LS) students spent between 9.7 seconds and 14.3 seconds per icon (interaction). The (LS) student 4 spent the maximum of 16 sessions on Unit 2.

In Table 16, 100% of the students tried Unit 3. The four (LS) students 1, 2, 4, and 5 tried all the topics or (100%) of Unit 3, but none completed the unit. The (LS) student 4 completed 5 of 7 topics. The (LS) students spent between 18.4 seconds and 24.6 seconds per icon (interaction). All the (LS) students spent between 17 and 22 sessions on Unit 3, more sessions than any other unit.

Unit 4 was inaccurate due to the over-written audit trails. In Table 17, the remaining audit trails showed that, 80% of the (LS) students tried the unit, but 0% completed. The (LS) student 3 showed the most tried at 39%. The (LS) students 1 and 4 spent 0 and 0.5 seconds per icon respectively. The other (LS) students spent between 13.5 seconds and 16.5 seconds per icon (interaction). The (LS) students 4 and 5 spent only 1 and 2 sessions respectively. The other (LS) students spent between 18 and 23 sessions.

In Table 18, 100% of the students tried Unit 5. The (LS) students 1 and 4 tried 100% of the unit and completed 89%. The (LS) student 3 showed the largest percentage of units tried at 39%. The (LS) students spent between 15.8 seconds and 23.7 seconds per icon (interaction). The (LS) students spent between 7 and 21 sessions.

In Table 19, 80% of the students tried Unit 6. The unit was 100% tried by (LS) student 2, but 0% completed. Two (LS) students 1 and 5 tried 75% and completed 50% of the unit. The (LS) student 3 showed the most tried at 39%. Two (LS) students 1 and 4 spent 10.1 and 10.8 seconds per icon (interaction) respectively. (LS) students 1 used 8 sessions, while (LS) student 4 used 2 sessions. The (LS) students spent between 0 and 8 sessions.

The audit trails of Low-scoring student 2 were somewhat scattered. Even though the student spent time in the topics/units, it was often spent navigating for short periods of time all around in different topics and units.

In Tables 14 through 19, the ranking of the units by percentages of completed units are Unit 5, 3, 2, 6, 1, and 4, with means of 47%, 46%, 26%, 20%, 10% and 0% respectively. The ranking of the units by percentages of tried units are Unit 3, 5, 6, 2, 1, and 4, with means of 97%, 73%, 60%, 54%, 40% and 16% respectively. The ranking of the units by time per icon are Unit 1,3, 5, 4, 2, and 6, with means of 16.3, 13.1, 11.6, 9.3, 6.5 and 4.2 respectively. The ranking of the units by number of sessions are Unit 3, 5, 2 and 4, 6, and 1, with means of 19, 15, 9, 9, 4 and 3 respectively.

In Tables 20 to 25, the (HS) students time-on-task for Units 1 to 6 completed and tried are displayed. In Tables 20, 67% of the (HS) students tried Unit 1. The (HS) student 1 tried 50% or 2 topics and completed 50% or both topics. The (HS) students 3, 6, and 7 did not spend any time in Unit 1. The other (HS) students tried at least 25% of the unit. The (HS) student 2 tried 75%, but completed 0%. The (HS) students spent between 0.0 seconds and 23.4 seconds per icon (interaction), with the exception of the three (HS) students that spent no time on this unit. The (HS) students 1 and 8 spent 126 minutes in 3 sessions and 123 minutes in 5 sessions respectively. The (HS) students 4 and 2 spent 232 minutes in 5 sessions and 254 minutes in 8 sessions respectively. The (HS) student 2 spent the maximum of 8 sessions on Unit 1.

TABLE 20

(UF) High-scoring Students' Time-on-Task (Unit 1 Completed/Tried)

UNIT 1 (Min)	Time (Sec)	Time Icons	No. of Per Icon	Time Sess.	No. of Complete	4 Topics Unit	Complete Unit	Tried
U1 BENCH	**59**	**3559.0**	**1396**	**2.55**	**4**	**(4/4)**	**100**	**100**
HIGH 1	126	7577.5	711	10.7	3	(2/2)	50	50
HIGH 2	254	15219.1	2084	7.3	8	(0/3)	0	75
HIGH 3	0	0.0	0	0.0	0	(0/0)	0	0
HIGH 4	232	13919.0	1017	13.7	5	(1/1)	25	25
HIGH 5	96	5756.1	589	9.8	2	(0/1)	0	25
HIGH 6	0	0.0	0	0.0	0	(0/0)	0	0
HIGH 7	0	0.0	0	0.0	0	(0/0)	0	0
HIGH 8	123	7368.0	580	12.7	5	(0/1)	0	25
HIGH 9	5	304.0	13	23.4	1	(1/1)	25	25
Sum (6/9)	836	50143.7	4994	77.5	24	(4/9)		
Mean(67)	93	5571.5	555	8.6	3	44	11	25

KEY:

- Min (minutes) rounded to nearest minute
- Sec (seconds). rounded to nearest tenth
- No. (Number)
- Icons (interactions)
- Time Per Icon in seconds
- Sess. (Sessions)
- Min. (Minimum)
- Max (Maximum)

TABLE 21

(UF) High-scoring Students' Time-on-Task (Unit 2 Completed/Tried)

UNIT 2 (Min)	Time (Sec)	Time Icons	No. of Per Icon	Time Sess.	No. of Complete	7 Topics Unit	Complete Unit	Tried
HIGH 1	0	37.8	16	1.7	2	(0/1)	0	14
HIGH 2	662	39,[illegible]42.0	4421	9.0	21	(6/7)	86	100
HIGH 3	522	31305	3285	9.5	17	(6/7)	86	100
HIGH 4	419	25151	2182.0	11.5	16	(4/5)	57	71
HIGH 5	295	17690.5	1905	9.3	8	(3/3)	43	43
HIGH 6	806	48388.99	4705	10.3	23	(7/7)	100	100
HIGH 7	295	17714.3	1895	9.3	7	(3/4)	43	57
HIGH 8	236	14140.4	982	14.4	8	(0/3)	0	43
HIGH 9	0	0.0	0	0.0	0	(0/0)	0	0
Sum (8/9)	3236	194159.5	19391	10.0	102	(29/37)		
Mean(89)	360	21573.3	2155	8.3	11	78	46	59

KEY:

- Min (minutes) rounded to nearest minute
- Sec (seconds). rounded to nearest tenth
- No. (Number)
- Icons (interactions)
- Time Per Icon in seconds
- Sess. (Sessions)
- Min. (Minimum)
- Max (Maximum)

TABLE 22

(UF) High-scoring Students' Time-on-Task (Unit 3 Completed/Tried)

UNIT 3 (Min)	Time (Sec)	Time Icons	No. of Per Icon	Time Sess.	No. of Complete	7 Topics Unit	Complete Unit	Tried
HIGH 1	884	53040.0	2917	18.2	26	(3/7)	43	100
HIGH 2	766	45960.0	3854	11.9	21	(3/7)	43	100
HIGH 3	469	28140.0	2710	10.4	22	(7/7)	100	100
HIGH 4	676	40560.0	2042	19.9	27	(5/7)	71	100
HIGH 5	623	37380.0	2418	15.5	25	(5/7)	71	100
HIGH 6	415	24900.0	2517	9.9	17	(6/7)	86	100
HIGH 7	10	600.0	51	11.8	1	(0/1)	0	14
HIGH 8	455	27310.4	1252	21.8	17	(4/6)	57	86
HIGH 9	1053	63180.0	2396	26.4	27	(6/7)	86	100
Sum (9/9)	5351	321060.0	20157	145.6	183	(39/56)		
Mean(100)	595	35673.3	2240	16.2	20	70	62	89

KEY:

- Min (minutes) rounded to nearest minute
- Sec (seconds). rounded to nearest tenth
- No. (Number)
- Icons (interactions)
- Time Per Icon in seconds
- Sess. (Sessions)
- Min. (Minimum)
- Max (Maximum)

TABLE 23

(UF) High-scoring Students' Time-on-Task (Unit 4 Completed/Tried)

UNIT 4 (Min)	Time (Sec)	Time Icons	No. of Per Icon	Time Sess.	No. of Complete	18 Topics Unit	Complete Unit	Tried
U4 BENCH	**331**	**19864.9**	**3752**	**5.29**	**18**	**(18/18)**	**100**	**100**
HIGH 1	0	0.0	0	0.0	0	(0/0)	0	0
HIGH 2	193	11590.4	1287	9.0	10	(0/2)	0	11
HIGH 3	197	11815.72	2498.6	4.7	6	(1/1)	6	6
HIGH 4	849	50939	1916.0	26.6	23	(0/4)	0	22
HIGH 5	0	0.0	0	0.0	0	(0/0)	0	0
HIGH 6	1762	105691.1	7782	13.6	20	(0/6)	0	33
HIGH 7	0	0.0	0	0.0	0	(0/0)	0	0
HIGH 8	568	34066.0	1668	20.4	20	(0/4)	0	22
HIGH 9	429	25756.5	1983	13.0	15	(0/2)	0	11
Sum (6/9)	3998	239858.8	17134.6	87.3	94	(1/19)		
Mean(67)	444	26651.0	1904	9.7	10	5	1	12

KEY:

- Min (minutes) rounded to nearest minute
- Sec (seconds). rounded to nearest tenth
- No. (Number)
- Icons (interactions)
- Time Per Icon in seconds
- Sess. (Sessions)
- Min. (Minimum)
- Max (Maximum)

TABLE 24

(UF) High-scoring Students' Time-on-Task (Unit 5 Completed/Tried)

UNIT 5 (Min)	Time (Sec)	Time Icons	No. of Per Icon	Time Sess.	No. of Complete	9 Topics Unit	Complete Unit	Tried
HIGH 1	407	24401.1	997	24.5	12	(1/6)	11	67
HIGH 2	982	58928.0	3561	16.5	37	(6/9)	67	100
HIGH 3	605	36299	2697	13.5	25	(8/8)	89	89
HIGH 4	532	31934	1766.7	18.1	17	(5/6)	56	67
HIGH 5	741	44461.0	2591	17.2	25	(9/9)	100	100
HIGH 6	1107	66395.58	3574	18.6	39	(8/9)	89	100
HIGH 7	0	0.0	0	0.0	0	(0/0)	0	0
HIGH 8	280	16779.5	849	19.8	13	(3/5)	33	56
HIGH 9	938	56305.3	2265	24.9	20	(9/9)	100	100
Sum (8/9)	5592	335503.5	18300.7	152.9	188	(49/61)		
Mean(89)	621	37278.2	2033	17	21	80	60	75

KEY:

- Min (minutes) rounded to nearest minute
- Sec (seconds). rounded to nearest tenth
- No. (Number)
- Icons (interactions)
- Time Per Icon in seconds
- Sess. (Sessions)
- Min. (Minimum)
- Max (Maximum)

TABLE 25

(UF) High-scoring Students' Time-on-Task (Unit 6 Completed/Tried)

UNIT 6 Minutes	Time Seconds	Time Icons	No. of Per Icon	Time Sess.	No. of Complete	4 Topics Unit	Complete Unit	Tried
HIGH 1	0	0.9	1	0.9	1	(1/1)	25	25
HIGH 2	57	3414.0	407	8.4	3	(0/1)	0	25
HIGH 3	95	5677	405	14.0	3	(1/2)	25	50
HIGH 4	51	3070	118.0	25.0	1	(0/1)	0	25
HIGH 5	183	10995.0	623	17.6	6	(0/2)	25	50
HIGH 6	0	0	0	0.0	[illegible]	(0/0)	0	0
HIGH 7	68	4092.1	226	18.1	3	(1/2)	25	50
HIGH 8	0	0.0	0	0.0	0	(0/0)	0	0
HIGH 9	158	9496.2	[illegible]	15.4	5	(1/2)	[illegible]	50
Sum (7/9)	612	36745.1	2395.0	100.5	22	(5/11)		
Mean(78)	68	4082.8	266	11.2	2	45	14	31

KEY:

- Min (minutes) rounded to nearest minute
- Sec (seconds). rounded to nearest tenth
- No. (Number)
- Icons (interactions)
- Time Per Icon in seconds
- Sess. (Sessions)
- Min. (Minimum)
- Max (Maximum)

In Tables 21, the (HS) student 9 did not spend any time in the unit, so that 89% of the (HS) students tried Unit 2, with a mean of 59%, as compared with (LS) mean of 54%. The (HS) students 2, 3, and 6 tried 100% of the unit. The (HS) students 6 completed 100% of the unit. The (HS) students 2 and 3 completed 86% of the unit. The (HS) students 1 and 8 completed 0% and tried 14% and 43% respectively. The (HS) students spent between 1.7 seconds and 14.4 seconds per icon (interaction), with the exception of the one (HS) student that spent no time on this unit. The (HS) student 6 spent the maximum of 23 sessions on Unit 2.

In Tables 22, 100% of the students tried Unit 3. The seven (HS) students 3, 6, 9, 4, 5, 1, and 2 tried 100% of the unit, and completed 100%, 86%, 86%, 71%, 71%, 43% and 43% of the unit respectively. The (HS) student 7 completed 0% of the 14% tried, spending only 10 minutes in Unit 3. The (HS) students spent between 9.9 seconds and 26.4 seconds per icon (interaction). The (HS) student 9 spent the maximum of 27 sessions on Unit 3.

In Unit 4 the remaining audit trails showed that, 67% of the (HS) students tried the unit, but 0% completed, as shown on Table 23. The (HS) student 6 showed the most tried at 33%. The (HS) stude[illegible] completed the most, with 6% tried and 6% completed or one of eighteen topics tried and completed. The (HS) students spent between 4.7 sec[illegible] and 26.6 seconds per icon (interaction), with the exception of the three (HS) students that spent no time on this unit. The (HS) student 4 spent the maximum of 23 sessions on Unit 4.

In Table 24, 89% of the (HS) students tried Unit 5. The (HS) student 7 did not spend any time in the unit. The four (HS) students 2, 5, 6 and 9 tried 100% of the unit. The (HS) students 5 and 9 also completed 100% of the unit. Eight out of the nine (HS) students completed at least 11% of Unit 5. The (HS) students spent between 13.5 seconds and 24.9 seconds per icon (interaction), with the exception of the one (HS) student that spent no time on this unit. The (HS) student 6 spent the maximum of 39 sessions on Unit 5. Unit 5 had the most number of student sessions with a sum of 188.

In Table 25, 78% of the students tried Unit 6. The unit was 50% tried by four (HS) student 3, 5, 7, and 9 and 25% completed. The (HS) student 1 completed and tried 25% or one topic out of one topic was tried and completed. The (HS) students spent between 0.9 seconds and 26.0 seconds per icon (interaction), with the exception of the two (HS) students that spent no time on this unit. The (HS) student 5 spent the maximum of 6 sessions on Unit 6.

In Tables 20 through 25, the ranking of the units by percentages of completed units are Unit 3, 5, 2, 6, 1, and 4, with means of 62%, 60%, 46%, 14%, 11% and 1% respectively. This was comparable to the (LS) students with only units 3 and 5 reversed by a slim margin of 2%. The ranking of the units by percentages of tried units are Unit 3, 5, 2, 6, 1, and 4, with means of 89%, 75%, 59%, 31%, 25% and 12% respectively. This was comparable to the (LS) students with only units 2 and 6 reversed. The ranking of the units by time per icon for the (HS) students are Unit 5, 3, 6, 4, 1 and 2, with means of 17.0, 15.[illegible], 11.2, 9.7, 8.6 and 8.3 respectively. Only Unit 3 in second place compares with (LS) students' time per icon of 13.1 to 16.2. The ranking of the units by number of sessions for (HS) students are Unit 5, 3, 2, 4, 1 and 6, which compared with the (LS) students' Units 3, 5, 2 and 4, 6, and 1. The (HS) students' number of sessions means of 21, 20, 11, 10, 3, and 2 respectively, compared with the (LS) students' of 19, 15, 9, 9, 4 and 3. These third and fourth place rankings compared with the (LS) students' number of sessions for Units 2 and 4.

In Tables 26 and 27, the (UF) Low-scoring and High-scoring students time-on-task sums for percentage of units completed and tried are displayed. The time in hours is calculated from the time in minutes divided by sixty and rounded to the nearest one-hundredth of an hour. The means and ranges, both maximums and minimums, are calculated and displayed for each category.

In Table 26, the (LS) students mean was 27.31 hours or 1639 minutes. Add the mean of 245 minutes in the test banks from Table 12, for a total number of minutes of

TABLE 26

(UF) Low-scoring Students' Time-on-Task Sums (Units Completed/Tried)

Units	Time in Hours	Time in Minutes	Number of Interactions	Time Per Interactions	Number of Sessions	Completed Units in Percents	Tried Units in Percents
UNIT 1	9.63	578	1598	21.7	15	10	40
UNIT 2	24.73	1484	7925	11.2	47	26	54
UNIT 3	54.98	3299	9396	21.1	97	46	97
UNIT 4	24.63	1478	4254	16.2	44	0	16
UNIT 5	43.73	2624	8596	[illegible].3	77	47	73
UNIT 6	6.13	368	2077	10.6	18	20	60
Mean	27.31	1639	5641	16.5	50	25	57
Max.	54.98	3299	9396	21.7	97	47	97
Min.	6.13	368	1598	10.6	15	0	16
Range	48.85	2931	7798	11.1	82	47	81

TABLE 27

(UF) High-scoring Students' Time-on-Task Sums (Units Completed/Tried)

Units	Time in Hours	Time in Minutes	Number of Interactions	Time Per Interaction	Number of Sessions	Completed Units in Percents	Tried Units in Percents
UNIT 1	13.93	836	4994	10.0	24	11	25
UNIT 2	53.93	3236	19391	10.0	102	46	59
UNIT 3	89.18	5351	20157	15.9	133	62	89
UNIT 4	72.15	4329	17135	14.0	94	1	12
UNIT 5	93.20	5592	18301	18.3	188	60	75
UNIT 6	10.20	612	2395	15.3	22	14	31
Mean	55.43	3326	13729	13.9	102	32	48
Max.	93.20	5592	20157	18.3	188	62	89
Min.	10.20	612	2395	10.0	22	1	12
Range	83.00	4980	17762	8.3	166	61	77

1884, which is 25.1% of Alberta Education's guidelines of 125 hours or 7500 minutes. The (LS) students spent 25.1% of their time interacting with the CAI and 74.9% doing other class activities. The (LS) students mean of time per icon was 16.5 seconds. The (LS) mean of the number of sessions was 50. The minutes per session mean of 1639 minutes divided by 50 sessions would be 32.8 minutes per session. The (LS) students' mean showed that 25% of these students completed all six units. The (LS) students' mean showed that 57% of these students tried all six units. Unit 5 and 3 had the maximum unit completion percentages of 47% and 46%, while Unit 4 had the minimum of 0%. Unit 3 had the maximum unit tried percentage of 97% and Unit 4 had the minimum of 16%.

In Table 27, the (HS) students mean was 55.43 hours or 3326 minutes. If the test bank mean of 225 minutes is added from Table 13, a total number of minutes of 3551, which is 47.3% of Alberta Education's guidelines of 125 hours or 7500 minutes. The (HS) students spent 47.3% of their time interacting with the CAI and 52.7% doing other class activities. In Tables 26 and 27, the (HS) students mean of time per icon was 13.9 seconds, as compared to the (LS) students' of 16.5 seconds. The (HS) mean of the number of sessions was 52, which was slightly higher than the (LS) students' 50 sessions. The minutes per session mean of 3326 minutes divided by 52 sessions would be 63.9 minutes per session, as compared to the (LS) students' of 32.8 minutes per session. This is a difference of 51% more time per session was spent by (HS) students as compared to (LS) students. The (HS) students' mean showed that 32% of these students completed all six units. The (HS) students' mean showed that 48% of these students tried all six units. The (HS) students completed 32% compared to (LS) students' 25% and tried 48% compared to 57%. The (HS) students completed 67% of the units they tried compared to 44% for the (LS) students. Unit 3 and 5 had the maximum unit completion percentages of 62% and 60%, while Unit 4 had the minimum of 0%. Unit 3 had the maximum unit tried percentage of 89% and Unit 4 had the minimum of 16%. The maximums for the (HS) and the (LS) students were similar with Unit 5 and 3 both being comparable. The minimums for the (HS) and the (LS) students were both Unit 4.

Audit Trails: Subjective Feedback

The audit trails contained the subjective feedback, interspersed with the time-on-task data. The subjective feedback (typed comments) resided in the location of the topic and unit location the student was in at the time. This data was not categorized by type or topic by the CAI software. The CAI developers initially received student audit trail print-outs, from the (UF) teacher or researcher, to select and extract the subjective feedback. The (UF) teacher changed this by placing a typographical error tabulation sheet up on the wall in the classroom. The students typed their subjective feedback to the CAI first, and then checked the tabulation sheet to record errors found, by topic and unit. The (UF) teacher then sent the sheet to the CAI developers. The CAI developers received the sheet to correct or modify the CAI program for inclusion in an updated version.

The subjective feedback was collected and compiled from the (UF) Low and High-scoring students' audit trails, as shown on Tables 28 through 32. The researcher grouped the subjective feedback or typed comments into the following categories: Mathematical Editing Corrections (Table 28), Design Editing Corrections (Table 29), Students' Opinions (Table 30), Questions and/or Suggestions (Table 31), and Other Non-descriptive (Table 32). Eleven out of the fourteen, (UF) Low-scoring students and (UF) High-scoring, students made comments, displayed in Tables 28 to 32.

The more students and teachers that used the Mathematics 30*CAI* course, the more typographical errors were found. In Tables 28 and 29, the mathematical and design editing corrections noted by the students, within context by topic and unit were useful for the CAI developers to make corrections or modifications. These changes brought about new versions of the Mathematics 30*CAI* course available to the classes upon request. In the case of Unit 4, the navigation devices incorporated and tested by the CAI developers and (UF) students was a direct result of the problems that the students encountered. Some

TABLE 28

Subjective Feedback: Mathematical Editing Corrections

- Won't allow 3 decimal places
- Answer is weird, first says it's wrong then says it's correct.
- to the exponent 1/7x, should be written as x/7 or 1x/7.
- In this question I have put the answer as 2.631, but the computer refuses to accept this answer, saying that the answer is 2.631!!! My answer is right but the computer won't except it!
- It won't accept 3 decimal places.
- It didn't say how many decimal places it will accept.
- THE ANSWER IS WRONG!
- would not accept right answer .
- In the answer the computer gave, it should have had the five at the end of the answer. The computer forgot to put it in.
- this is not a very good answer. it would be better to write -1(-5)^n
- this answer is incorrect. It should read 11217 when 'n' is 30.

TABLE 29

Subjective Feedback: Design Editing Corrections

- (1,-2) and (1,2) do not match
- (0,2) and (1,2) don't match
- There are two pages stuck together onto one screen!
- screen overlap - rectangular box
- Still a merging between two of the screens and this particular screen is hard to read - too squished together
- screen overlap
- page number unclear
- Statement is doubled when answer is correct.
- previous page overlaps current page
- In topic 2 the page number didn't change since page 5
- All the sentences are being printed on top of one another!
- should read
- should read " after four more swings" I can't even read it.

TABLE 30

Subjective Feedback: Students' Opinions

One (LS) Student's Opinions:

- this is the stupidst computer in the world what
- This computer @#@#@#@# big time!
- To: [student name] hey you can work on this computer if you want o.k.! Tell [the teacher]!

Other (LS) and (HS) Students' Opinions:

- Let me through!!!
- I feel this unit is too complex to be taught in this way. It is much too confusing to comprehend. Especially when your teacher is busy with other students. Please make this unit easier to learn!!!!!

TABLE 31

Subjective Feedback: Questions and/or Suggestions

- Not sure what to do, because there is no equal sign. So how do we solve for x?
- In number 12 of Topic 2 of logarithms, show how the answer was achieved by using the calculator!
- How do you get the interest for the interest for the second year?
- It should put how to do the question in steps for the question that we don't understand in the practice exercise.
- I don't understand any of the examples that are used!!!!!
- thats mean, you should give us a chance to answer before the computer answers it for you. how are you supposed to learn if you are not permitted to answer the question!
- lost me on the previous card
- too much repitition , two examples would have been enough
- this is not a very good answer. it would be better to write -1(-5)^n
- The derived formula should be the focus where as the formula a=...should be optional

TABLE 32

Subjective Feedback: Non-descriptive

- nothing
- KIR
- ITS

students stated that they felt challenged to find and correct the computer's mistakes. The students were very aware of the time guidelines in the course and if they received no personal benefit in taking the time to type in subjective feedback, then they stopped. The (LS) and (HS) students' typed comments were non-existent after the initial use in Unit 4. Students were reluctant to spend time on anything not directly related to their completion of their course. The (UF) students continued to use the teacher's printed error sheet to record changes to be made by the CAI developers. The CAI developers worked bi-weekly with the (UF) class, until the routing and navigation problems encountered with Unit 4 were resolved. The observed students' verbal feedback and typed subjective feedback influenced the restructuring of the Mathematics 30^{CAI} course through the incorporation of the navigation scroll bar, the book marks placement, and the teacher-chosen route where the audit trails resided, as explained in Chapter 3.

In Table 30, the typed comments were directed towards working with the Mathematics 30^{CAI} course and the computer use. Only two, (UF) High-scoring students 7 and 8 had limited, previous computer experience. In Table 30 under the heading "One (LS) Student's Opinion" the first two comments state a negative reaction to the use of the computer. In Table 30 under the heading "Other (LS) and (HS) Students' Opinions" the tone of the statement "Let me through!!!" portrays a frustration with the lock-step method or computer-controlled interactions of the student in Unit 4, before the CAI developers' changes.

In Table 30, the third statement under the "One (LS) Student's Opinions" expressed a need for peer-tutoring work with another student in Unit 4. These two students worked side by side, but on their own computers, throughout Unit 4. Two "Other (LS) and (HS) Students' Opinions" expressed the navigation problems and difficulties of Unit 4 that most of the class expressed verbally before the CAI developers corrected the navigational problems to use a "learner-controlled" as opposed to "computer-controlled" strategy.

In Table 31, the "Questions and/or Suggestions" categories expressed a need for the Mathematics 30^{CAI} course to show in other ways the "how" and "why" of the mathematics, not just the answers. Personal preferences indicated by the subjective feedback comments reflected the different needs of the students. Most students verbalized the need for more graphic displays to show step by step procedures, as in the comment "show how the answer was achieved by using the calculator". The typed comment "too much repetition , two examples would have been enough" stated the need for optional examples, exercises and/or further explanations to be available, as an option. In Table 32, the "Non-Descriptive" subjective feedback could not be interpreted as anything understandable, so was placed in this category.

Researcher's Observations

The Urban, Full-year, ten month, class had a teacher and the students in a computer-filled classroom. Each student had a computer in [illegible] of them. There was no specific seating order, so the students often sat at different [illegible] in each class. The students came into class each day, turned on their computers, and then organized their notebooks, text books and/or other materials, such as a personal calculator. Calculators were also available on each computer. The students started the Mathematics 30^{CAI} course, then signed on to the computer with their identification code and password. This automatically, opened the audit trails and started the writing of the file, until the students quit the Mathematics 30^{CAI} course.

For the first three months of the course, before this automated process, the students had to start the computers using a computer diskette and copy the audit trails to the hard drive so that the original file could not be overwritten. If the audit trails got over-written the student had to start over in that topic, because the initial audit trails restart location was lost. The students could only move ahead one screen at a time. The students and teacher wanted the routing to be changed to enable the students to move anywhere in the

Mathematics 30^{CAI} course. The CAI developers started to work out a solution. The High-scoring student 9 was the furthest ahead in Unit 4, when the computer diskette became over-loaded and over-wrote the system and audit trail files. The computer diskettes became too small for storage and the hard drives had to be used. The CAI developers made changes to accommodate this problem. There were further changes to allow the teacher to decide on which hard drive and specific location the audit trails would reside for security. The temporary solution was that the teacher could bypass the sections in the topic that the student had lost because of over-written audit trails. The students and teacher were satisfied with the changes made by the CAI developers with the navigational improvements to the Mathematics 30^{CAI} course.

The navigation improvements were made so that the student could go ahead or back in the materials with the use of a navigational bar. This bar appeared on each screen and marked the location where the student was and had been in the course. The student pointed to the location on the bar where they would like to be routed and then were moved or routed there.

The teacher was responsible for the technical and instructional problems in the class. This was very demanding and the teacher spent a lot of class time initially with technical difficulties. After the major technical problems were solved the class set into a regular routine of spending time-on-task in the Mathematics 30^{CAI} course. The students constantly asked questions of their classmates, as well as the teacher. The teacher worked mainly with different individuals in each class and sometimes coached small groups. The teacher set the deadlines for class homework assignments and tests to be done, as in a traditional class. The teacher and students shared a relaxed, classroom atmosphere, with intermittent periods of conversation and laughter. Interruptions by the teacher involving the whole class were kept to a minimum, but at times class assignments were checked and voluntary group question and answer sessions were held, or unit tests were written. The teacher administered paper and pencil pre-scheduled, unit tests.

Most of the students preferred to work alongside a classmate that went through the topics at about the same pace. The students would then check answers and ask questions of each other. If the student or students needed more help then they called for the teacher. Three of the Low-scoring students needed som[illegible]nce by the teacher at each session. High-scoring students 8 and 9 often compet[illegible] other for speed in completing topics and attaining high class achievement [illegible]

High-scoring student 9 often verbalized a displeasure of having to work with the computer, but enjoyed the self-paced CAI materials. This student stated "that one month of review time was saved by being able to start the Mathematics 30^{CAI} course ahead of the rest of the class". This student finished the course materials six weeks early to review for the diploma examination. This student, along with a few others, gave the CAI developers some advanced insights into improvements for the CAI. This High-scoring student 9 su[illegible]d more meaningful or simplistic explanations for topics in various sections, that [illegible] student/learner perspective. Many of these ideas were adapted by the CAI deve[illegible].

Other students had problems with the Mathematics 30^{CAI} course due to the textual content. One student had difficulty interpreting so much written material, since English was a foreign language. In a traditional class, where the teacher lectured, it was easier for them to comprehend the materials. The teacher or another student often read the screens aloud and interpreted the text when necessary. This student used spare time and noon hours to work on the Mathematics 30^{CAI} course. Another student stated a problem with remembering anything that was not self-written. This student spent most classes taking notes from the screens. Another student h[illegible] or eye sight and even with glasses had difficulty with the size of text on some screens.

Two (LS) students were not highly motivated by the computer or the Mathematics 30^{CAI} course materials. They needed teacher intervention to keep them working on task. They often wasted time socializing or using the navigation devices to jump from unit to unit. One of these students settled into working in the Mathematics 30^{CAI} course within the first month, while the other continued with this behavior for three months, before some improvement was shown with student interactions noted.

Sometimes students sat idle for long periods of time logged into the CAI. The teacher usually intervened often, to re-direct their focus or teach a topic. They seemed uninterested in both the mathematics content and the CAI method of instruction. Two of these (LS) students frequently vocalized their dislike for having to use the computers.

The High-scoring students 7, 8, and 9 often spent long periods of time interacting with the CAI, before taking a break. They seemed to take the teachers guidelines and applying them to the way they routed through the CAI course, giving themselves personal deadlines for completing the topics or units. They were time-oriented and self-directed in their pursuit of a satisfactory completion time for the Mathematics 30^{CAI} course. This was shown in the completion of most of the units that they tried. Most of the class relied on the teacher for their deadlines and to keep them on task.

For most of the High-scoring students, Unit 1 was thought of as known material for review, so many of them skipped many topics in this unit and tested themselves from the text book or in the test banks. Some of the students chose the text book and/or teacher worksheets in place of a Mathematics 30^{CAI} course unit, often to cut down on the time needed to go through the CAI.

It was interesting to note that the students found the test bank useful, even though the answers and tabulation of the scores were inaccurate. Most students' reasons for using the test banks were: "to use a non-threatening environment to pre-test or post-test their knowledge" "to get a feel for the types of questions/format that would be asked on the diploma exam" and/or "to out-smart the computer by challenging it for the correct answer". The students that used the test banks, usually continued to make use of it throughout most of the units of the Mathematics 30^{CAI} course, as shown previously in the tables.

Inter-relational Comparison

Figures 1 through 7 and a summary of this Chapter are used to report and analyze the inter-relational comparisons of the students' achievement scores, the audit trails of time-on-task and subjective feedback, and the researcher's observations. The Figures 1, 2, and 3, summarize the class achievement scores of the students from both the (RS) and (UF) classes.

As Figures 1 and 2 show, the (RS) and (UF) High-scoring students' class unit achievement score means for the group were very comparable across all the Units with the (RS) students scoring slightly higher in Units 5 and 6. All the Unit means for both (RS) and (UF) High-scoring students were above 80%. The (RS) and (UF) Low-scoring students' class achievement score means for the group were comparable on Units 2 and 6. One Low-scoring student in each class brought the means down for (RS) students' Unit 3 and (UF) students' Unit 5. All other means for both (RS) and (UF) Low-scoring students were close to or above 50%.

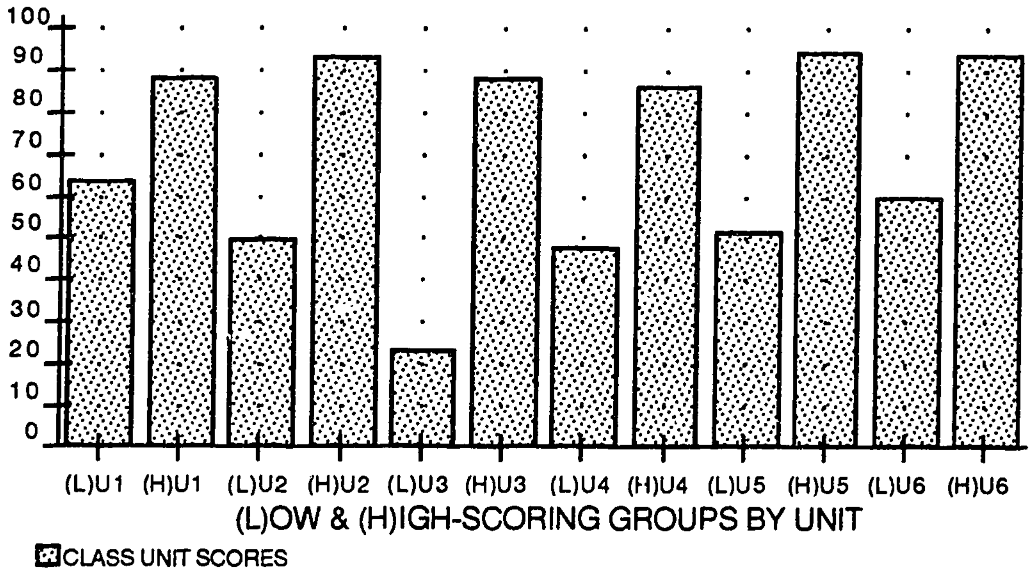
As Figures 2 and 3 show, the (UF) High-scoring students diploma unit achievement score means for the group were the same or higher across all the Units with the exception of Unit 2, which was 25% lower. The opposite was true for the (UF) Low-scoring students, where the diploma unit achievement score means for the group were the from 5% to 30% lower across all the Units with the exception of Unit 6, which was the same.

The minutes for the time-on-task per unit are shown In Figure 4, using the Alberta Education's guidelines. The Alberta Education ranking of time-on-task from most to least by unit would be Unit 4, 5, 3, 6, and 1 or 2.

In Figure 5, the sum for time-on-task for each of the (UF) Low-scoring, (UF) High-scoring student groups are compared with Alberta Education total time. These sums included the (UF) Low and High-scoring time-on-task. Both the (UF) Low and (High-scoring group means were comparable to each other, but were less than 30% of the Alberta

FIGURE 1

(RS) Low and High-scoring Students' Class Achievement Scores' Means in Percent by Unit.



(UF) Low and High-scoring Students' Class Achievement Scores' Means in Percent by Unit.

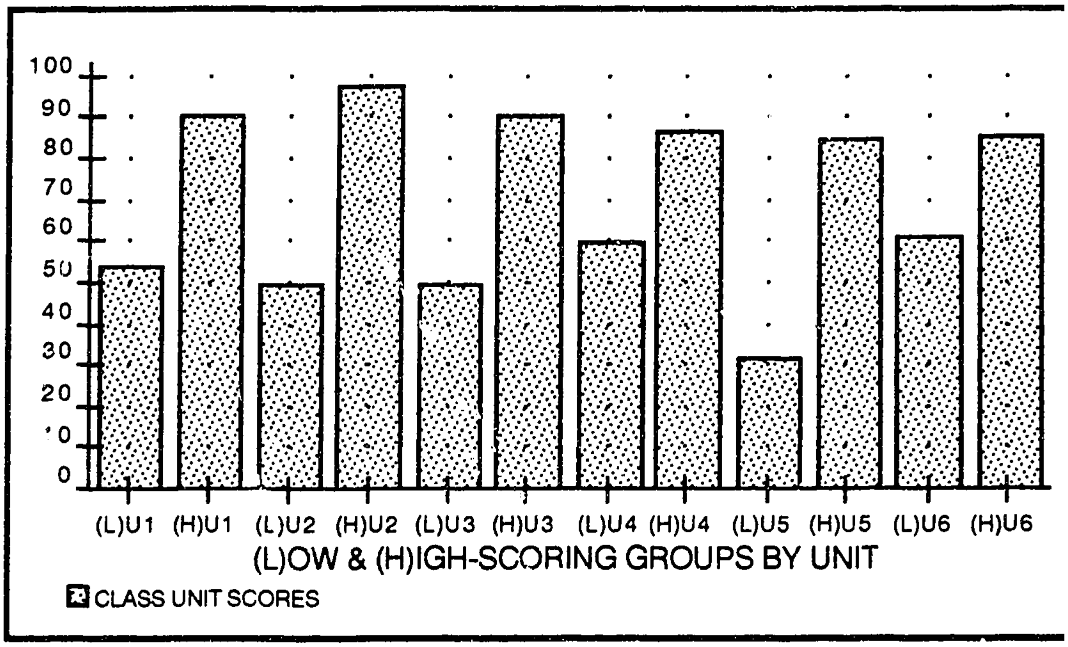


FIGURE 3

(UF) Low and High-scoring Students' Diploma ExaminationScores' Means in Percent by Unit.

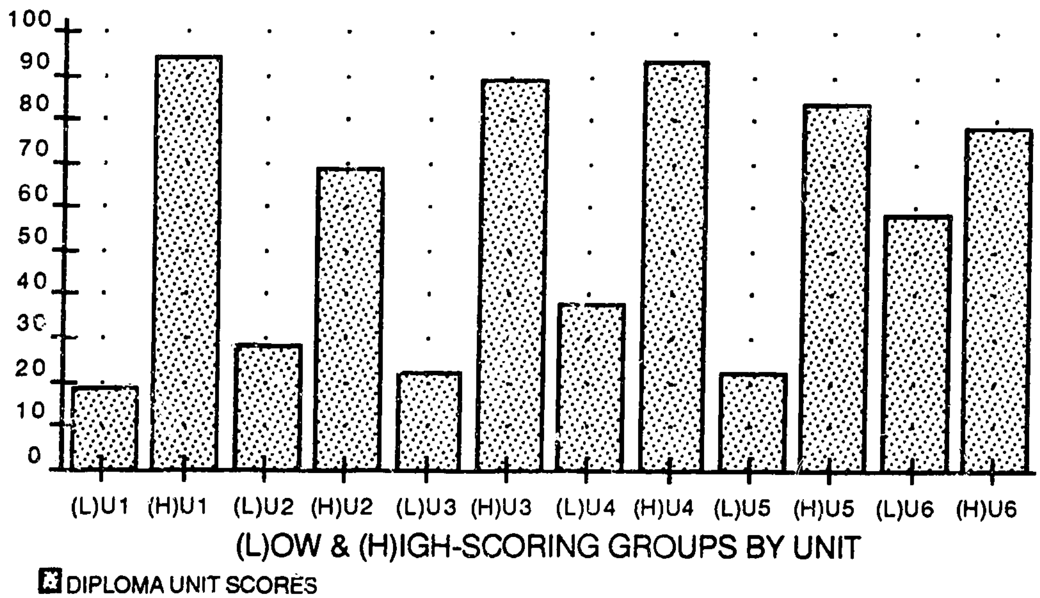


FIGURE 4

<u>Alberta Education Minutes of Time-on-Task per Unit.</u>

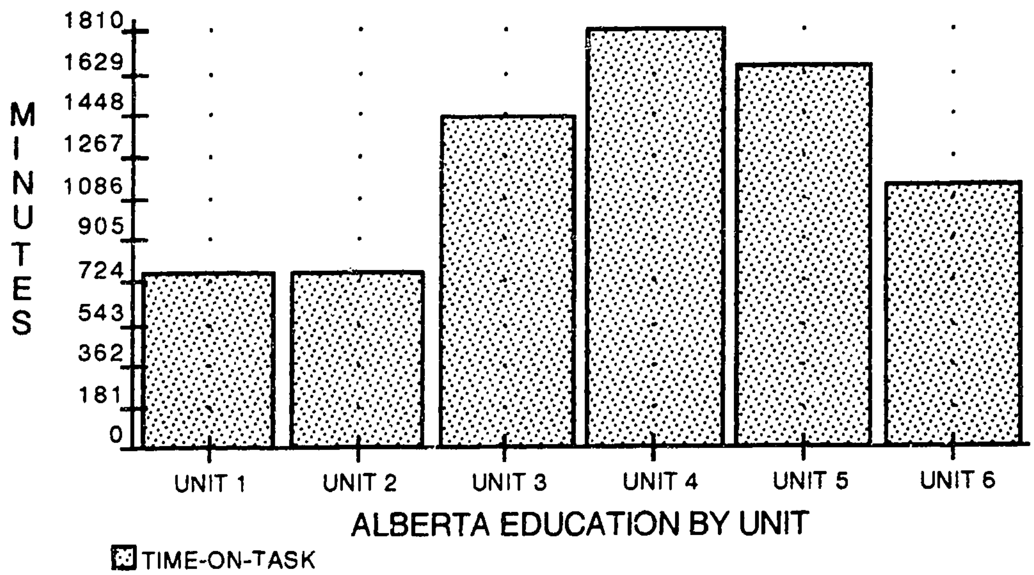


FIGURE 5

Time-on-Task: (UF) Low and High-scoring Students Compared to Alberta Education.

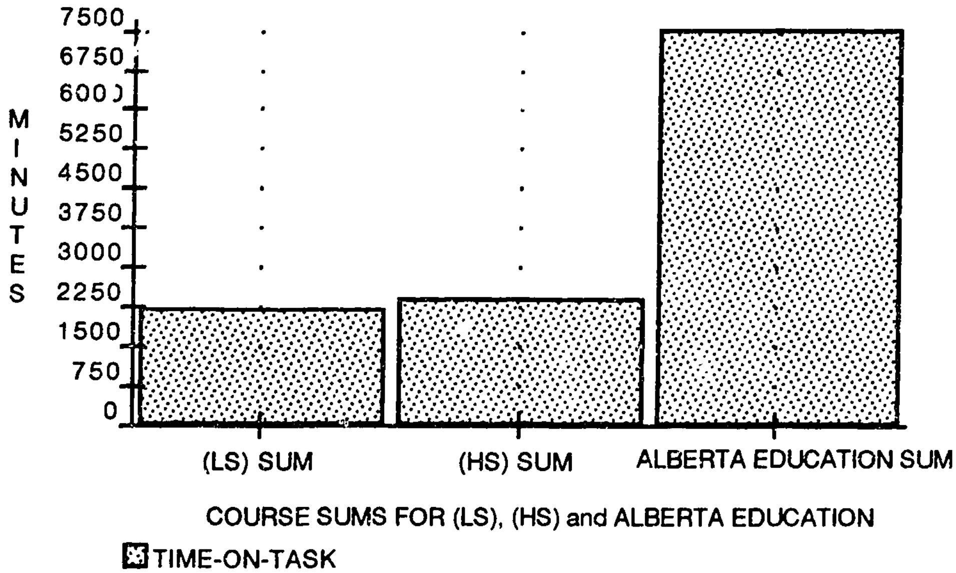


FIGURE 6

Time-on-Task: (UF) Low-scoring Students Compared to (UF) High-scoring Students by Unit.

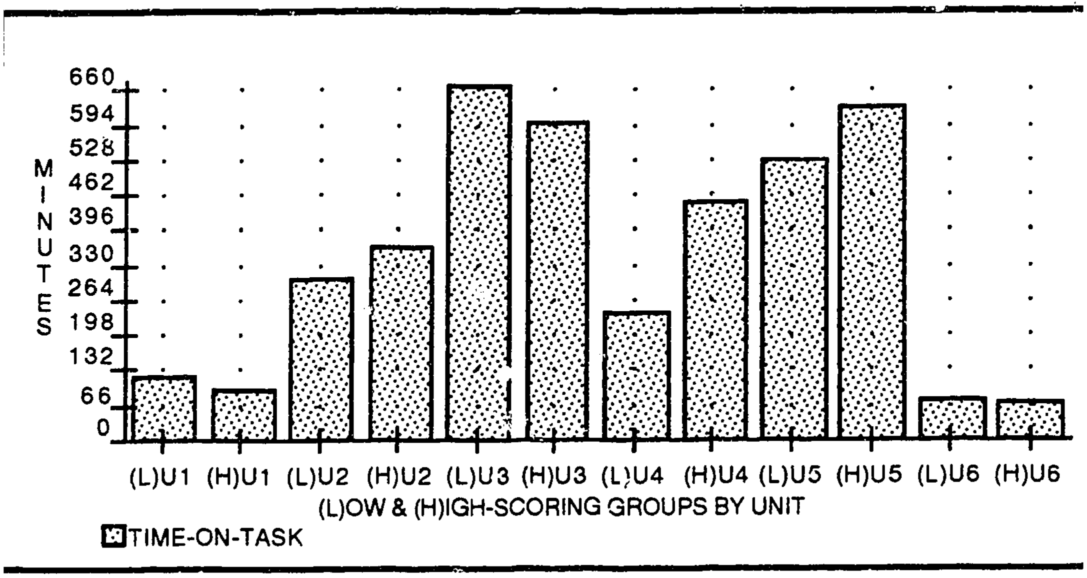
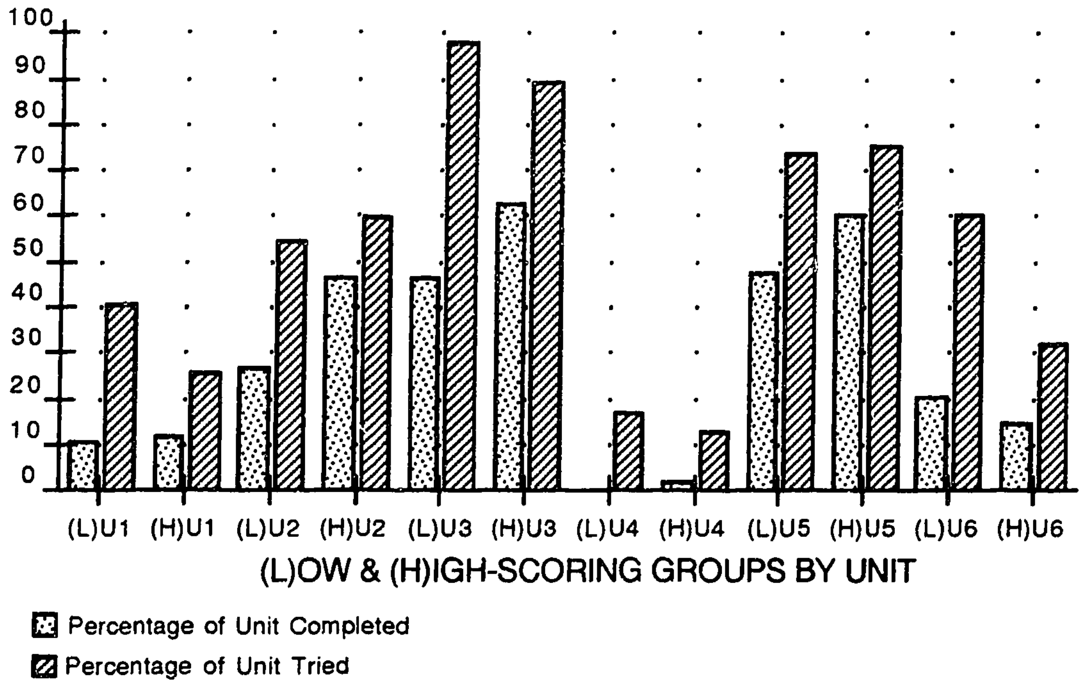


FIGURE 7

Percentage of Completed and Tried Units for (UF) Low-scoring Students Compared to (UF) High-scoring Students by Unit.



Education guidelines. This meant that more than 70% of the time for (LS) and (HS) groups was spent in other classroom activities.

Both the (UF) Low and High-scoring groups spent comparable minutes of time-on-task by unit with the exception of Unit 4, as shown in Figure 6. In Units 1, 3, and 6 (LS) students spent slightly more time. The ranking of time-on-task as compared with Alberta Education, as shown in Figure 4, should have the (LS) and (HS) students spending more time-on-task in Units 4 and 6 and more comparable time-on-task between Units 1 and 2. Students spent more time than was shown on Unit 4.

In Figure 7, the percentages for completed and tried units are shown for (LS) and (HS) students. With the exception of Unit 5, (LS) students tried more than 50% more than they completed in unit percentages. (HS) students completed between 50% and 75% of all units that they tried, with the exception of Unit 1 and 4. Units 2 and 5 were the highest completion rate for both (LS) and (HS) students.

When comparing the class unit scores, in Figure 2, with the time-on-task, in Figure 6, the (HS) students highest scores were only marginally higher in Units 2, 5 and 6. The time-on-task was spent mainly in Units 3, 5 and 4, but the completion rate, as shown in Figure 7, was highest in Units 2, 5 and 3 for the (HS) students.

For the (LS) students, the highest class scores were in Units 1 and 6, with the lowest time-on-task spent in Units 1 and 6 and the lowest completion rate in Units 1, 4, and 6, as shown in Figures 2, 6, and 7.

The diploma examination unit scores, as shown in Figure 3, showed the (HS) students scoring marginally higher in Units 1, 4, and 3, and lowest in Unit 2. These scores differed from the time-on-task, completion rate and class unit scores in Figures 6, 7, and 2.

The (LS) students scored the lowest on Units 1, 3, and 5 on the diploma examination and highest on Unit 6 and 4. One of the highest students' class marks was for Unit 6, but the least time was spent and lowest completion rates were in Units 6 and 1.

The (UF) Low and High-scoring students' feedback was mainly received through the audit trails during Unit 4. At least two of the five, (LS) students did not like working with the computers or the CAI initially.

The researcher observed the (UF) students relying mainly on the teacher for the initial Units 4 and 1. All but two of the (HS) students were rushed into completing Unit 6 at the end of the CAI course, therefore they used more traditional teacher instruction at this time. Most of the (UF) students needed their time-on-task to be directed by the teacher, so the teacher set deadlines and other directional guidelines, as to what topics to focus on or to miss if rushed for time. This may have been the reason for the (LS) students high percentage of trial in the units with a low percentage of completion. They could have been sampling or over-viewing some of the units.

Summary

Both the Rural Semestered (RS) and the Urban Full-year (UF) CAI students' class means were higher than the Alberta diploma examination average by 4.1% and 6.5% on two different diploma examinations. The (RS) students wrote the January 1991 diploma examination and the (UF) students wrote the June 1991 diploma examination. This seemed to support previous studies in that CAI improved achievement scores. However, not all students achieved high scores on the diploma exam. In fact, in the (RS) class, three students scored below 40% and three scored above 80% out of twenty students completing the Mathematics 30*CAI* course. In the (UF) class, five students got below 40% and ten achieved above 80% out of twenty-three students.

The (RS) and (UF) students' class achievement scores were comprised of the teacher-administered assignments and tests per unit. There were no standardized examinations to compare the two classes. The diploma examinations were different examinations written either in January or June of 1991 and could not be used for comparison. The (UF) Low and High-scoring students spent the least amount of time-on-task in the Mathematics 30^{CAI} course, in Units 6, 1, and 2, as shown in Figure 6, but received achievement scores that were consistent with the other units, as shown in Figure 2. In Figure 4, the assumed Alberta Education guidelines used for estimating time-on-task by unit did not correspond with the (UF) Low and High-scoring students actual time-on-task, as shown in Figure 3.

The (UF) students total time-on-task in the CAI course, showed that neither the Low-scoring nor the High-scoring students spent more than 2250 out of 7500 minutes in the Mathematics 30^{CAI} course, as shown in Figure 5. This meant that even though the intention of the course was for the students to interact mainly with the CAI during class time, this was not the case. Some students that spend little or no time on the Mathematics 30^{CAI} course used other resources i.e., the textbook, other students, the teacher or other unknown resources to achieve their unit mark. The students that scored highest on the units did not spend the most time-on-task or complete the most units. The (LS) and (HS) students spent similar time per icon. One could also conclude that the students' achievement scores could not be attributed either positively or negatively, solely to the Mathematics 30^{CAI} course.

In Figure 7, the (UF) High-scoring students completed the same number of units or slightly above the Low-scoring students in all units except Unit 6. The (UF) Low-scoring students tried approximately the same or slightly more of the units, than the High-scoring students with the exception of Unit 2. These completion rates by unit in Figure 7, seemed to have no bearing on the achievement scores by either the (LS) or (HS) students, as shown in Figure 2.

The subjective feedback in Tables 28 through 32 contained mainly comments of a correctional nature, with a number of suggestions and a few negative comments from three students. This may have affected the students' Unit 4 achievement scores or time-on-task, but owing to the incompleteness of the audit trails, the data was inconclusive.

The researcher's observation of the (UF) class seemed to be useful in gaining further insights into the human-computer interactions in the CAI environment as a whole. The observation helped to detect problem areas in the Mathematics 30^{CAI} course and to suggest strategies throughout the formative evaluation process.

In Chapter 5 the conclusions, strategies, and suggestions for further research are stated.

CHAPTER V: CONCLUSION

Overview

The purpose of this study was to develop strategies for improving the Mathematics 30^{CAI} course. This Chapter summarizes the study, states conclusions, and provides suggestions for further research. An over-view for both Rural, Semestered (RS) and Urban, Full-year (UF) students are given for the students' achievement scores. Strategies are stated for the (UF) students' audit trails of time-on-task, unit completion, and subjective feedback. The researcher's observation of the (UF) class are noted.

(RS) and (UF) Students' Achievement Scores

There were no standardized topic or unit examinations in the CAI course that could compare the (RS) and (UF) students' class achievement scores. The same Alberta standardized diploma examination was not written by all the (RS) and (UF) students, therefore could not be used for comparison. This confounded the variables. A strategy for improving the CAI course is be to incorporate standardized topic and unit tests into the CAI course. Further research could then make use of valid students' achievement score comparisons.

(UF) Students' Audit Trails:

Time-on-Task. In the Urban Full-year (UF) class, most students spent a portion of every class on the CAI course. If the students spent the total 125 hours, the time-on-task results showed that it would have been impossible to complete all topics and units in the Mathematics 30^{CAI} course. This was based on the analysis between the mean time-on-tasks percentages for Low and High-scoring students and the comparison to their percentages of units completed. For both the (RS) and (UF) students, some optional out-of-class time was available to use the CAI course in the classroom. Some students could use the time available others were unable to use this time. A strategy for the improvement of the CAI is to make the CAI course more accessible to the students in regards to time and location. The technological advances and the availability of personal computers in the home make it feasible for the CAI to be given to every student on CD ROM to use at home and at school. Further research could be used to explore whether given the time and availability the students would complete the Mathematics 30^{CAI} course.

The (UF) Low and High-scoring students' time-on-task results showed that less than one-third of the students' 7500 minutes of class time were spent on the Mathematics 30^{CAI} course. The students chose to make use of the other human and textbook resources available to them as well. If the objective of the Mathematics 30^{CAI} course was for the students and teachers to use the CAI as an integral part of the classroom environment, then the CAI seemed to have served its purpose. If the CAI course sought other objectives, then further research could be used to seek alternative solutions for the improvement of the Mathematics 30^{CAI} course.

All the (UF) students used the unit test banks to some degree, even though they were incomplete and under revision. Most of the students suggested that non-judgmental, topic and unit test banks were useful feedback tools to access knowledge and apply towards a course of action. The time spent in the test banks sometimes clarified areas for review or omission. The teacher suggested that topic and unit test banks in the CAI program would solve many of the problems involved with teacher-written and administered student achievement tests. The CAI test banks could contain multiple, standardized tests that the student could write or rewrite when prepared. For example, the more current version of the Mathematics 30^{CAI} course increases the number of questions in the test bank by randomizing values and inserting them into common equations or formulas. A strategy for the improvement of the CAI is to incorporate a dual test bank system; one for student use and another for teacher use for accessing the students' performance. Further testing and research would be required after the incorporation of any test bank system into the Mathematics 30^{CAI} course.

This was the (RS) and (UF) students first exposure to any course totally on CAI. Alberta Education in conjunction with British Columbia, Saskatchewan, Manitoba and the Canadian federal government started working together in 1991 to develop all the mathematics courses from grade 9 through grade 12 on computer. One of the advantages to having all the courses available on computer would be the continuity from year to year and teacher to teacher of the content and presentation of the curriculum. The benefits that these students and teachers suggested was the learning continuum would not necessarily be grade or time-based. A strategy for the improvement of the CAI course is to merge multiple levels of the mathematics curriculum into the CAI materials. Further research could be used to explore the feasibility and success of this kind of CAI curricular expansion.

If a multiple leveled mathematics CAI course was used from inception with students, would a time factor be important or just the mastery of the content? There is considerable speculation in the literature that is currently addressing this question, but this study will not address this topic other than stating the findings that this version of the CAI course did not contain extensive competency testing. The CAI interactions were composed of mainly trial and error answers given to move ahead to the next screen. A strategy for improving the CAI is to incorporate some competency testing to allow the student to spend appropriate amounts of time to master the CAI materials. The competency testing and mastery learning research is plentiful and would have to be analyzed and applied for inclusion into the Mathematics 30^{CAI} course.

Time-on-Task: Percentage of Units Tried and Completed The (UF) Low-scoring and High-scoring students tended to spend about the same amount of time-on-task, both by interaction and unit, as shown in the Tables 12 through 27 in Chapter IV. However, the quality of interaction throughout the CAI, as shown in the original audit trails displayed mainly "return" or "enter" keystrokes. Two of the (LS) students tended to navigate haphazardly in and out of a topic or unit, rarely completing a topic. They were more easily distracted and tended to spend less productive time on the computer, often sitting in front of the same screen of the tutorial seemingly without absorption or interest. A strategy for the improvement of the CAI is to incorporate more meaningful interactions intermittently throughout the CAI course. This would test student comprehension and may keep the student motivated. Further research would be used to balance the students' time-on-task with their comprehension and motivation of the interactions.

The teacher often intervened to set-up a time-line for the completion of a topic or unit, or to do small group review without the computers, to minimize instruction time. One strategy is to have a course completion timeline by topic or unit built into the CAI course. It would be a time-based guide for the students. It could project completion time for the topics or units based on current, cumulative time-on-task. This may motivate the students to complete more of the materials in a shorter period of time. Further research would be used to explore and test the possibilities.

Subjective Feedback. The (UF) students made two things apparent: one, they wanted the flexibility to navigate freely within the CAI, and two, they didn't want to use the mathematics curricular time learning how to use the computer. A variety of navigation tools were tried, with the final construction being a small vertical bar displayed on each screen. This navigation bar showed the student's location and showed screens previously viewed in the topic. A pointer resided on the side of the bar to be manipulated by the student for relocation in the topic. The navigation bar was both easy to use and useful as a student's guide to monitor their position. A strategy is to continue to use a visual navigation guide for the student to orient and route themselves freely within the CAI course.

At the beginning of this study, the (RS) and (UF) students had to acquire some computer expertise before using the CAI course. They had to learn to start up their computers, do some keyboarding, use computer diskettes, and copy files from diskette to a hard drive. For most (UF) students, with no previous computer experience, this proved frustrating. In January of 1991, the audit trails were automated to write to the CAI program and the (UF) students no longer copied files or used diskettes, thereby reducing the computer expertise required. The CAI program had included pull-down menus and fast-key commands for ease of use inside the CAI course. The use of simplistic screens, so that visibility of options were apparent, such as the navigation bar and pull-down menus, were useful in making the CAI course more "user-friendly". A strategy for improving the CAI is to continue to reduce the amount of computer expertise required to use the CAI course. The advances in computer technology has widened the realm of possibilities, for example; a speech-activated CAI course may be common place in the future. Further research could explore the variety of possibilities.

The (UF) students' subjective feedback, although not intended for any other use than allowing for the students to type comments, became a vehicle to communicate CAI problems and opinions back to the teacher and the CAI developers. The comments got fewer and farther in between after the initial startup problems were resolved. The students' and teachers' subjective feedback was an important tool to help with proof-reading of the multiple-routing CAI course. The more people to access the course the greater the opportunity of finding and correcting typographical errors. A strategy for the improvement of the CAI subjective feedback component is to find a more efficient way to organize, collect and forward to the CAI developers useful components of the subjective feedback. The subjective feedback did not discriminate enough to lead to specific strategies to improve the CAI course. A strategy for the improvement of the CAI may be to incorporate more measurability into the subjective feedback, i.e. rating scales interspersed throughout the topics of the CAI course.

The students stopped typing in subjective feedback, after the initial Unit 4 problems, even though the CAI developers and the teacher encouraged it. The students suggested that there may be some personal advantage to using the subjective feedback component with modifications. If the students placed "bookmarks" or typed in comments at problematic or notable areas in the CAI course that could be summarized and viewed as a study guide for the students, this could be a useful resource. A suggested strategy would be to incorporate an individualized study guide composed of a student's summarized subjective feedback.

Some of the student's negative comments and lack of time-on-task may have reflected the thought that the Mathematics 30^{CAI} course might not be an excepted form of instruction for everyone. A strategy to improve the CAI course may be to tailor the CAI course towards a specific population of students, i.e. high-achievers. However, further research may reveal other variables for the successes or failures of various components in the CAI course.

Researcher's (UF) Class Observation

Four out of the five (UF) Low-scoring students, by the researchers observation, relied heavily either on the teacher, the text book or other students for direction and answers. The teacher would intervene to give an alternate explanation, if the student was having difficulty comprehending the CAI materials. Peer tutoring and discussion was continuous throughout the Mathematics 30^{CAI} course. The dialogue between the (LS) students and teacher seemed to be needed for two main reasons; to get the student back on task and/or to explain or summarize a topic. This led the researcher to believe that a strategy to improve the CAI course is to vary the delivery method of the program to allow for student differences. Another strategy would be to supply more remedial materials for the low-achievers. Further studies may analyze more closely the effect of the individual differences of the student to interacting with the Mathematics 30^{CAI} course.

The Mathematics 30^{CAI} course had mostly textual screen displays. Some students appeared to have difficulties in understanding the textual explanations and the addition of sequential graphs, pictures and tables helped considerably over the textual displays alone. In May of 1991, the Mathematics 30^{CAI} course included samples of computer verbal feedback and animated graphic screens. The students seemed motivated by the diversity, but the computer speed became so unbearably slow, that the students started to bypass these sections after viewing them once. A strategy is to implement multimedia into the CAI course, as appropriate to the current computer technological advances. Continual research will be needed to support the testing and incorporation of multimedia in the CAI course.

As observed by the researcher, the nine (UF) students above 80% seemed to be self-directed and selective in what topics or units they spent their time on. They tended to use the test banks more to test their knowledge before starting another topic. If they thought they knew the materials sufficiently they would skip over the topics or the units. They spent more of their time with new or difficult materials, approaching the CAI materials in a linear manner. The (HS) students tended to interact with other students to challenge the content of the CAI, text book or even the teacher. Two of these students finished the course ahead of schedule by a month or more. One of these two students appreciated not having to waste time with class review for a month at the beginning of the course waiting for the other students to catch-up. This (HS) student scored 100% on the June 1991 Diploma Examination. The lock-step or "computer-controlled" method proved frustrating for these students and with their help the navigational devices were programmed and incorporated into the CAI switching the emphasis to "student-controlled". A strategy is to continue to include navigational devices to allow varied routing for students through the CAI course. Research into "student-controlled" versus "computer-controlled" have, as discussed in Chapter 2, positively affected attitude but negatively affected low-achievers' achievement scores, so further research could be used to discover if a balance could be incorporated.

The researcher observed students with varied learning styles and handicaps. One student had to take notes continuously in order to retain her knowledge of the subject matter. One student, who spoke English as a second language, needed help from the teacher or another student to interpret the screens. A strategy is to incorporate multi-sensory approaches into the CAI course.

The original number of students involved in this study dropped from forty-nine to forty-three early in the study, it was beyond the scope of this study to analyze in detail any hidden agendas that the students may have had for quitting the CAI course. All their reasons seemed valid, as stated in Chapter 1. Future studies may show individual preferences to a specific method of instruction, which means they may have chosen the traditional class over the CAI class. The researcher observed the students that were placed in the Mathematics 30^{CAI} (UF) class as they showed up to class on the first day. Many were anxious about taking mathematics on the computer, without previous computer experience. Others were anxious about being involved in a pilot study that they felt might waste valuable time and resources, when it resulted in a grade 12 course mark, consisting of class marks and a provincial standardized diploma examination. Two clichés the researcher heard that day were: "Can't teach an old dog new tricks" and "Why do I have to be the 'guinea pig'?". They were concerned about an experimental course at the grade 12 level that most of the students needed to attain credits towards their graduation by June of 1991.

Over half of the (UF) students finishing the CAI course in June of 1991 recommended the Mathematics 30^{CAI} class over the traditional Mathematics 30 class. The (UF) school used the newer versions of the Mathematics 30^{CAI} course during the next two years for two more (UF) CAI classes.

Conclusions

The researcher has suggested the following strategies for the improvement of CAI. A strategy for the improvement of Mathematics 30^{CAI} course is:

- to incorporate standardized topic and unit tests into the CAI course.

- to make the CAI course more accessible to the students in regards to time and location.
- to incorporate a dual test bank system; one for student use and another for teacher use for accessing students' performance.
- to merge multiple levels of the mathematics curriculum into the CAI materials.
- to incorporate some competency testing to allow the student to spend appropriate amounts of time to master the CAI materials.
- to incorporate more meaningful interactions intermittently throughout the CAI course.
- to have a course completion timeline by topic or unit built into the CAI course.
- to continue to use a visual navigation guide for the student to orient and route themselves freely within the CAI course.
- to continue to reduce the amount of computer expertise required to use the CAI course.
- to find a more efficient way to organize, collect and forward to the CAI developers useful correctional components of the subjective feedback.
- to incorporate more measurability into the subjective feedback.
- to incorporate an individualized study guide composed of a student's summarized subjective feedback.
- to tailor the CAI course towards a specific population of students.
- to vary the delivery method of the program to allow for student differences.
- to supply more remedial materials for the low-achievers.
- to implement multimedia into the CAI course, as appropriate to the current computer technological advances.
- to continue to include navigational devices to allow varied routing for students through the CAI course.
- to incorporate multi-sensory approaches into the CAI course.

In conclusion, this study has revealed more questions than it has answered. The researcher's choice of two heterogeneous groups of students at the start of the study, ended with groups that could not be compared. The variables chosen did not always support drawing meaningful conclusions. Some variables chosen turned out to be confounded. This study examined more administrative-type strategies than instructional-type strategies. The instructional strategies may be more useful in improving a CAI course. At the beginning of future studies more questions should be addressed, so that important variables are not overlooked and that the data can provide more conclusive results. Given the knowledge gained by the researcher from this study, the following questions may suggest other variables or more information that could be used to devise instructional strategies:

1. What are the CAI objectives and the expected outcome of the students interacting with the CAI course?
2. Are all members of the group expected to achieve a certain mastery level?
3. What is the introductory level of the students' knowledge as shown by previous marks, competency test, or pre-test?
4. What other information about the student is needed?
5. What data is required of the students' audit trails or performance recordings?
6. Where do the students receive instruction, i.e. from peers, teachers, tutors or parents?
7. How do the students spend their subject area time in class and at home?
8. What type of subjective feedback would be useful, i.e. topic ratings, lists of positive versus negative or opinion questionnaires?
9. What unit observation would be more beneficial; the group or the individual?
10. What type of group should be studied; i.e. homogeneous or heterogeneous?

The researcher must decide which of these factors or combination are most important for their study. These suggestions are to be used as guidelines for future researchers to gain further insights into instructional strategies by focusing on a few variables in a number of in-depth studies.

REFERENCES

Akbari-Zarin, Mansour & Gray, Mary W. (1990). Computer Assisted Instruction and Critical Thinking. Journal of Computers in Mathematics and Science Teaching, 9(4), 71-78.

Alberta Correspondence School Curriculum Support Branch. (1988). Distance Learning Project North. Alberta: Alberta Education. Edmonton, Alberta.

Alberta Education. (1990). Mathematics 30. Distance Learning - Alberta Education: Alberta Education. Edmonton, Alberta.

Alberta Education. (1990). Mathematics 30 - Learning Facilitator's Manual. Distance Learning - Alberta Education: Alberta Education. Edmonton, Alberta.

Alderman, D. L., Appel, L. R., & Murphy, R. T. (1978). PLATO and TICCIT: An Evaluation of CAI in the Community College. Educational Technology (April), pp. 40-45.

American Association of School Administrators. (1982). Time on Task. Arlington, VA.: Publications Fulfillment, AASA.

Authorware. (1990). Authorware - Working Model. Minneapolis, MN: Authorware, Inc.

Avner, R. A., (1981). Update of PLATO-Based Physics Teaching. (Unpublished data). Urbana: University of Illinois.

Bangert-Drowns, Robert L., Kulik, James A. & Kulik, Chen-Lin C. (1985). Effectiveness of Computer-Based Education in Secondary Schools. Journal of Computer-Based Instruction, 12(3), 59-68.

Barnes, Judith M. (1990). A Formative Evaluation of a Mathematics CAI Unit. DISSERTN: Thesis (M. Ed.)--University of Alberta.

Boyd-Barrett, Oliver & Scanlon, Eileen. (1991). Computers and Learning. Wokingham, England: Addison-Wesley Publishing Company.

Carroll, John B. (1963). A Model of School Learning. Teachers College Record, 64, 33-38.

Dalton, David W., Hannafin, Michael J. & Hooper, Simon. (1989). Effects of Individual and Cooperative Computer-Assisted Instruction on Student Performance and Attitudes. Educational Technology Research and Development 37(2), 15-24.

Dick, Walter & Carey, Lou. (1985). The Systematic Design of Instruction - Second Edition. Glenview, Ill.: Scott, Foresman and Company.

Dinkheller, Ann, Gaffney, James & Vockell, Edward. (1989). The Computer in the Mathematics Curriculum. Santa Cruz, California: Mitchell Publishing, Inc..

Ediger, Marlow. (1989). Microcomputers in the Mathematics Curriculum. Journal of Computers in Mathematics and Science Teaching 9(1), 45-50.

Englert, Thomas James, Ph.D. (1972). A Comparitive Study of the Effects on Achievement and Changes in Attitude of Senior High School Students Enrolled in First Year Algebra Under Two Different Teaching Approaches. Dissertation Abstracts International A - Humanities and Social Sciences 33(1972-73), 1076-77.

Fabricant, Mona. (1986). Using Mathematical Software - Enrichment or Restriction? Teaching Mathematics: Strategies That Work. Portsmouth, NH: Heinemann Educational Books, Inc.

Flagg, Barbara N. (1990). Formative Evaluation for Educational Technologies. Hillsdale, New Jersey: Lawrence Erlbaum Associates, Inc., Publishers.

Gagne, R. M., Briggs, L. J., & Wager, W. W. (1988). Principles of instructional design (3rd ed.). New York: Holt, Rinehart and Winston.

Giacquinta, Joseph B., Bauer, Jo anne, & Levin, Jane E. (1993). Beyond Technology's Promise. New York, NY: Cambridge University Press.

Hasselerharm, E. & Leemkuil, H. (1988) The Relation between Instructional Control Strategies and Performance and Attitudes in Computer-Based Instruction. Enschede: Twente University.

Hawkins, R. P., Bosworth, K., Chewning, B., Day, & Gustafson, D. H. (1985). Adolescents' use of computer-based health information. In M. Chen & W. Paisley (Eds.), Children and computers. Beverly Hills, CA: Sage. 228-245.

Heiman, Marcia, Narode, Ronald, Slomianko, Joshua, & Lochhead, Jack. (1987). Teaching Thinking Skills: Mathematics. Washington, D.C.: National Education Association of the United States.

Johnson, Kerry A. & Foa, Lin J. (1989). Instructional Design - New Alternatives for Effective Education and Training. New York, N.Y.: Macmillan Publishing Company.

Kysilka, Marcella L. (1990). Product or process: what is effective learning? Effective Learning Into a New ERA. London, Great Britain: Jessica Kingsley Publishers Ltd.

Larkin, Jill H. & Chabay, Ruth W. (1992). Computer-assisted Instrucion and Intelligent Tutoring Systems: Shared Goals and Complementary Approaches. Hillsdale, New Jersey: Lawrence Erlbaum Associates, Inc., Publishers.

Lee, Ann Louise Moore, Ph.D. (1973). A Comparison of Computer-Assisted Instruction and Traditional Laboratory Instruction in an Undergraduate Geology Course. Dissertation Abstracts International A - Humanities and Social Sciences 34(1973-74), 2073-74.

Levin, Tamar & Long, Ruth. (1981). Effective Instruction. Alexandria, Virginia: Association for Supervision and Curriculum Development.

Liedtke, Werner Walter. (1970). Mathematics Learning and Pupil Characteristics. DISSERTN: Thesis (Ph. D.)--University of Alberta.

McGivney, Raymond J. Jr. (1990). Experiences Teaching a Software Aided Mathematics Course for a General University Audience. Journal of Computers in Mathematics and Science Teaching 10(1), 49-57.

McMahon, Albert Joseph, Jr., Ph.D. (1979). The Relationship Between the Pupil Control Ideology of Mathematics Teachers and Student Attitude Toward Mathematics. Dissertation Abstracts International A - Humanities and Social Sciences 40(1979-80), 2524-25.

McNichols, Joan. (1986). Manipulative Materials Make the Difference. Teaching Mathematics: Strategies That Work. Portsmouth, NH: Heinemann Educational Books, Inc.

Mis, Frederick W. (1990). Computer-Assisted Instruction. The New Learning and Telecommunications Technologies - Their Potential Applications In Education. Springfield, Ill.: Charles C Thomas. 71-85.

Munby, Stephen. (1990). Assessing, recording and reporting achievement - after the Education Reform Act. Effective Learning Into a New ERA. London, Great Britain: Jessica Kingsley Publishers Ltd.

Murray, Mark A. (1990). The Role of Technology in Distance Education. DISSERTN: Thesis (M. Ed.)--University of Alberta.

Nickerson, Raymond S. & Philip P. Zodhiates. (1988). Technology in Education: Looking Toward 2020. Hillsdale, N.J.: Lawrence Erlbaum Associates, Publishers.

Papert, Seymour (1993). The Children's Machine. New York, NY: Harper Collins Publishers.

Pieters, J. M., Simons, P. R. J. & Leeuw, L. de. (1990). Research on Computer-Based Instruction. Amsterdam, Holland: Swets & Zeitlinger B. V., Amsterdam/Lisse.

Rieber, Lloyd P. (1994). Computers, Graphics, & Learning. Dubuque, Iowa: Wm. C. Brown Communications, Inc..

Research Advisory Committee of the National Council of Teachers of Mathematics. (1990). Mathematics Education Reform and Mathematics Education Research: Opportunities, Obstacles, and Obligations. Journal for Research in Mathematics Education 21(4), 287-292.

Scheirer, Elinor A. (1990). The triangular relationship of the teacher, knowledge, and the child: accountability in action. Effective Learning Into a New ERA. London, Great Britain: Jessica Kingsley Publishers Ltd.

Shirey, John Reginald, Ph.D. (1976). The Effects of Computer-Augmented Instruction on Students' Achievement and Attitudes. Dissertation Abstracts International A - Humanities and Social Sciences 37(1976-77), 3386-87.

Shlechter, Theodore M. (1991). Problems and Promises of Computer-Based Training. Norwood, NJ: Ablex Publishing Corporation.

Sovik, Nils, Eikeland, Hans Magne, & Lysne Anders. (1981). On Individualized Instruction - Theories and Research. Oslo, Norway: Nye Intertrykk as, Lommedalen.

Steinberg, Esther R. (1991). Computer-assisted Instruction - A Synthesis of Theory, Practice, and Technology. Hillsdale, New Jersey: Lawrence Erlbaum Associates, Inc., Publishers.

Taylor, Fitz J. (1981). The Index-of-Learning Difficulty (ILD) Paradigm as Theory for Research on Individualization of Instruction. On Individualized Instruction - Theories and Research. Oslo, Norway: Nye Intertrykk as, Lommedalen.

Tschofen, Yvonne. (1973). The Mathematizing Mode Re-examined. DISSERTN: Thesis (M. Ed.)--University of Alberta.

Walker, Decker F. & Hess, Robert D. (1984). Instrucional Software - Principles and Perspectives for Design and Use.Belmont, California: Wadsworth, Inc..

Wang, Margaret C., Haertel, Geneva D. & Walberg, Herbert J. (1990). What Influences Learning? A Content Analysis of Review Literature. Journal of Educational Research, (84)1, 30-40.

Williams, Carol J. & Brown, Scott W. (1990). A Review of the Research Issues in the Use of Computer-Related Technologies for Instruction: An Agenda for Research. International Journal of Instructional Media 17(2), 95-106.

Wyles, B. (1984). The Myth: Computer-Assisted Instruction (CAI) Translates Qualitative Skills and Demands that the Humanists Among Us Become "Technocrats.". Paper presented at the meeting of the American Association of Community and Junior Colleges.

Appendix:

TABLE 33

Engagement Rate Form

ENGAGEMENT RATE FORM

Observation 1 2 3 4 5 6 TIME Actual Time Observed	TOTAL	ENGAGEMENT RATE
ASSIGNED		ENGAGED ASSIGNED
MANAGEMENT/ TRANSITION		
SOCIALIZING		
DISCIPLINE		
UNOCCUPIED/ OBSERVING		
OUT OF ROOM		
TOTAL UNENGAGED		
ENGAGED		

Source: Research for Better Schools, Inc.
(American Association of School Administrators, p. 69).

TABLE 34

Allocated Time Log

ALLOCATED TIME LOG

State ________
District ______
School ________
Teacher _______
State # _______
District # ____
School # ______
Teacher # _____
Date __________
Grade _________
No. of Students
Present _______

	(A) Activity	(B) Beginning Time	(C) Ending Time (B)-(A)	Time in Minutes
1				
2				
3				
4				
5				
6				
			TOTAL______	

Source: Research for Better Schools, Inc.
(American Association of School Administrators, p. 70).