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UNIVERSITY OF ALBERTA

A FORMATIVE EVALUATION OF A MATHEMATICS CAI UNIT

by

Judith M. Barnes

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 PSYCHOLOGY

EDMONTON, ALBERTA

FALL, 1990

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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 acceptance, a thesis entitled A Formative Evaluation of a Mathematics CAI Unit submitted by Judith M. Barnes in partial fulfillment of the requirements for the degree of Master of Education.

Dr. Gene Romaniuk

Dr. Milt Petruk

Dr. Len Stewin

Dr. Roger Palmer

Date August 31, 1990

Abstract

The purpose of this study was to conduct a formative evaluation of computer assisted instruction materials for high school mathematics. The materials chosen were produced for Alberta Education to teach Mathematics 30 using computer assisted instruction (CAI). Subjects included the students enrolled in Mathematics 30 in two high schools in a county in Alberta. Entry level mathematics skills of both groups of students were assessed using a pretest. The first group of students used the CAI materials to learn the concepts in Mathematics 30. Based on feedback from this first group the CAI materials were modified. A second group used these modified CAI materials. Both groups completed the same paper and pencil mathematics posttest after completing the lessons. The mean length of time students took to complete each topic in the unit was reported. The study was mainly descriptive and involved informal interviews with the students and mathematics teachers who used the materials. The purpose of these interviews was to determine their opinions about the CAI materials and CAI as a method of learning mathematics. The results of these interviews were summarized into a number of statements about the materials and students' and teachers' perceptions of their use.

Acknowledgements

Throughout the course of this study I received support, guidance and assistance from my advisors, Dr. Gene Romaniuk and Dr. Milt Petruk. Dr. Romaniuk's knowledge of research design and attention to detail helped me considerably. Through my interactions with Dr. Petruk I was able to better focus on the project and solve problems and face hurdles posed by the research process. He has been a constant support through this process and has provided motivation for the completion of this task. I would also like to thank Dr. Len Stewin and Dr. Roger Palmer, the other two committee members, for their involvement in the project and thought provoking questions. Both were appreciated.

I would like to thank the many students and teachers who participated in this project. Without their willingness to become actively involved this project would not have been possible. Considering the many demands on time and energy placed on students and teachers, I appreciate the time they devoted to this project. These individuals were extremely supportive and cooperative.

Two people who work at DERS, Gary Kirk and George Buck, have been both supportive and helpful throughout the thesis process. Their interest in the project and willingness to advise on technical matters have been an integral part of this process. They are valued friends and colleagues and I thank them for their friendly assistance and willingness to share their expertise.

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Chapter I

Introduction

Researchers have demonstrated that programmed instruction methods using computer technologies can increase learning in many content areas and populations (Hannafin, 1985). Kulik, Bangert-Downs, and Williams (1983) integrated findings of 51 independent evaluations of computer-based teaching at the secondary level in a meta-analysis and identified increased student achievement in mathematics as being a result of computer assisted instruction (CAI) interventions. Burns and Bozeman (1981) used a meta-analysis approach to integrate 40 separate studies of CAI in mathematics and concluded that "the analysis and synthesis of many studies do point to a significant enhancement of learning in instructional environments supplemented by CAI." This leads one to hypothesize that CAI may be beneficial to the learning of mathematics. However, further research into this topic is necessary.

Rationale Underlying the Study

There is a growing movement to use CAI as a form of presentation and delivery of instruction. CAI has been shown to reduce instructional time and produce achievement gains for students. These reasons have provided impetus for the development of CAI materials, particularly in business and industry training applications. Since these gains may be attainable by methods other than CAI, there should be sound educational reasons for making the move to use CAI for instructional purposes within public education.

Some of these educational reasons may be identified by determining the opinions of teachers and students toward CAI. Through examination of these opinions it may be possible to assess the potential effect of these materials on both the cognitive and affective domains. It may also be possible to assess the potential uses of and concerns about CAI materials based on student and teacher reactions. Changes that will enhance CAI materials and make them more useable by students and teachers should also be identified. Modification of current CAI materials and production of new materials can then proceed based on the concerns identified by students and teachers. These evaluation steps should accompany any effort to develop CAI materials.

The development of Mathematics 30 CAI materials was the first endeavor in which an entire course was developed in CAI format by Alberta Education. In view of this fact it was imperative that evaluation of the Mathematics 30 CAI materials be undertaken to determine the potential of this type of instruction. Because Alberta Education had not yet conducted a large scale study to investigate the Mathematics 30 CAI materials, a need for evaluation was identified. This thesis reports an evaluation of one of the units of the Mathematics 30 CAI materials.

Development of Mathematics 30 CAI Materials

In 1988, Alberta Education undertook a large project to revamp the existing Mathematics 30 correspondence materials. During July and August, 1988, mathematics teachers from the Calgary area and Alberta Correspondence School (ACS) were brought together to write new mathematics materials for ACS. These teachers wrote the first draft of the new ACS Mathematics 30 materials which was put into high quality print form using a computer program called Ready, Set, Go[1]. These materials consisted of student workbooks which incorporated text and graphics. These workbooks were intended for distribution through ACS. In September and October, of that same year (1988), students who were enrolled at ACS and were registered in Mathematics 30, began using the new ACS Mathematics 30 materials.

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[1] A desktop publishing package used with the Macintosh Computing System and distributed by Manhattan Graphics Corporation, 163 Varick Street, New York, New York, 10013

Also in September, 1988, another project, which used the draft ACS Mathematics 30 materials, began in cooperation with ACS and the Apple Innovation Support Centre[2] (AISC), University of Alberta. The ACS Mathematics 30 draft materials were forwarded to the AISC where staff members at AISC converted the ACS Mathematics 30 print materials to CAI materials by transferring text and graphics from Ready, Set, Go files to files created by the authoring system called Course of Action[3]. The resulting CAI materials closely paralleled the design and content of the ACS Mathematics 30 print materials. These CAI materials were enhanced through the animation of existing static images and through the addition of new animations (animated images) where it was deemed pedagogically appropriate by the authors. Further enhancements to the CAI materials involved modifying the question and practice exercises so that students could enter responses and receive feedback messages, thereby making the CAI materials interactive.

The original correspondence print materials had been designed for distance delivery and the CAI materials were designed for the same purpose. The intent of these materials was not to replace instruction by teachers in schools but rather to make it possible to deliver Mathematics 30 to students who were geographically located in places where there was not access to qualified mathematics teachers.

Ideally, the evaluation of the materials should have been conducted in environments which closely resembled those in which the CAI materials were intended to be used. This would have meant conducting research in areas with little or no access to mathematics teachers, which would have meant a remote site at a distance from large communities. However, this would also have restricted the number of students and created problems with provision of computer equipment for the study. It would also have restricted the

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[2] AISC is housed in the Faculty of Education, University of Alberta. AISC is Directed by Dr. M. Petruk, a professor with the Department of Adult, Career, and Technology Education and Executive Director of Apple Canada Education Foundation.

[3] A course authoring package, marketed by Authorware, Inc., 8500 Normandale Lake Blvd., Suite 1050, Minneapolis, Minnesota. U.S.A. This authoring package has subsequently become known as Authorware Professional.

researcher's ability to observe the experience of students and to respond to unanticipated problems that might have arisen when the new materials were tried for the first time. As a result, this researcher chose sites which required only small commuting distances each day, and allowed access to a larger number of students and the required computer equipment.

The study was conducted in two schools in a suburban county of a large city in Alberta. The researcher was present while Mathematics 30 students used the CAI materials during the class time allotted to them. The Polynomials Unit of the Mathematics 30 CAI materials was used by students for this study. This unit was chosen because it had been complete at the time the research was planned. It was a small unit so was more manageable for the researcher in regards to time needed for completion. It also posed a smaller threat to students in terms of the time needed, in case the materials were unsuccessful in teaching the material.

All students who used the CAI materials were given both a mathematics pretest and a posttest. The researcher also held discussions with students and teachers of Mathematics 30 who used the CAI materials to identify their concerns about the Mathematics 30 CAI materials. Observations were also made of students using the CAI materials. The interviews and observations provided data which were useful in determining areas of strengths and weakness in the CAI materials. After assessing this information, the CAI materials were modified to improve the quality of the materials.

Statements of Problems

A formative evaluation was conducted which involved the collection of data by interviewing students and teachers and examination of student achievement on a pretest and posttest. The following problems were addressed through this formative evaluation.

1. What do students and teachers report as their opinions of the Mathematics 30 CAI materials?

2. What is the impact of the CAI materials on student achievement?

Definition of CAI

Computer Assisted Instruction (CAI): This term is used to refer to a variety of methods of instruction through the use of a computer. Names have been devised to refer to these varied methods. Each of these names has a specific meaning within a particular context. These names include *computer-aided instruction, computer-aided education (CAE), computer-assisted learning (CAL), computer-assisted training (CAT), computer-based education (CBE), computer-based instruction (CBI), computer-based learning (CBL), computer-based training (CBT), computer-managed instruction (CMI)* and *computer-managed learning (CML).* For the purposes of this study the term *computer assisted instruction (CAI)* will not be used in the generic sense defined above but will refer specifically to the interactive delivery of instruction by computers.

Importance of the Study

The results of this study should provide educators and instructional designers with useful information about the potential of CAI in mathematics education. The information gained from this evaluation should make it possible to produce quality CAI materials and to improve current CAI materials. By understanding the ways in which CAI materials are used and perceived by teachers and students involved in mathematics education, it may be possible to improve both CAI materials and mathematics education.

Outline of the Thesis

The current chapter reviewed the development of the Mathematics 30 CAI materials which form the basis of this study. The purpose of this study, as stated in this chapter, was to conduct a formative evaluation of the Mathematics 30 CAI materials. A review of literature is contained in Chapter II of evaluation studies of CAI, including meta-analysis and formative evaluation approaches. Chapter III describes the research methodology of this study, including the sample, the study design and the data collection and analyses. The data analyses is reported in Chapter IV which describes and discusses the results of the student and teacher interviews, and the performance data and test score descriptive statistics. Chapter V summarizes the study, states conclusions, and provides suggestions for further research.

Chapter II

Review of Literature: Evaluation of CAI

Two forms of evaluation - summative and formative - exist for evaluating instruction (Scriven, 1967). Both forms of research have been used to evaluate CAI. Meta-analysis is one method of summative evaluation which has been used to compile results of many CAI studies to determine effect size of various factors influencing CAI. A meta-analysis methodology involves sampling previously conducted studies. The meta-analysis research reported here involves a cross-section of CAI studies. These studies have been drawn from a number of different years. The number of studies used for each meta-analysis also varies.

Meta-Analysis of CAI Studies

According to Bangert-Downs (1985), CAI is the use of computers for tutoring or drill and practice. A quantitative or meta-analytic review was conducted by Bangert-Downs of studies comparing computer-based education (CBE) to conventional instruction in pre-college classrooms. Of the 500 reports collected, only 74 were deemed suitable for study. All of the 74 reports "measured achievement test performance after a period of instruction"(p.2). Five studies examined "student attitudes toward computers" and twelve "measured student attitudes toward the course content. The collected studies gave very favorable impressions of the effectiveness of CBE"(p. 2).

> Exposure to CBE seems to encourage students to think favorably of the computers they must inevitably work with in our society. Therefore, learning through computers, not just about computers, offers important benefits for the attitudinal and intellectual growth of students in a technological world. ... CAI is effective, as shown by the research, in a variety of settings. Achievement test scores were especially improved by computer assisted instruction (Bangert-Downs, 1985, p. 4).

Kulik, Kulik, and Bangert-Downs (1984) used a meta-analysis approach to review 29 studies that were collected from computer searches of the Comprehensive Dissertation Abstracts database and ERIC databases (Research in Education and Current Index to Journals in Education), and from bibliographies from the documents obtained in computer searches. Studies considered for inclusion in this meta-analysis had to: a) involve elementary school classrooms (grades 1 to 6), b) include both control and experimental (CBE) groups, and c) be free of methodological flaws like "aptitude differences between groups, unfair "teaching" of the criterion test to one of the groups, or differential rates of subject attrition from the groups being compared" (Kulik et al., 1984, p. 6). Effect sizes were determined from the information provided in each study by calculating the difference between the two group means and dividing the difference by the standard deviation of the control group. The net result was an effect size of 0.48. This positive result supports the hypothesis that CBE is effective.

Bangert-Downs, Kulik, and Kulik (1985) also used a meta-analysis approach to review 42 studies that were collected from: major reviews of CBE studies of secondary education, computer searches of the Comprehensive Dissertation Abstracts database and ERIC databases, and from bibliographies from the documents obtained in computer searches. The studies included in this meta-analysis were those which: a) involved secondary school classrooms (grades 7 to 12), b) included both control and experimental (CBE) groups in classroom settings, c) were free of methodological flaws (like those mentioned in the previous study), and d) were available through interlibrary loans from university libraries. The studies covered the years 1968 to 1983. Eleven of the 42 studies used commercially produced software. The remaining studies used locally developed software. Thirty-five of the studies used mainframe computers. Half of the studies used a commercial test to determine achievement while the remaining studies used locally developed instruments. Effect sizes varied from study to study, but were calculated as in the Kulik et al. (1984) study. The net result for the nine computer managed instruction studies was an effect size of 0.40, while the effect size for CAI studies was .36, and the effect size for CEI (computer enriched instruction) was .07. There was a relationship between effect size and publication year ($r=.39$, $p<.05$) but type of computer was a confounding variable. The result is somewhat positive but not as positive as the previous study. However, the result is used to support the hypothesis that CBE is effective.

Kulik and Kulik (1985) used a meta-analysis approach to review 101 studies that were collected from: 1) an earlier meta-analysis by Kulik, Kulik, and Cohen (1980), 2) computer searches of the Comprehensive Dissertation Abstracts database and ERIC databases (Research in Education and Current Index to Journals in Education), and 3) bibliographies obtained from the documents listed in the first two parts of this approach. Kulik, Kulik, and Schwalb (1986) used a meta-analysis approach similar to that used by Kulik et al. (1985). They reviewed 24 studies that were collected from: 1) an earlier meta-analysis by Orlansky and String (1979) (cited in Kulik et al., 1985), and 2) and 3) above.

In both studies, the documents which were finally listed met the criteria that the studies: a) involved real teaching, b) provided quantitative results, c) were free of crippling methodological flaws, and d) were retrievable from the ERIC database or from university or college libraries by interlibrary loan. Effect sizes were calculated for the results of the studies that met the above criteria.

Of the 101 studies in the Kulik et al. (1985) document, 99 reported results comparing control groups to computer-based education (CBE) groups. Seventy-seven of the 99 studies reported that the CBE group had higher examination averages. The average effect size in the 99 studies was 0.26, which is a positive result for CBE. This analysis did not find significant differences in effectiveness between computer assisted instruction, computer managed instruction, and computer-based instruction programs.

Of the studies reviewed by Kulik et al. (1986), all 24 reported data on achievement examinations. Effect sizes were calculated for these study outcomes and 23 reported positive effects for CBE. The effect size was 0.42. "CBE has basically positive effects on adult learners" (Kulik et al., 1986).

The investigators (Kulik et al., 1985; Kulik et al., 1984; Kulik et al., 1986) did not appear to control for instructional methods in either of the meta-analyses described above. The computer programs used in these studies could have been drill and practice, simulation, tutorials, or any other type. The programs could have incorporated extensive or very little interaction between user and computer. No consideration was given to these factors. Also, the CBE situations were neither controlled nor described. It is possible that some studies involved students using a program for only one hour, in which case the Hawthorne effect might be present. However, some of the studies could have involved students using entire courses taking many hours to complete, in which case the Hawthorne effect would likely have little effect.

Clark and Leonard (1985) randomly sampled 30% (42 studies) of the original 128 studies used by Kulik et al. (1985), Kulik et al. (1984), Kulik et al. (1980), and Kulik et al. (1986) in a meta-analyses of primary, secondary, and college levels.

Clark and Leonard suspected that factors such as the 'John Henry' and 'same teacher' effects confounded the data in these studies and that the gains found in these studies could be attributed to these confounding factors. The factors considered by Clark and Leonard were the 'same teacher' effect and the 'John Henry' effect.

The 'same teacher' effect refers to the fact that in most of the research, there is a systematic influence of different instructional methods, content and/or novelty by using only one teacher. Clark (1983) suggested that controlling these effects by involving studies of longer duration (limiting the effect of novelty) and keeping the 'same teacher' reduces the gains with CBI to insignificant amounts.

The 'John Henry' effect can occur when the teacher is kept constant in the experiment, but consciously or unconsciously the teacher puts more effort into the process and thereby reduces the impact of technology upon learning. Clark stated that "Kulik's data clearly indicates that control problems exist in many of the studies selected for analysis"(p. 12). This may indicate that the research that has been used to support the use of CAI is unreliable and that other research approaches are needed to determine the effects of CAI.

Formative Evaluation

Development of instructional materials often involves conducting an evaluation. The purpose of conducting an evaluation may be "to identify aspects of the course where revision is desirable [at a point] ... midway in the curriculum development" (Cronbach, 1963, p. 674). The term formative evaluation was coined by Scriven (1967) to refer to the type of evaluation conducted for the purpose of improvement of the product being developed.

In practice, formative evaluation often is restricted to the use of materials with learners (Stakenaes & Mayer, 1983). One approach to formative evaluation which requires learner input is Developmental Testing (Weston, 1986). As the name implies, the testing of materials is done during the development of materials. This approach may incorporate one-to-one sessions with learners or testing sessions with groups of learners.

Another approach to formative evaluation which uses learner input is the Three-Stage Model (Dick & Carey, 1985). Through this process, individual students test the materials. The materials are then revised. The revised materials are then tested with small groups of students and revised again. These further revised materials are then tested in a situation similar to that for which they were designed. Revisions are made based on this trial and the materials are then deemed ready for use.

Testing in situations which closely model the actual use situations are often referred to as field testing and may be an approach to formative evaluation in their own right.

Through field testing, the materials are not the only thing tested. "Utilization procedures are also tested and use problems are discovered" (Weston, 1986).

An additional approach to formative evaluation using learner input is Learner Verification and Revision (LVR) (Komoski & Woodward, 1985). Like the previously mentioned approaches, this approach requires individual or group input from learners. However, unlike these other approaches, the cycle of testing of materials and revision is continuous during the life of the material. Initially, this may seem like an expensive proposition but this process may extend the life and use of the materials.

Learners are invaluable to the process of formative evaluation, as they can verify the assumptions made by the developer of the material. Data from learners can be in many forms. For example, comments by learners and observations of learners may serve as useful data for improving materials. In addition, attitudinal data can be collected either by talking to students or through questionnaires. Another source of data are test data gathered generally through pretests and posttests (Geis, 1987).

Two problems exist in using evaluation data from learners. "There have been only limited attempts directed towards the translation of revision suggestions, particularly those made by learners, into revision reality. ... The methods of data collection from students are cumbersome, costly, time consuming and rarely representative of realistic circumstances" (Saroyan & Geis, 1988, p. 103).

Students need not be the only source of data in evaluation (Weston, 1986). Expert review is another approach to formative evaluation which is often used. An instructional designer is an expert who may be involved in the review to ensure that "all the components of the instructional design model employed have been implemented in the materials" (Saroyan & Geis, 1988, p. 105).

A subject matter expert (SME) uses his/her experience to judge content (Faust, 1980) and "review the instruction attending to questions of accuracy, emphasis, timeliness, and inclusion and exclusion of material" (Geis, 1987, p.3). A SME may be a master performer in the area, or a teacher may serve in this role. A teacher may also serve as an audience specialist, providing information about the target population-- the teacher or student group to use the material.

Experts are often relied on to provide evaluation data before revisions are completed. It may be more cost-effective to rely on experts than to conduct developmental testing with student input. "And since it often enlists leaders and opinion makers as reviewers, it may positively affect the acceptance of the new materials" (Geis, 1987, p.6).

Formative Evaluation Studies of Computer Use and Mathematics

Beevers, Foster, and McGuire (1989) conducted a field test of computer assisted learning mathematics (CALM) materials designed to tutor first year undergraduate students in engineering and science, in the area of calculus. The CALM materials were developed to replace traditional paper-and-pencil tutorials previously used at Heriot-Watt University in Edinburg, UK. These tutorials were developed by a team from the mathematics department at the University. The materials had been tried by 200 students in engineering and science during a 25-week course. The results of these students on exams in calculus and algebra were compared to those of students who had not taken the CAL lessons. The two groups had no difference in their marks in algebra, a course in which CAL was not used. The same groups were compared based on their calculus exams and the CAL group had scores 15% above those who had not had the CAL tutorials. This preliminary finding lent support to continued study of the CAL materials.

To assess the materials, students who had failed their calculus course were asked to attend a summer course. Since the summer course was only five weeks in duration, students were asked to choose from the entire 25-week course a set of topics to study. Each student was asked to develop questions which indicated the areas in these topics where she/he had difficulty. Of the 38 students who were accepted into the summer course, 34 started the course and 32 completed the five-week course. Students first attended a lecture which taught them about one of the common problems encountered by the students. The students then used a computer tutorial which supplemented the lecture. The students were asked at the end of this lecture/tutorial session to provide questions which they still were unable to answer and to provide additional feedback about the computer or lecture sessions. Two lecturers then addressed the students' problems and concerns. After the lectures, students were asked again to express their concerns and once again they were addressed by the lecturers. This student-centered discourse continued for each topic throughout the course. The CALM was a part of the process of solving students' problems.

This process of continual checking with students and additional lecture developed into a teaching strategy which incorporated the CALM materials but did not use them as a sole source of information for students. This strategy has now been incorporated into the approach to teaching classes during the regular session. Conventional lectures are still taught, but the CALM lessons are used by students to supplement these lectures, to provide practice, and to clarify concepts. Students are then asked to generate questions which identify the difficulties with the content. These problems are then addressed by lecturers in a session devoted to these problems.

There was no discussion of recording the problems and incorporating them into a revised CALM lesson or the development of a new lesson to solve the problems. There also appears to have been little attempt to incorporate the student concerns in revised lectures. These approaches may reduce the need for extra sessions if these teaching materials could be improved. However, this study does point out the need for formative evaluation through student feedback in order to address concerns of students and improve the teaching process.

Messerly (1986) conducted a study to determine if growth in mathematics skills occurred when hearing-impaired high school students used CAI mathematics lessons. Two groups of students were involved in the study. The first group contained five senior students with an average grade score of 7.5 on the mathematics section of the Stanford Achievement Test (SAT). This group was considered to be at an average level for hearing-impaired on this test. The second group involved three sophomore students with an average grade score of 4.2 on the SAT. This group was considered below-average on the SAT. The SAT was used as both the pretest and posttest in this study.

Students spent a minimum of 90 minutes per week from September to February using mathematics software. The results of the study show that a statistically significant increase in computation skills and total score resulted when students in group one used CAI. The difference in scores for application of mathematics approached significance. No statistically significant difference resulted for concepts. For group two, the application score showed statistically significant increases while the concepts, computation and total scores showed no difference. Messerly (1986) cautioned readers that the novelty of using a computer may have accounted for the noted increases (p. 75). However, Messerly noted that these scores showed educationally significant changes as well as statistically significant ones (p. 76). These cautiously optimistic outcomes add to the body of knowledge which supports the use of mathematics software with hearing-impaired students in the classroom. It would have been interesting to know what students thought about the program and to what they attributed their success.

An evaluation of the SCOPE computer education program was conducted by Lai (1984). Three hundred and seventy students in grades 6 to 12 were involved in the study. Pretest and posttest data included information about student attitudes, cognitive ability, and other items intended to assess progress. In addition, data were collected from teachers and laboratory assistants.

Gains were shown by students in the areas of mathematics problem-solving, computer programming, and attitudes. Students liked the organization, pace, and questioning opportunity available on the computer. Students regretted not having enough time on the computer.

A description of student behavior, physical facilities, field trips, parental involvement, curriculum, and instructional strategies were provided for the project and the SCOPE program. In addition, observations of students involved with the program were described. It appears that the results were positive regarding the use of this program.

A more detailed description of the study would have been useful in order to assess this study and make it possible to replicate. However, the design using pretest, posttest and attitude data, as well as that from teachers involved, was useful to the design of the current investigation.

Garrison and Purves (1985) conducted a study to compare a traditional classroom to video tape lessons and CAL (computer assisted learning) mathematics lessons in the Alberta Vocational Centre, Calgary, Alberta. From two classes of adult students, enrolled in grade 11 classes, a selection of 30 students was drawn (20 for the traditional classroom lessons, five for the video tape lessons, and five for the CAL lessons). Considering the lack of a random sample it is not unlikely that the three groups were very different in demographics and background.

Both groups of students for the video tape and CAL lessons were volunteers. Students using the CAL lessons had to be registered into one hour time blocks. Students using the video tape lessons could take lessons at their own convenience and students in the classroom took lessons during their regular classroom time.

A measure of students' attitudes was taken on a semantic differential questionnaire, both before and after using the lessons. No further information was given regarding this instrument or its validity and reliability. However, no change in attitude was noted from pretreatment to posttreatment.

An achievement score was calculated from the instructor's unit test. The results of the unit test indicated that the CAL group did not do as well as the other two groups, but this was inconclusive since sampling was not random and students with less mathematics skill may have been in this group. It is also possible that the test was more representative of the content in the teachers' lessons, both in the classroom and on the video tapes, than in the CAL lesson which was devised by an outside source.

A questionnaire was taken by each student in the video tape and CAL groups. The CAL students gave higher ratings to hardware and lessons than did the group using the video tape, but this may be a result of sampling limitations. Satisfaction with instructional method showed no difference between the two groups.

Students' comments suggested a desire for a greater number of questions with feedback and a reduction in branching choices in the CAL lesson. These adult learners appeared to want to learn the essential material in the most efficient manner possible which means reducing branches, which may only confuse them, and increasing the feedback to questions so clarification of ideas could occur. This may have been partly due to the fact that these adult learners may have had special needs and requirements. It may also be due to specific needs of the five individuals who used the CAL lessons. More information about the students' experience and demographics is needed to help put these results in context. It may also be a result of the mathematics subject area which was studied. Discussions with students to determine their reactions to the experience may also have provided more information regarding their responses. With only five students in the CAL group, discussions may have been possible and would probably have been helpful in understanding the kinds of uses the students made of the lessons and why they felt the need for increased interaction and decreased branching.

A study, which attempted to investigate student branching choices, was conducted by Robson, Steward, and Whitfield (1987). A sample of secondary school students used five computer-delivered tutorials in the following five mathematics topics: algebra, percentages, standard form, circle, and trigonometry. Each tutorial dealt with one of these areas. None of these areas were new to the student. This allowed the student to concentrate not only on what was being learned, but on the choices made while using the tutorials. Each session using one of the tutorials lasted 35-40 minutes. The sessions occurred every two weeks.

Each student used the five computer tutorials. Each of the tutorials contained four subtopics, which students could choose. Student choices were based on information gained from 1) a pretest which provided exercises in each of the subtopics, 2) a demonstration by their teacher of each of the subtopics, and 3) a description of each subtopic and an example provided by the tutorial. Students could also choose to randomly select a subtopic.

The path chosen by each student, while using the computer, was recorded in a data file and analysed. Students made early use of the examples provided by the program in guiding their choices. They also used these examples when difficulties were encountered. Only after viewing all four subtopics did most students make use of the random choice feature.

Some other branching strategies appear to have developed for some students. These include 1) "only change subtopic after a correct solution, [2)] one correct attempt is usually not sufficient evidence to change type, and [3)] having got[ten] one problem correct it is unlikely that any subsequent attempt will be wrong" (Robson, Stewart, & Whitfield, 1987, p. 97). Without analysing actual student performance data, these strategies would not have been noted. This study, although not conclusive, provides support for the use of performance data in studying student use of CAI and describes another dimension of student computer usage, that of branching strategies.

According to Romaniuk and Montgomerie (1976) "performance data ... includes the student's response to a question, the classification of that response by the computer, the time taken by the student to respond, and the current status of the student" (p. 2). "The ability [of the computer] to easily collect voluminous amounts of information about the student as that student progresses through a course" is reported by these authors (p. 2). Based on the extensive experience of these authors in the area of CAI development and analysis of student performance recordings, Romaniuk and Montgomerie (1976, p. 2) stated that "authors who produce courses of significant length, quickly realize that either they have to ignore most of the performance data, or that some automatic way of compiling the performance data into meaningful form must be found." As a result, the current study was designed with analysis of performance data kept to compiling and reporting means and standard deviations of students' time taken to complete the course.

Computer Usage Interaction

England (1985) stated that "*interaction* between the student and the computer is the major advance offered by the computer medium. ... Observation is necessary to monitor the learning strategies of the students during computerized instruction" (p.24). Two experiments were conducted by England to substantiate these statements.

The first experiment involved completion of an English language exercise, and comparison of students' skills while using a computer to skills of students completing the exercise in a traditional format. For the students using a computer, a paragraph with twelve blanks in it was displayed on the computer screen; students were to fill in the blanks. For the other students a paper-and-pencil format was used. This used the same paragraph and twelve blanks positioned in the same place on the page as that on the computer screen. All students were informed that this exercise was not a test and were encouraged to access assistance when completing the exercise. Students in the traditional setting could ask for help from the teacher. Students using the computer could get clues by using a 'help' feature on the computer. The clues provided were definitions of words or the nature of words for a particular blank. The computer-based clues were intended to provide the type of feedback a teacher might give a student if asked for help. This involved providing a synonym and a clue as to the word's function.

The two tasks were similar, but the interaction of students in acquiring help was different for the two groups. In the traditional group, although students did have difficulty filling in the blanks, little interaction with the teacher occurred. Of those students who received help from the teacher, not all benefitted because they still gave wrong answers. The computer group also resisted assistance. Students using the computer either did not notice the prompt to get help, thought they were cheating when they got help, or thought the computer was keeping some kind of record of the help they received and, therefore, were leery of getting help.

Later, half of the students in the computer group were encouraged to request assistance through use of the help feature. As a result, more students used the help option. The computer help that was received was neither more or less effective than the teacher supplied help, as judged by the correctness of the students' answers. However, the students using the computer took longer to complete the exercise.

The second experiment described student pairs using a question and answer program. The program asked students questions and based upon their answers, added information to a data base which was empty at the start of the program. Students worked in pairs, interacting as they worked. The interactions differed between pairs depending on the knowledge, personality, and creativity of the students involved.

Students entered questions into the computer, as well as answers, so that the computer could acquire more information. The breakdown of a typical interaction is described by England (1985, p.27). After a knowledge base had been built up in each computer, students were moved to other computers so they could try other question and information banks. Some students complained about questions that had been developed by other students. They felt some of the questions were frivolous. The formation of questions is a task usually left to teachers. These students had little experience in devising questions. However, through the process of generating questions, the students showed an understanding of the criteria involved in describing a problem. If the researcher had simply used the results of tests or questionnaires, the insights into student interactions would not have been possible. This study provided a good rationale for further study of student interactions with computers.

Another study of student interaction while using computers was conducted by Ronau and Battista (1988) with eighth grade students. They compared student responses to questions on a test administered by computer with a similar test administered in a paper-and-pencil format. The tests were used to diagnose problems in understanding the concept of ratio and proportion and were administered before the students had been taught ratio and proportion.

Four groups of students, all taught by the same teacher, were involved in the study. Each group contained twenty students drawn from the population of eighth grade students from one school. Sampling and group assignment strategies were not discussed. Group one received the computer test followed by the paper-and-pencil test. Group two received the paper-and-pencil test followed by the computer test. Group three only received the computer test. Group four only received the paper-and-pencil test.

A Pearson product-moment correlation coefficient was calculated for total scores on tests taken by computer and the paper-and-pencil versions of the test. This correlation was calculated for those students who had taken both tests. The correlation of .63 was reported; this indicates that the two tests are similar although not identical.

A t-test was used to compare the means of total test scores on the computer test to the means of the paper-and-pencil test. Ronau and Battista (1988) stated that the results showed that the computer version of the test was significantly more difficult than the paper-and-pencil test. This statement is erroneous. The t-test compared final scores and found that the test scores on the computer version were significantly lower than the scores on the paper-and-pencil test. The reason for the lower scores may be due to different difficulty levels of items, but may also be caused by the difference between taking a test on the computer as compared to taking a test using the paper-and-pencil format. One way to distinguish whether this, in fact, is the case would be to give students both versions of the test in computer mode and another group of students both tests using a paper-and-pencil format.

Student answers on the tests were marked as unclassified, correct, or incorrect. The incorrect answers were put into one of eleven categories: omitted, inverted, improper, addition, simplify, subtraction, multiplication, algebra, incorrect only, inverted addition, or procedure error. Students using the computer test produced more unclassified and omitted answers. This may have been due to the fact that students using the computer who wanted to leave a question unanswered and go onto the next question, were supposed to enter <ESC>to do so, but may have simply entered any number and then continued.

Another possible confounding variable was the fact that students completing the paper-and-pencil test could return to previous questions and change answers, but students who completed the computer test could not. This may account for the higher number of omissions produced by the computer group.

A further problem encountered by the computer group was the entry of equations with variables. Students, using the computer, were forced to first enter the variable and then enter the numeric components of the equation around the variable. This was an unreasonable procedure forced by the computer restrictions which may have made the computer test more confusing for the students to complete. Students who completed the paper-and-pencil test could enter the equation in any way they liked, which is a more reasonable process.

Student interaction while using a computer was different from that of students using paper-and-pencil format. This difference was empirically verified in this study and possible reasons were discussed. In essence, there is a need to understand the types of interaction variables that may influence data collection before embarking on research in the area of CAI.

Mayer and Raudebaugh (1987) used a computer system to collect student performance data on a daily basis. Two pilot tests were conducted involving students from eighth grade science classes in two junior high schools in Ohio. The first school involved 80 students and the second 105. The students used an earth science unit designed for the study as the treatment condition.

The data were collected from a bank of 80 multiple choice items. Half of these items were specific to the unit taught and half were related to the topic, but not specific to it. The answers to questions and time taken to respond were recorded by the computer system. In addition, attitude items from the semantic differential instrument were used to obtain further information.

The study was designed to take a total of 40 school days to complete; 10 days as a baseline (answering questions before the unit began), 20 days of treatment (using the earth science unit), and 10 days of follow-up (answering question specific to or related to the unit). However, given restraints in school one, only 26 of the anticipated 40 days were available for the study and students were only able to complete less than half of the earth science unit. The breakdown of the 26 days into baseline, treatment and follow-up was not specified.

The only significant trend to appear for the first pilot group was that response time for completion of items decreased as students proceeded with the program. All other effects, including attitude change and difference in answer correctness, were not significant.

The second pilot group of students showed, during the baseline phase of the study, that they tired of answering questions about information they had not been taught. This was demonstrated by falling performance scores and quickening of responses. However, when the students began the treatment phase, and were being taught the information about which questions were asked, they showed a steady increase in knowledge. Student performance remained high after the treatment was discontinued. This study provides information about student performance which would not have been available if the collection of microcomputer collected performance data had not been used. However, this approach does not attempt to interpret the relationship of student performance and time variables which is an area that needs investigation.

Participant Satisfaction with CAI and CAL

Carlson and Dostaler (1984) reported a formative evaluation of a computer-assisted learning (CAL) pilot project using courseware supplied to remote schools by telephone lines to terminals. The courseware consisted of junior high school mathematics, language arts and computer programming (using BASIC). The evaluation involved visiting four pilot sites where interviews and questionnaires were completed by teachers and students.

An attempt was made to train teachers to implement the CAL programs into their classes. A three day training session was deemed unsuccessful due to lack of interest by some teachers and problems with a lack of availability of the actual courseware to be used in the pilot project. A problem with a lack of follow-up training was also expressed by Carlson and Dostaler. Several features that seemed to facilitate CAL usage were: 1) a secure teachers' room in the school where sharing of information between teachers could take place and passwords could be kept, 2) a teacher-aide to supervise terminals so the teacher would be relieved of this duty, 3) easy access to the terminals by students, even after school hours, and 4) student access to a teacher who could help them when difficulties were encountered by the student. Difficulties with teacher assess to computer terminals, and funding for software were problems expressed by the teachers in the project. A great need for more training in use of computers was identified by teachers. Guidance from the provincial agencies was also needed regarding requirements of students to meet objectives outlined by these agencies.

The students in the Carlson and Dostaler (1984) study reacted favorably to CAL, as evidenced by their questionnaire returns and interviews. They enjoyed: 1) the sense of control over their own learning, 2) immediate feedback provided by CAL, 3) working without embarrassment of errors, and 4) the added status the computer brought to mundane mathematics tasks. The students expressed a desire for more time to work at the terminals.

An explanation suggested by Carlson and Dostaler for the heavy use of the CAL mathematics courses and perceived gains by students in mathematics were the easy access to the terminals (because of their physical location in the school), the appropriate level and sequencing of the courseware, the large amount of time and development the courseware received prior to the pilot test, and teachers who were better trained to handle the material (p. 20).

The impressions conveyed by teachers suggested several factors contributed to high student usage and success while using CAL. Computers seem to have had a positive motivational influence on students. The testing strategy incorporated into the CAL packages required that students acquire a certain degree of proficiency before being allowed to proceed from one unit to the next unit. This fact, and the perception that computer work is more intense and demands greater concentration than does classroom participation, contributed to the positive effect produced during the pilot test.

For the most part, teachers described the CAL material as being introduced without taking into account the specific situational variables present in the schools. Some of these factors included: 1) a lack of technical support for the project, 2) limited access to computer terminals for students, 3) inappropriate location of the terminals (so that disruption of learning results), 4) software in some content areas which was designed at a higher entry level than actual student entry levels, 5) limited curriculum and content limitations, 6) software not closely aligned with the objectives outlined by the sponsoring educational agencies, 7) an inability by teachers to assess and assign lessons appropriate to student interests and level of entry, 8) lack of planning for implementing the program, 9) no time available for teachers to become familiar with both CAL and the curriculum materials prior to implementation of the pilot project, and 10) a lack of training to handle technical problems, scheduling, record-keeping, integration of the material into regular programs, student testing, selection of students and other problems of implementation.

This study outlined some of the positive outcomes of computer usage with students, but also detailed some of the utilization problems which potentially negatively effect any attempt at implementation of computer software in schools. These points, although specific to this situation, may also be pertinent to other implementation projects.

Flynn (1982) conducted a formative evaluation of CAI materials which had been designed for training foster home staff. "This evaluation was undertaken to provide information on issues of feasibility, installation and implementation of CAI" (p. 1). After an extensive literature review of CAI, Flynn came to the following conclusion: "Since most written material has already dealt with efficacy, it was felt there was a greater need to provide a formative evaluation" (p. 36).

A sample of certification and placement specialists from licensing agencies was selected based on recommendations made by consultants from the Bureau of Regulatory Services. A random sample was not used due to budget and geographical limitations. Flynn visited the bureau and administered the computer aided lessons in Certification And Licensing to subjects who wished to participate. The subjects, on an individual basis, used a computer provided by the researcher; the computer was connected via a telephone connection to a mainframe computer at a distant site. "After the participants had finished they were asked to fill out an evaluation form which sought individual information, reactions to the experience and opinions on the feasibility of CAI as a training tool" (p. 9).

The questionnaire was divided into the following three parts: 1) demographic information regarding "lessons selected, prior licensing and certification experience, sources of training, prior computer experience, percentage of work time devoted to licensing and certification, and gender of the participant", 2) "attitudinal data constructed on a five point Likert scale [which] concentrated on respondent attitudes toward computer usage, the feasibility of CAI lessons in training, [and] the format and structure of the lessons", and 3) "open-ended questions dealing with lesson improvement, future use of CAI, and any additional comments on the experience" (p. 10). The questionnaire was deemed effective, by Flynn, in meeting the objective of formative evaluation of CAI. This questionnaire was useful in the development of the interview schedule used for the current study.

Another study, useful for interview schedule development, was conducted by Macfarlane (1985). Formative evaluation was used to assess the impact of a CAI package called "CHOICES (Computerized Heuristic Occupational Information and Career Exploration System)" which "is a career information system developed by Employment and Immigration Canada in 1977" (p. 2). Data to assess the CAI package were collected by means of questionnaires and/or interviews with students using the CHOICES program and counsellors/teachers who had used CHOICES in career counselling.

Researchers developed interview schedules and questionnaire items after participating in two workshops, which outlined use of CHOICES, and interviewing Vocational Career Center staff who used CHOICES. Through interviews, counsellors/teachers and students were asked direct questions regarding their use of CHOICES. "During their interview, counsellors/teachers were asked to discuss the ways in which CHOICES had been implemented in their schools, their impressions of the process and its advantages/disadvantages, and suggestions for change. Students were asked to complete a questionnaire dealing with ... their use of the computer, follow-up activities and their perceptions of the usefulness of CHOICES as a career counselling tool" (p. 3). Guidance counsellors distributed and collected the questionnaires from students. Group interviews were conducted with counsellors/teachers.

Descriptive data from the questionnaires and interviews of both students and counsellors were reported. Although the specific findings of Macfarlane's study are not pertinent to this literature review, the type of reporting used was regarded to be helpful by this researcher. The data were reported in the following sections.

1) *Implementation of CHOICES*. This section included uses of CHOICES, students awareness of CHOICES, and training for counsellors.

2) *Using the Computer*. Information regarding the actual use of the components of CHOICES was stated here.

3) *Advantages of CHOICES*. This section was subdivided into two subsections; advantages for students and advantages for staff. Students were asked to discuss use of the program and the guide that accompanied the program. They also were asked to provide information about self-initiated activities related to the information they received from CHOICES. Counsellors often recommended activities for students as follow-up. Students were also asked to evaluate features of CHOICES including its value to them, and the appropriateness and usefulness of information. Counsellors were asked to discuss advantages CHOICES had for themselves, the students, the counselling process, and the guidance department. The motivating effect of CHOICES was also discussed.

4) *Disadvantages of CHOICES*. Information regarding time necessary for student use, operating problems, and reading and student comprehension skills necessary were discussed here. Students had difficulty identifying disadvantages and mainly suggested changes. Counsellors were better able to identify disadvantages of the program.

5) *Comparison of CHOICES with Other Interest and Aptitude Inventories*. CHOICES was compared with other interest and aptitude inventories to determine extent and effect of use.

6) *General Impressions*. General impressions were gathered from students and counsellors by a section at the end of the questionnaire for additional comments regarding CHOICES. Counsellors were asked if CHOICES should remain in their school.

7) *Suggestions for Change*. Throughout the interviews and questionnaires, counsellors and students were asked to make suggestions to improve CHOICES itself, the use of CHOICES, or the implementation in the school. Of the few suggestions made, most came from counsellors.

These seven sections were considered during the development of the interview schedule used for the current study.

A Field Trial by the Alberta Correspondence School

Montgomerie (1982), in conjunction with the Alberta Correspondence School (ACS), conducted a research study into the use of the Telidon system[4] to field test a Mechanics 12 course offered by ACS. The field trial involved print materials for instruction, question/answer/remediation sequences via the Telidon system, and practical experience via access to a journeyman mechanic in the community.

The purposes of the study were to determine the effectiveness of the Telidon system (involving multiple choice questions with immediate response to answers). This was accomplished by: 1) comparing the Telidon-based materials with traditional correspondence methods (which involved print materials with paper and pe[illegible]nswers), and 2) determining the opinions of subjects using the Telidon system.

Five groups of students took part in the study. All students who wer[illegible]d in Mechanics 12 at participating schools in Alberta were involved in the s[illegible], this was not a representative sample of students in Alberta, but rather a popul[illegible] students in these schools. The students were assigned to five groups but the assi[illegible] criteria and number of students were not specified.

4 The Telidon system is "a videotext system which permits information stored in data banks to be retrieved in the home, office, or school" (Turnbull, 1984, p. 3). This system was chosen because of several advantages for education: high quality graphics, user friendliness, and easy access to information using the system.

The first of the five groups was called the experimental group and involved Telidon instruction along with shop instruction. Two comparison groups (called Comparison Group #1, and Comparison Group #2) used traditional correspondence instruction along with shop instruction. Comparison Group #3 used traditional correspondence instruction without shop instruction and Comparison Group #4 used traditional in-school instruction along with shop instruction.

In order to determine if the group achievement means were similar, each student in each group was administered a pretest. Via an analysis of variance statistical test, it was determined that there was no significant difference between the means of the five groups. Each student also completed the Mechanical Reasoning portion of the Differential Aptitude Tests (cited in Montgomerie, 1982, p. 20). Again, no significant difference between the group means was found.

After completing the course, students' achievement was measured by a written posttest and students' attitudes toward the course were measured by the School Subjects Attitude Scales (cited in Montgomerie, 1982, p. 20). From the report, it cannot be determined if there was a significant difference in achievement scores between the groups. This question was not answered by the discussion section of the report. However, there was no significant difference between the attitude scores as measured by the School Subjects Attitude Scales.

Those students in the experimental group who were available when interviewers were in the school were interviewed to determine their perceptions, attitudes, and observations about the Mechanics 12 course and the Telidon system. It is not clear if these interviews occurred during, or after completion of, the course. Overall, the students were pleased with the Telidon system.

The students had some criticisms of the Mechanics 12 course and the administration of the course. They wanted instruction, as well as testing, to be available on the computer. Students were critical of exclusive use of multiple choice questions and felt that the incorporation of a full size keyboard would allow them to enter answers to a broader spectrum of question types. The computer response time was too slow for some students and the branching within the system sometimes was in error. Students had no way to correct these problems. Sometimes the information on the screen was overwritten by other information without warning, making it impossible to answer correctly. Students desired an electronic message facility so they could communicate with instructors at remote sites.

The teachers who were involved with the experimental group of Mechanics 12 students in the trial schools were interviewed by a member of the evaluation team. The reactions of the teachers to the immediacy of feedback were favorable. They also felt that a message facility would be useful to provide an ability to communicate with ACS and would be useful for teachers to be able to monitor student progress. They were also concerned with the extent of reading that was required and the reading level of the materials. It was felt that this feature limited the effectiveness of the materials and the opportunity for some students to succeed with the materials. Teachers desired the computer system to recommend activities the student could undertake to review or learn the material when it was apparent, through testing, that this was needed. They wanted other correspondence courses in different subject areas to take advantage of the computer system, but they felt the computer should also be involved in providing instruction, not just testing. There was no discussion as to when these interviews took place, and the extent of the interviews. A list of questions that were used in the interview was provided.

The results of student and teacher descriptive data are interesting. They provide insights into perceptions of technology by these two target groups and expectations of technology made by these groups. Although these results cannot be generalized, similar perceptions and expectations may be present in other subjects in other such studies.

The Alberta Correspondence School staff who were involved in the development of the Mechanics 12 course, were interviewed (Montgomerie, 1982). In addition, Alberta Government Telephones staff who were involved with the transmission of information using Telidon via telecommunications, were interviewed. These interviews were tape recorded, transcribed and analysed. However, no description of this information was provided in sections devoted to discussing interviews. How these interviews transpired, the subjects involved, and their roles in the project were not discussed.

Beside each computer was a log book to record problems encountered by students or staff while using the system under the experimental condition. This served as another source of data. School staff made written reports of personal perceptions of student performance and attitudes. Information from these two sources was recorded and a content analysis completed but, again, a description of this information was not provided in the report.

The Telidon system was found to be very expensive to maintain because of the telecommunication costs. However, recommendations were made regarding its continued use by ACS. Further recommendations were made that computer assisted learning should be a priority to ACS and that further development of materials in other subject areas should be undertaken.

Although the basic design of the study was useful, this report lacked specific details about the methodology and results to be helpful in the development of the current investigation. The methods used to collect and analyse data from interviews were not discussed. However, the interview questions were provided, which were useful to this author. Statistical methods used to analyse equality of groups and pretest and posttest data were not fully described, nor were the results reported from these methods.

Montgomerie (1982) wrote extensive descriptions of the Telidon system and its use in the project. This information would have been more useful if it were related to both the statistical results of the study and descriptive information provided by the subjects in the study. One recommendation by the author was that ACS examine existing and emerging systems capable of delivering computer based learning services. This is the focus of the current study.

Conclusion

The preceding studies provide support for the use of formative evaluation in the field of CAI research. The use of student and teacher data collected through interviews is effective in determining perceptions of CAI. In addition, the use of performance data and observational data are useful in determining how students use CAI and have helped to identify factors which potentially influence performance while using CAI. These include branching and interaction variables. Based on the information provided in this chapter a methodology was developed which is discussed in Chapter 3.

Chapter III

Methodology

This study consists of a formative evaluation of a portion of the Alberta Education Mathematics 30 CAI materials. Overall, Mathematics 30 is a 125 hour course composed of six units. The unit evaluated in this study is Polynomials (Unit One) which consists of 10% of the Mathematics 30 course.

Sample

A list of Alberta high schools with Macintosh computer[4] laboratories (containing at least 25 Macintosh computers) with local-area networks[5] was obtained from the Edmonton office of Apple Canada. The researcher identified a county in central Alberta which had several schools on this list. Three high schools from this county were selected for participation in this study. The principals of the three high schools in this county were contacted by telephone and were provided with information about the study. In all cases the principals granted permission for the study to be conducted. The principals provided names of the Mathematics Coordinators in each school; they were contacted by telephone and also provided with information about the study. In all cases, the Mathematics Coordinators responded positively and arrangements were made for further contact.

The researcher visited the first high school and presented a professional development day session which introduced teachers to the Mathematics 30 CAI materials. The unit of CAI material to be used in the study was placed on the school's Macintosh computer local-area network by the researcher. The six high school mathematics teachers were given an opportunity to view all the materials in the unit. The teachers were also

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4 The Macintosh computer is produced and distributed by Apple Computers, Inc., 20525 Mariani Avenue, Cupertino, California 95014.

5 A local-area network is used to connect machines to a file server which contains information used by those connected to the network.

provided a User's Guide that accompanied the CAI materials. The teachers, as a group, spent approximately three hours reviewing the CAI materials, after which they decided that they wanted the project to be conducted in their school. In the school, only one teacher had access to the computer laboratory in which the study was to be conducted. That teacher and his class became the sample from school one. The sample consisted of an intact class of 30 students enrolled in Mathematics 30 during February, 1990. The students were given consent forms which were to be completed by their parents or guardians. The completed forms were returned to the teacher who provided them to the researcher.

The researcher, after initial contact with the second Mathematics Coordinator, visited another high school in the same city as school one. The teachers at this second school were provided the CAI materials and given an opportunity to use the materials. The initial reaction from these teachers was positive and they also wished to be involved in the project. However, it was determined that the Macintosh computers in the laboratory did not have sufficient memory, so the school was not used for the project.

The third Mathematics Coordinator, from a school in a small city close to the first city, received the CAI materials for preview purposes. This included the User's Guide. The coordinator placed the materials on the school's Macintosh local-area network. After previewing the materials, the coordinator consented to have students from his class be involved in the study. The coordinator's intact class of 26 students enrolled in Mathematics 30 in March, 1990, formed the sample from school two. Consent was acquired from students' parents and/or guardians using the consent form provided by the researcher.

Design

On the first day of Mathematics 30 classes, students who were enrolled in one section of Mathematics 30 in the first school (school one) were provided with information about the project and given an opportunity to ask questions about the project. The mathematics teacher introduced the students to the outline of the Mathematics 30 course. He then introduced the researcher and the role of the CAI materials in the completion of the first unit of the course. Students were then given the mathematics paper-and-pencil pretest. This took most students the rest of the 80 minute class to complete the pretest (about 65 minutes for most students).

On the second day of class, the students met in the computer laboratory rather than in the classroom. The researcher introduced the students to components of the Mathematics 30 CAI materials and the computer network they were to use. By using a projection unit[6] attached to a Macintosh computer the students could all see videoscreen images displayed on a screen at the front of the room. This projection unit was used only for demonstration purposes. After the initial introduction to the CAI materials, the students were asked to place the system disk[7], which was provided by the researcher, into the disk drive and turn-on the computer. They were then to follow step-by-step directions given by the researcher in order to sign-on to the local-area network.

At this point it was determined that there was a 'break' in the network which meant that eight of the twenty-eight computers were not able to connect to the network. This created considerable disturbance for all students in the laboratory and necessitated several students being moved into pairs to share a computer for that day so they could also begin use of the CAI materials. At the end of the day the partners handed their disks in to the researcher. The performance recordings from the disk which had been used by the partners were copied onto the disk which had not been used by the partners. This meant that both had the performance recordings on their respective disks so that neither partner would have to start from the beginning of the CAI materials on the following day.

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6 The projection unit is a device used to project a 'green screen' image of the Macintosh display screen onto a vertical surface.

7 A system disk is used to activate the machine and allow it to use applications or access information from the server. All students required disks with systems to be able to connect to the network.

At the end of each day, all students handed their disks to the teacher who stored the disks and made the disks available to students on the following day. The teacher also provided the disks to the students at lunch hour if they wished to do extra work. The teacher actively encouraged students to take extra time at lunch to work because the teacher had allotted only six days for this unit and two of these were required for the pretest and posttest. Students were under time constraints imposed by the teacher to complete the unit in the allotted time.

Each day, thereafter, each student entered the computer laboratory, obtained the system disk which had his/her name on it, sat down at a computer, and 'signed on'. The CAI materials resumed at the screen display where the student had quit the previous day. When the student completed the first topic in Unit 1, the student 'closed' that topic and 'opened' the next topic. Each student continued this process until all five topics, numbered zero to four, were complete. Not all students had sufficient time during the allotted class periods to finish the unit, therefore, some students spent additional time at lunch hour in order to finish the unit. Other students simply did not complete the unit.

Four of the 30 students that constituted the sample from school one were interviewed by the researcher. Three interviews occurred on the last day students had to complete their use of the CAI materials and included only those students who had completed the CAI materials and had time remaining during the class. All students were given a posttest on the following day. Due to the fact that not all students completed the unit some students were being tested on topics they had not seen. Exact numbers who completed the use of the CAI materials are not available because the records of unit use were not recorded by the computer on the final topic. One student who finished the test early was also interviewed. Other students, besides those who had been interviewed, were unavailable for interviews due to their busy schedules.

The researcher was present during all scheduled classes when students used the CAI materials and during the testing periods. She acted as an observer of the process and determined if there were any problems with the CAI materials or tests. Difficulties which were observed by the researcher, noted by students, or discussed with the teacher, were recorded by the researcher. These problems with the CAI materials were corrected by the researcher in the two week period between completion of use of the materials by students in school one and initial use of materials in school two. The researcher also developed a student version of the User's Guide during this time period. This User's Guide had the addition of printed screen images to show the startup procedure and the deletion of information which showed how to load the CAI materials on the network and other material not necessary for student use of the material on the local-area network.

At school two, students had already completed two units of the Mathematics 30 course prior to beginning use of the Mathematics 30 CAI materials. Therefore an introduction to the Mathematics 30 course was not required. This allowed students more time to become involved with the study as compared to those in school one. During this class period there was only a brief introduction of the researcher to the students prior to the pretest. Upon completion of the pretest, the students proceeded to the computer laboratory. They received a system disk from the researcher and the student version of the User's Guide. The students put their names on the system disk and 'signed on'. They then used the CAI materials until the end of the 80 minute class period at which time they handed in their disks.

On subsequent days, students arrived at the computer laboratory, obtained their 'own' disks and began working on the CAI materials. The teacher also provided the disks to students for use during lunch hours. As in school one, students worked through each topic in the unit and received a posttest. The number of students who finished the unit was difficult to determine because students did not always finish one topic before proceeding to the next topic and some students 'skipped' topics in the middle of the unit and proceeded to later topics. It is difficult to know whether these 'skips' were the result of students losing track of where they were in a topic and therefore making the error of moving on before finishing or whether students moved on intentionally before completion of the topic.

Problems with the CAI materials which were observed by the researcher, or identified by the students and the teacher, were recorded for the purpose of future modifications. Four students who had completed the unit on the day before the pretest were interviewed. As with the students in school one they were self-selected by early completion. No students were interviewed after the posttest because of a lack of time.

Data Collection

Three types of data were used in the analysis: computerized student performance records obtained while students used the CAI materials, student pretest and posttest scores, and student and teacher interview data.

Student performance records were recorded on student disks by instructions embedded in the CAI materials. The information collected was a detailed record of elapsed time taken on each component of the unit, progression through the unit, and responses given while interacting with the unit. The analysis of this data was restricted to time data since data of this sort are generally useful in implementing a program which uses CAI materials.

Group means and standard deviations are reported for the pretest and posttest for students from both schools. These were used to examine the time taken to complete CAI materials.

Four students from each of the two groups of students were interviewed by the researcher. They were self-selected by early completion of the CAI materials or posttest. Their first-hand experience with the CAI materials and the effect of the CAI materials on their learning was assessed. These data form a perspective regarding the effectiveness of the materials.

This study further consisted of a critical evaluation of the CAI materials by the two teachers. Through interviews with the two Mathematics 30 teachers, their opinions of the CAI materials were assessed. Both teachers have extensive experience teaching Mathematics 30. Teachers' opinions of the material are important, because these teachers were regarded as experts on content and delivery, and have used the materials with students firsthand; they were aware of student reactions to the materials and problems the students encountered in using the CAI materials.

Instrumentation

Subjects in both groups were initially given a pretest, consisting of 33 items which measured achievement in selected Mathematics 20 skills and concepts mainly in the area of polynomials. This pretest was a paper-and-pencil form. The 33 multiple choice items for this test were drawn from a testbank devised by teachers employed by Edmonton Public Schools, Department of Continuing Education. Data on the validity and reliability of these items were not available. Based on this pretest, a score was established for each subject. Means and standard deviations of the pretest scores are reported for the two groups (in Table 2, Appendix A).

After completing the pretest, the students used the CAI materials. The number of students in the two schools, working with the materials on any given day, varied due to absences, students entering the unit, and students leaving the unit. Students at school one used an initial version of the CAI materials. Based on feedback from these students, changes were made to the CAI materials. These changes involved correcting spelling errors, incorrect answers to questions, improving parts of the program which were insufficient or confusing, and correcting problems which stopped the program from running properly (e.g., excessive looping or erroneous answer sequences required by the program). This revised version of the CAI materials was then administered to the students at school two. As with school one, the number of students in school two varied from day to day, particularly on the final day which preceded spring break. Upon completion of Polynomials (Unit 1), students at each school were administered a pencil-and-paper format posttest. The posttest included 35 items drawn from a testbank of questions devised for Alberta Education Departmental Examinations given in 1988 and 1989. The questions selected were on the topic of polynomials. Based on the posttest, scores were tabulated for each student.

Data Analysis

Students were given a pretest to assess skills and concepts from Mathematics 20 which were required to begin the Mathematics 30 Polynomials unit. Students completed the pretest on optical mark scoring sheets. These were later optically scored. The total number of correct responses was assessed for each student.

Students then used the Mathematics 30 CAI materials. A record of student performance was kept by the CAI materials. The record included system seconds since the startup of the computer for each student interaction with the computer. These were converted into minutes and totalled. The researcher used the 'Excel'[8] spreadsheet program to calculate total times for student use of the unit from the performance data for each student. Each student had three values calculated for each topic in the unit. These included lesson time, practice time, and total topic time. The lesson time was comprised of a sum of time spent reading examples and explanatory text. The practice time included the time students spent completing exercises and answering questions. The total of these two times was calculated and placed in the total topic time. Values for each student and topic were placed in an Excel data file. A total time to complete the unit score was then calculated as the sum of the total topic values for each student.

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8 Excel is a spreadsheet program distributed by Microsoft Corporation, 1989.

Upon completion of the unit, all students in attendance were given a posttest to determine their achievement. As with the pretest, students completed the posttest on optical mark scoring sheets which were optically scored. The total number of correct responses was assessed for each student.

Four students and the teacher involved with the project at each school were interviewed. The results of the interviews were transcribed and printed; these results were used to summarize student and teacher impressions of the CAI materials.

The results and discussion of the interview data and the pretest, posttest, and performance data are presented in Chapter IV. Conclusions follows in Chapter V.

Chapter IV

Results and Discussions of Pretest and Posttest, Performance Recordings and Interviews with Students and Teachers

The purpose of this research study was to conduct a formative evaluation of a CAI unit on polynomials using students enrolled in Mathematics 30 in two high schools. During this research, three types of student data were collected: performance data, pretest and posttest scores, and interview data. Interviews were also conducted with the two Mathematics 30 teachers who participated in the study in these two schools.

School Setting

The schools which participated in this project were selected because both had the computer equipment necessary for using the Mathematics 30 CAI materials. At each school, the CAI materials were loaded onto two Macintosh Plus[9] file server[10] computers linked to two Appleshare Networks[11]. A class set of Macintosh Plus computers was linked together by the network enabling information contained in the CAI materials, to be distributed to each of the students using a computer.

Each student was given a system disk which was used to start up the computer and then to connect to the network and get access to the CAI materials. The system disks were also used to store each students' performance data. The performance data for each student included student responses and latency times that corresponded to their progress through the course.

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9 The Macintosh Plus computer is produced and distributed by Apple Computers, Inc., 20525 Mariani Avenue, Cupertino, California 95014.

10 "An Appleshare file server is a Macintosh Plus, Macintosh SE, or Macintosh II computer with one or more hard disk drives that is part of an AppleTalk network system and has AppleShare File Server software installed." (p. xi) Apple Computer, Inc. (1988). AppleShare File Servers Administrator's Guide [Computer program manual]. Cupertino, CA: Apple Computer, Inc.

11 The Appleshare Network is produced and distributed by Apple Computers, Inc., 20525 Mariani Avenue, Cupertino, California 95014.

Each laboratory, at both schools, had two networks of computers with half of the computers in the laboratory connected to each network. Student use of computers was restricted to one network because each system disk recognized only one of the networks. When it was necessary for a student to move to the other network, assistance from a teacher was required to set up the disk and sign on. While it would have been technically acceptable for students to use any machine as long as it was on the same network, students were encouraged to use the same machine for the duration of the research.

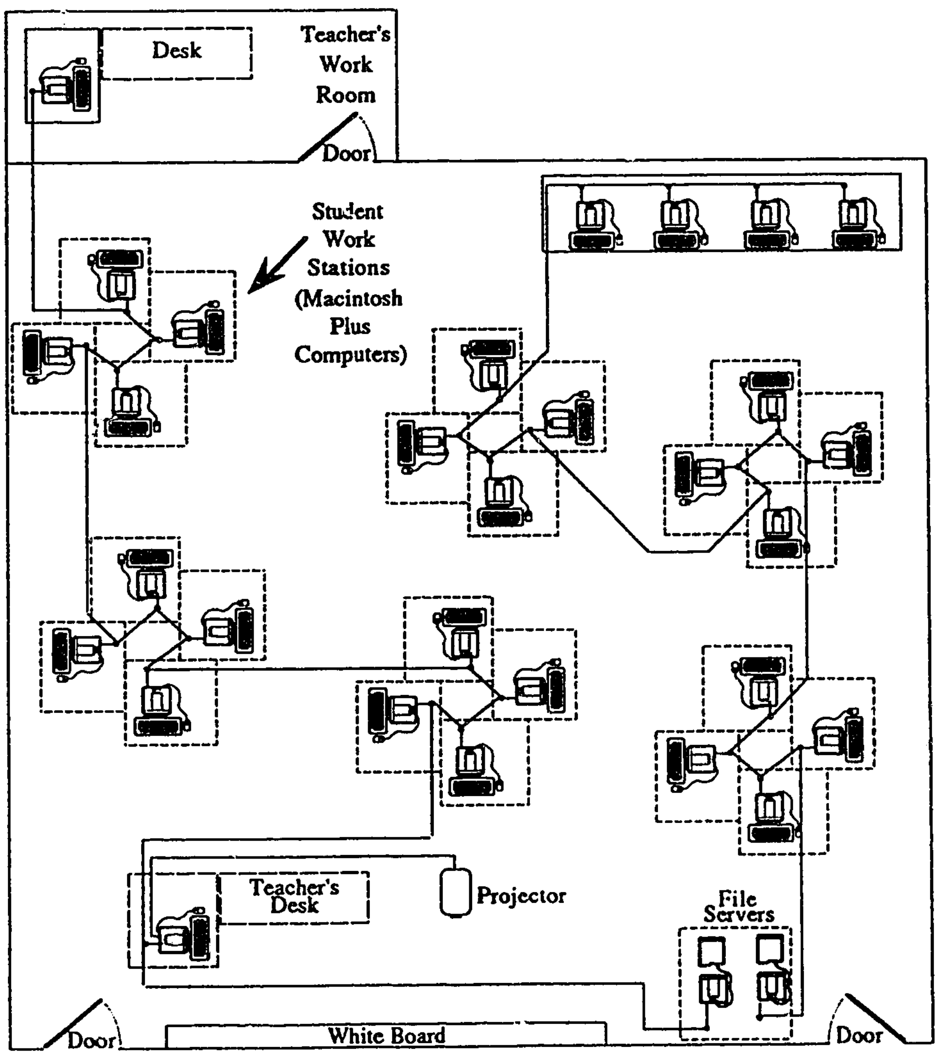

Figure 1. The arrangement of computers in school one's laboratory.

In school one the computers were grouped in clusters of four computers back to back and at an angle of 90° to each other (see Figure 1). These clusters were placed in the room so that student movement between the computers was easy. Interaction between those students using computers in a cluster was also particularly convenient due to the arrangement of the computers. If students encountered problems it was possible to easily access the people in one's cluster and get assistance. It was also noted that friendship groups attempted to sit at the same cluster of computers when this was possible.

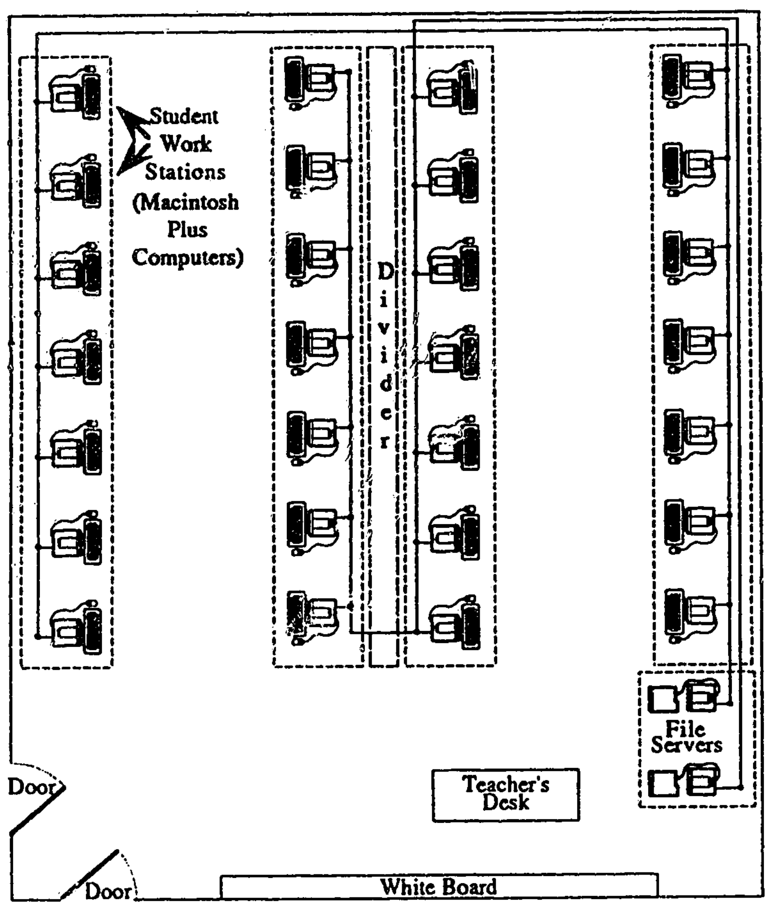

Figure 2. The arrangement of computers in school two's laboratory.

In school two, the arrangement of computers was different (see Figure 2). The computers were organized in four rows with two rows of computers facing one side wall and two rows facing the opposite wall of the laboratory. This arrangement allowed for student interaction which was not confined to students in a particular cluster of computers as it was in school one. Students' interactions in this setting tended to be within friendship groups between rows and across computers.

Performance Data and Test Scores

In order to collect student performance data, students were provided with a system disk on which the data were stored. The performance data consisted of student responses while using the CAI materials, the time elapsed while making these responses and the path taken by students through the materials. Only the time data were analysed. This analysis involved calculating times for each student for each topic. The total time for each topic included the time to take the lesson, and the time taken completing the practice exercises. From values calculated for each student at each school, a mean total time was calculated. The mean total times for each of topics 0, 1, 2, and 3 are reported for the two schools combined. The mean total time for topics 0, 1, 2, and 3 respectively were 25.21, 65.54, 37.96, and 59.37 minutes. For school two, the mean total time for topic 4 was 100.42 minutes. The mean total time for the entire unit (the sum of these preceding figures) was 288.50 minutes. From these values it is clear that the topics are not equal in length and some topics require far more time than others. A table of these values appears in Appendix A. In regard to this total time it should be noted that this total time is about 4.8 hours. If Alberta Education's time estimate for the unit of 10% of the 125 hour course, or 12.5 hours, is accurate then this amount of time is very fast for students to complete the unit. However, in discussions with the mathematics teachers at these two schools it was clear that 12.5 hours was not usually spent on this unit when the Polynomials unit was taught by traditional methods.

The pretest score for each student was calculated by adding the number of correct responses for each of the 33 multiple choice items. The pretest mean at school one was 45.2% and at school two was 39.1%; the pretest mean for the two schools combined was 42.1%. The score on the posttest for each student was calculated by determining the number of correct responses for each of the 35 multiple choice items. The posttest mean at school one was 52.2% and at school two was 64.8%; the posttest mean for the two schools combined was 57.7%. By looking at these scores there does appear to be an increase in scores from pretest mean to posttest mean. Traditionally, a t-test would have been used to compare the mean on the pretest to the mean on the posttest. However, this was not done because the pretest and posttest were different tests. The pretest was designed to determine students' entry ability; the posttest was designed to assess the students' achievements while using the CAI unit.

The preceding results may indicate that students achieved gains during the period of the treatment. However, these possible gains must be interpreted cautiously because many factors may account for them. One possibility is that students learned the material from the information provided to them in the CAI materials. Other possibilities are that the students used the textbook provided by the school, the review sheets provided by the teacher, the booklet provided by the researcher, or their own resources to achieve gains on the posttest.

The pretest scores show a slight difference between the two groups in that the school two group had a lower pretest mean. However, the group from school two had a higher posttest mean score. A comparison of the difference in posttest mean is not possible because data regarding completion of topic 4 for the students in school one are not available. It is possible that some students did not complete the final topic. Therefore, we cannot truly compare the mean posttest performance of the students from school one with that of the students from school two. It is possible that the two schools simply had different students who responded differently. Attrition may possibly account for these differences. Another possible explanation for the difference in mean posttest scores is that different versions of the CAI materials were used by the two groups of students. A further possibility exists that students' reactions to the tests were different, with one group 'taking the test more seriously' than the other group. Since it is impossible to determine which factor(s) may have caused this effect, these possibilities need further study.

Introduction to the Student and Teacher Samples

All students who participated in the study were in grade 12 and enrolled in Mathematics 30. The two mathematics teachers were mathematics specialists who had taught Mathematics 30 previously and were teaching Mathematics 30 at the time of this study. Questions were asked of each student and teacher regarding their computer and mathematics experience. Four students at each school were interviewed. The student interviews were conducted after students had completed using the CAI materials. The teacher interviews were conducted after teachers had reviewed the CAI materials and had interacted with students using the CAI materials.

Students From School One. The four students were Barb, Jan, Martin and Donald; all were in grade 12. Barb was comfortable with the use of a computer; therefore, using the CAI materials did not affect her feelings towards computers. She had never used a computer teaching program before. She was a good mathematics student although it was no longer her strongest school subject. She had taken Mathematics 20 about one year before entering Mathematics 30.

Jan was comfortable with the use of a computer, and thus using the CAI materials did not affect her feelings towards computers. She had never used a computer teaching program before. She stated that mathematics "is my worst subject. I don't catch on to it easy. I have to be taught it over and over again and have lots of practice." Jan had taken Mathematics 33 in the previous semester before taking Mathematics 30.

Martin was comfortable with computers, although initially not with the Macintosh computer because he had not used one before. However, after using the Macintosh computer, he was comfortable with it. The use of the CAI materials did not affect his feeling toward computers, although the experience may have affected his feelings toward the use of Macintosh computers. He had used a computer teaching program before to learn mathematics in grade five. Given the length of time since that use and the difference between grade five and grade twelve mathematics it was too difficult for him to compare these experiences. However, mathematics was one of the subjects with which he was comfortable. Martin completed Mathematics 20 the previous year.

Donald was comfortable with the use of computers and stated that "all a computer really is, is just a tool. It depends on what's in it, the program." The use of the CAI materials did not affect his feelings toward computers. He had used a computer teaching program before but it was a long time ago so he was unable to compare it to the Mathematics 30 CAI materials. Mathematics used to be one of the subjects Donald felt comfortable with, but his marks have been "going down hill" since grade 10. Donald had taken Mathematics 30 before and was repeating the course this term.

Students From School Two. There were four students who were interviewed in school two (as in school one); they were Carol, Paul, Mark and Cindy. All of these students were in grade 12 and enrolled in Mathematics 30. Carol was the only student who had not used a computer before this experience and was not initially comfortable with the use of the computer. However, after using the CAI materials she was very comfortable with the use of the computer. This experience had positively affected her feelings toward computers. The other students were all comfortable with a computer before using the CAI materials so no effect on their feelings toward computers was experienced as a result of these materials.

Carol was a good student in mathematics but she has found the CAI materials difficult to understand and "get through". She had completed Mathematics 30 in the previous semester. However, as the result of a trauma she had lost much of her memory of previous mathematics courses. She was enrolled in Mathematics 31 and through this course and a second try at Mathematics 30 she was recovering much of what she had lost.

Paul was comfortable with the use of computers and used computers as much as he could. He had used a computer teaching program while in junior high, but it was a long time ago so he could not recall the details. Mathematics was not one of the subjects with which he felt comfortable. Paul had taken Mathematics 33 before entering Mathematics 30.

Mark was very comfortable with the use of computers as his family had a number of computers at home. The use of the CAI materials did not affect his feelings toward computers. He reported that he had used a computer teaching program before to "test out" some materials intended for children's use by his father's business. These materials were not really teaching programs but questionnaires or games which were not very similar to the Mathematics 30 CAI materials. Mathematics was one of the subjects with which Mark felt comfortable but he indicated he was not a strong mathematics student. He stated that he had taken Mathematics 33 last semester for extra credits but it had helped his progress in Mathematics 30.

Cindy, the fourth student in school two, enjoyed the use of computers, so using the CAI materials had no effect on her feelings toward computers. She had never used a computer teaching program before but liked learning Mathematics this way. She was a strong student in mathematics and other subjects. Cindy entered Mathematics 30 after completing Mathematics 20 last year.

The Teacher Sample. Terry, the teacher at school one, was confident that he could work with a computer, but was not particularly comfortable with computers. He had not enjoyed the use of computers in the past because he had found that computers saved hours of work in some areas but "give you hours of work on places you didn't expect to do it."

Despite Terry's lack of comfort with computers, he had used computer programs to teach with and was comfortable with this process. He had not used a "fully integrated program like this one" before, but used a program which allows students to create graphs. He used this program after teaching all the material in class. His rationale for this was that students could "play around with the variables and see how that changes things. They hopefully already have the theoretical background...It helps them review and reinforces the teaching." He said that this graphics program was "not as good as the Mathematics 30 [CAI] program" but he enjoyed its use with students despite its shortcomings.

Dan, the teacher at school two, was a computer network supervisor in his school and was confident and comfortable with computers. He had a positive opinion of computer use as he used a computer regularly. He compared the CAI materials written for Mathematics 30 to the Plato system he used for demonstrations. He thought that both were "very logically sequenced but allow[ed] some flexibility". He thought, however, that the Mathematics 30 CAI materials were different from the Plato system in that they were not as limited as the Plato system. He also thought the Mathematics 30 CAI materials were also more directed toward a topic than the Plato system.

In getting started using the CAI materials and getting the materials installed on the network the two teachers reacted quite differently. This reaction may be attributed to the fact that the first school used an early version of the CAI materials. The teacher from school one thought that assistance or detailed notes were required so that the program could be multi-launched[12] on the network. At the second school this was not a major concern. The materials were supplied along with a User's Guide and the CAI lessons were placed by the teacher on the network without difficulty.

When asked about problems with the mathematics concepts contained in the CAI materials Dan stated that the problems appeared to be "of a puristic nature", and Terry felt

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12 When a program is multi-launched on the computer system one copy of the program is used by many users.

the concerns were "points where interpretation is always sort of a moot point among academic math[ematics] teachers". Although both agreed that the problems existed, Dan said "I don't know whether the concerns are worth spending time on". Terry thought care should be taken and careful attention should be paid "to being accurate to the language".

Discussions With Others and Help

Of the four students interviewed at school one, all discussed the program with students around them. They helped their friends and received help from friends near them. Students were asked if mathematics or computer related problems occurred which necessitated students acquiring help. Barb and Jan responded that they needed mathematics help as well as help using the computer. Martin and Donald said that the mathematics was fairly straightforward, but they needed help when there was "a glitch in the program" or a computer error.

At school two Cindy discussed the program with a friend nearby and the two worked together most of the time. She needed help mostly to review or recall forgotten information. Carol, Mark, and Paul worked mainly independent of their classmates. Carol had not used a computer before, so she thought help was necessary in getting started, but not after that. She thought that generally the mathematics material was clear, although on occasion she wasn't certain about "what to do" and as a result required assistance in the mathematics area. Paul and Mark thought the use of the computer was straightforward and the mathematics self-explanatory. As a result, both received little help from classmates or teachers.

At both schools, most of the students required assistance with conceptual problems in mathematics. Two of the four students interviewed at each school needed some help to understand the mathematics. Therefore, it may be necessary in the future use of these versions of the CAI materials to provide support for students in the form of peer or teacher tutoring and assistance. However, if the CAI materials are expanded and modified to include additional help and correct errors this may reduce the need for assistance from teachers or peers.

The amount of assistance received from classmates and teachers varied between students and schools. At school one, all four students who were interviewed required computer assistance. At school two, only two of four students interviewed required such assistance. Several factors may have contributed to this difference; however, one possibility is that the student samples interviewed for the two schools were different.

A second possible reason may be that the two groups received different introductions to the materials. At school one the researcher explained the program's use and showed students the components and how they were to be used. At school two, students received a students' User's Guide which could be used to get started.

A third possible explanation for varying degrees of assistance required by students was that different versions of the software were used at the two schools. The students in school one used the CAI program which had technical and design problems. This necessitated more assistance for these students. Before using the CAI materials at school two, all known technical and design problems were corrected, which may account for reduced need for assistance by students in using the CAI materials.

Course Design Factors

Students' reactions to specific parts of the CAI materials; namely, screen displays, questioning techniques, concept development and the navigator[13], influenced the way in which the CAI materials were used and have affected student reaction to these materials.

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13 The navigator is a menu that students may use to move around in the program. It allows students to move back one page or many pages or to a particular page and then forward again to return to where they left off.

In addition, the User's Guide and introduction to the program are discussed because they affect the use of the CAI materials.

Displays

Text. At school one, Barb, Jan, and Martin thought that the text on the display screen was usually easy to read. Donald agreed that usually the text was easy to read, but small text was sometimes used in "little notes" on the side of the screen and these were sometimes not noticed and more difficult to read than the rest of the text. All four students at school two thought that the text on the screen was easy to read. However, Carol thought that keeping track of f(x) and P(x) and all the other functions in topic 4 was "a bit confusing". Both teachers thought the text was easy to read.

The amount of text presented on the screen at one time was generally suitable for students at school one, although each student made interesting comments at this point. Donald thought that several times "things started getting crowded" on the screen "and a little bit messy" which made it difficult to determine the order of progression through the screen display. However, this only occurred in a few cases.

Barb thought the amount of text presented at one time was suitable but the total amount of text used "got to be a lot of reading after a while", which was a problem. Jan thought the amount of text at one time was suitable "because you could press return and it would show you a little bit at a time. ... It just put up a paragraph at a time which was good." Martin thought that having to press the return key between each point slowed down the program. On further examination this only occurred when the objectives for the topic were being presented and each point was "faded in and out". This slowed one's ability to move forward which Martin did not like. Martin had a tendency to want to move through the material very quickly. Terry, the teacher at school one, had a reaction similar to that of Martin. He would "just as soon have the whole thing come on. Maybe the students liked it this way but ... if you want to get through things you get into the habit of banging the return [key] perhaps too fast. ... Let the thing get on with it at least."

The amount of text presented at one time was generally suitable for all students and their teacher at school two, but the amount of text in total posed a problem for the students. Carol said she "was floored at first" by the amount of text because she wasn't used to such a large amount. She also was used to learning one concept at a time and then doing activities to "get confident with that before going on". Paul echoed this sentiment when he said there was "too much reading before you got to do something." He thought it "might have been better [to] do some questions in the middle" of the text. Cindy thought that sometimes she was "reading and reading and reading and would forget the stuff at the beginning." She thought it "could possibly have been condensed to get the key ideas across." Mark thought that the amount of text presented at one time in the explanation of synthetic division was too much and he "had to go back and read that again just to make sure [he] got it right." He also thought that it could have been "a little more brief and to the point."

Graphics. In addition to text on the screen displays, there were graphic displays used. The graphics can be divided into two types. The first type of graphic is an icon that appears on the screen to distinguish one section of a lesson from another. These usually accompany titles of sections or highlight portions of information with a section such as the use of the "key idea" icon. These graphics can be thought of as extrinsic to the content. The other type of graphic is intrinsic to the content and involves actual graphs of polynomials or arrows to indicate direction or to add emphasis. Students and teachers tended to approach questions about graphics by talking about one or both types of graphics.

All students at school one thought the graphs of polynomials were useful and interesting. Barb said "the graphs were cool." Martin said they made the concept "a little more interesting"; Jan also agreed. Donald said "When you plotted the points and then the computer drew the graph for you it was kind of intriguing the way it was designed to do that. ... If you watched how it drew the graphs in the other ones you could look at the point and you could basically tell which kind of graph it would be."

Terry, the teacher at school two, thought the graphs were helpful. But he thought they detracted in some cases from the point being taught. He said that the inability to display a "decent curve" when explaining curved functions and tangential cuts of these graphs left some students not grasping "the idea of how a graph flows through the axis as it cuts there." However, he added that "other than that, though for the most part, the graphics were very good."

Donald was the only one to comment on the icon type of graphic. He thought some of the icons helped him to understand the information "like the key idea, the fact that you've got the idea in there to stress the point. ... Other ones I just couldn't seem to draw any reference to. ... For the most part they seemed like decorations to liven it up a bit. ... They weren't useless, but they weren't helpful really. They were just kind of there."

All the students from both schools thought the graphics did not detract from the point being taught. At school two, all students and their teacher agreed that the graphics were helpful in understanding the information. Carol thought "they just made it possible to see what was going on."

Animation. The use of animation, motion on the screen, was generally helpful to students to clarify the concept being taught. Jan "thought that [animation] was neat." Barb thought it "broke the monotony of reading." Donald thought it clarified the point when it drew the line or curve and showed how it would be drawn. He also liked the garbage compactor in which the student placed polynomials that were not functions with integral coefficients. He thought "it stresses the idea that you were throwing it out, that's not the one you need." Martin thought that the use of motion didn't clarify the concept being taught but it did add interest, although he "didn't learn anything from it." However, he thought it was worth keeping in for interest sake.

Martin, Jan, and Donald thought the use of motion was never confusing, although Donald thought it was slow when used to indicate movement from one question to another in topic 4. Barb did find the motion confusing "the odd time", but she repeated those sections and understood the concepts. She would have liked to see more use of motion on the screen.

The teacher at school two, thought the "dissolves and fades" and other "graphic trickeries" were probably overdone. He thought they would be "okay here and there", but thought they "can be overdone, particularly when they are set at a very slow speed." He was concerned that students may become bored or disinterested because of the slow pace of progression through the materials caused by the special effects.

The reaction of students at school two to the use of motion on the screen was mixed. Paul thought the motion did not help to clarify the concept being taught, but he said it wouldn't matter if motion was removed from the program. It didn't confuse the learning of a concept but it didn't enhance the learning either. Mark, on the other hand, thought the graphics did generally help clarify concepts. "You can watch it and see where it's moving instead of just flashing on." The motion was never confusing to him. Carol echoed Mark's reaction when she said "It moves things across so you find out where things came from. They don't just throw it at you and say figure it out." She also did not find the motion confusing. Cindy found the motion helpful and not confusing.

It appears that the majority of students thought the motion was helpful to clarify concepts and to add interest. Only Paul disagreed with these two ideas. This near consensus may indicate that, in general, animation was useful. This may also show that it is not appealing and useful for all students. It is necessary to consider this when developing CAI materials for student use. It would have been useful to know why one student disliked animation, while the majority found animation useful or at least interesting. It is possible that Paul's extensive background of using computers had brought him into contact with extensive graphics. By comparison, the graphics in the CAI program would perhaps be less novel and less interesting.

Questioning

All students at school one thought that the way that questions were asked was fine. Jan did say that a few times she didn't understand the question. This occurred later in the course when things "got more complicated" but she asked the teacher for clarification and then could answer the question. Barb also had this experience but felt it was because she wasn't understanding the concept, so she didn't understand the question. Donald and Martin said the questions were straightforward.

Jan and Barb thought there was generally enough opportunity to give answers to questions while using the program. Donald and Martin thought there was "lots" of opportunity; when asked, they said there wasn't any excess of requirements for answers during questioning.

Terry, the teacher at school one, thought the questions were generally fine. He thought there was adequate opportunity for students to interact with the computer by providing answers. However, according to Terry, a few questions gave some of the students problems. He believed that "referring to an equation as having zeros ... detracts" from the correctness of questions.

Dan, the teacher at school two, thought that in general the questions were effective but "sometimes the wording was confusing." He added that the "content was fine. You've done quite well with that." In addition, he thought there was enough opportunity for students to give answers and interact with the program.

At school two, Carol, Mark and Cindy, on occasion, found the questions confusing. On several occasions, Carol found that she was unsure of what was expected of her. Mark found this to be a problem when the answer was five-halves and he entered

2.5. The computer continually displayed an error message, but didn't inform him of the error. He thought the addition of a statement of expectations or accepting decimal responses would have solved the problem.

Cindy found rhetorical questions a bit confusing because she thought she was supposed to enter an answer. This was especially a problem when she was in the practice exercises and answering questions when a question was presented, but which she was not supposed to answer. Paul did not express concerns about the questions.

Paul and Mark thought there were enough questions to answer to maintain their involvement. Mark commented that "at the end it always lets you fill in the questions asked. That was enough." Paul, however, added that it would be nice to have the questions interspersed within the lesson. Carol also thought the proper placement of question sequences could have improved the materials. She wanted an example, then some questions, and then more examples, followed by more questions. She also wanted more questions to answer. Cindy also thought there could have been more practice questions, but she would make the additional questions optional so that a student who understood the material would not be forced through these additional questions.

Feedback

The remaining questions asked of the students and teachers focused on feedback received after responding to questions. For Donald, the type of feedback and amount of feedback provided was enough to let him know when he was correct or when he was wrong. He said "it wasn't really much like fireworks or anything like that but it would say *Yes, you're right!* ... or if you were wrong it would say *No, try again.*" The other three students at school one had greater concerns about the feedback component of the CAI program.

Jan said she "didn't know why it popped up the answer all of a sudden because she wanted to try a little bit more ... or if it would give you a little hint, a way to figure it out, not give you the answer. ... If you just get the answer you don't know how to get it." She preferred a step-by-step explanation of how to get the answer when she had problems. She said that when the computer directed her to "check the sign", it helped.

Martin thought the hints were "simplistic". He said "If you had to take a hint it said 'just try this answer'. It didn't say 'try to factor'. ... [Hints could be presented in stages] hint number one, hint number two... ." He thought the feedback to correct responses were "just like a little check. ... I didn't need a big celebration on the screen or anything." He would have liked to have seen more feedback that showed him how to proceed and not just the answers.

Barb said "I didn't like the way when you asked for help they gave the answers so you couldn't figure it out for yourself. ... If for the help, instead of giving the answers, they'd give an extra little hint." She also would have liked questions after each example "because then you know that the concept that they just finished teaching you is to apply to these types of questions so that when you see it again then you'll know to use that [process]."

Terry, the teacher at school one, thought that for "some of the hints it would be nice if they gave you a parallel question or something like that. Something to get you onto the direction instead of a hint 'try 5' which happens to be the answer." He said that the feedback that was given was "clear and concise" although not particularly helpful. He suggested that a set of simpler examples be provided which would "remind" students "of various little factoring techniques" and other mathematical techniques required for completion of the questions. Provision of a "simpler example and guidance through it" may assist a student in completing questions that are difficult.

Dan agreed with Terry that there were problems with feedback in the form of hints. He said "More directed prompts would have been helpful. Some questions did provide a staged response when they [students] were given a hint. But the majority of the help responses were simply the answer. ... In some cases the progressive answer needed to be the steps to the right answer as a response to a wrong answer as opposed to just the right answer."

Cindy, one of Dan's students, agreed with his reaction and stated that:

> when it [questions] had the little 'I don't know pad' if you got the answer wrong it would print up the answer. It may have taken you one answer to try to figure out what they were asking and then the answer came up and you really didn't have the opportunity to answer. If there is an 'I don't know' then the computer shouldn't have to put up the answer unless you ask for it.

Mark expressed a similar sentiment. "If you asked for help it sometimes would just give you the answer straight out. It would say 'the zeros are 1, -1 and 3'. It would have helped if there had been some way it could have showed you 'maybe this' or 'try it this way' instead of giving the answer straight out." Paul said he'd like to be given a chance to think about the possible correct answer before being given the answer. When only the correct answer was given as the feedback message, he tried to work backwards from it. But he thought the chance of error existed when this process was used and it would have been better if the appropriate steps had been displayed.

Concept Development

Related to the process of questioning is that of concept development. Terry, the teacher at school one, thought that the CAI materials did not take too much time while developing an idea. He felt that "we pushed the kids to go through it fast" and they did "because we encouraged them to go through it fast. But even if they had gone through it slower I don't think it [there] was enough meat there for the kids to learn the topic well enough. They need more problems to work on" and more examples. But then, "what happens is you push the kid even faster to finish it in the time period and it becomes self-defeating."

Terry had concerns about the lack of student control of rate of progression through the CAI materials. He described the use of the program as follows: "When you're on a roll you want to move through an area but of course you can't because you can only go as fast as it [the computer] is going to churn through this." He adds "When you want it to slow down, well yeah, it slows down but it doesn't really add extra things in to help you in the area you are finding difficult. It just means that the page sits there longer in front of you. ... There are areas where you are very definitely sitting there waiting and there's not much you can do about it."

Donald, in agreement with Terry's statements, thought that the course took too little time to develop an idea. He thought the materials were adequate to get the ideas across. Conversely, Jan thought that sometimes the materials had too much "gibberish" that wasn't needed. She would have preferred less written messages and more showing of how to do things. Martin and Barb both thought that the program moved too quickly through on some ideas and concepts. However, Barb thought sometimes she just got tired of reading as the reading seemed to "drag on". In these cases she says more examples and greater interaction would have been helpful. Martin did not get tired of waiting for the program to "get to the point", as it moved so quickly. Jan thought that the introduction which told her what the program was going to do was less desirable than just "getting to the program." Donald thought that he had to wait a bit for the program to return to the menu when he completed one topic in the unit and wished to move on to the next, but this was the only time he thought waiting for the program was problem.

At school two, all four students thought the CAI materials did not take too much time to develop an idea. However, all four students thought that sometimes they got tired of waiting for the program to 'get to the point'. Carol attributed this to her previous experience in the unit when she said "In the first section I knew the stuff so it just seemed to go on and on." Mark said he "skipped through it if [he] already knew it." Paul thought "a couple of times it was too long". He would have preferred to move on rather than waiting. Cindy thought sometimes the program gave information which made her ask of the program "what are you trying to tell me?" She thought these presentations could have been "shorter and more precise." She said "Instead of explaining a whole bunch of things and then saying 'and now this is what we have been trying to tell you and now here are some examples. Do you wish for more information? ... If you still misunderstood then maybe you could ask the computer for more information and more examples and maybe a different way of showing it to you."

Dan summarized the student opinions well in his statement that there was "too much detailed information to be processed in written form before we see anything like an example. About that there is some concern." However, he felt that the time taken to develop an idea was "not excessive in comparison to the amount of time we would spend provincially." He indicated that the topics, as outlined by Alberta Education, were "a bit excessive no matter how you look at them."

Carol, Mark and Paul had no suggestions for improving the materials. Dan described the materials as "a very standard sort of conservative presentation of the topic" and "very logical". In fact he said that these materials were "far more logical than the typical textbook" and "far more sequenced in order with the Alberta Curriculum." He thought there were sufficient examples, in most areas, and in "one or two instances" there were too many. But he emphasized that "it's the student's option to read them. They don't have to spend a lot of time on them."

At school one, Donald thought the program could be "spruced up" with the use of color. Jan, like Cindy, wanted "less writing and more showing." Barb thought point-form notes might be more helpful and easier to go through. Martin described a chess game at home which he used: "When you play it you can show the computers thinking and put it up on the screen and it will show all the possible moves." He would like to see something like that in the mathematics materials. For the questions, have the examples available. He thought it would "remind you" and it could be "more repetitive."

Martin and Barb thought that sometimes more examples would have been helpful and that there were never too many. Donald thought the number of examples were appropriate. Jan thought that sometimes there were too many examples, but not often. For the most part, the number of examples was appropriate. Cindy, Mark, Paul, and Carol thought the number of examples was appropriate, but Carol thought more practice would have been helpful.

Examples

Students were told that "The examples generally just showed you how to do the problem." They were asked by the researcher "Would you have liked it if the program asked you questions as part of the examples?" Martin and Barb answered affirmatively. They thought the procedure would keep them more involved with the instructional materials. Donald wanted to see some examples first and then be presented with exercises. Jan wasn't sure she'd like to have to answer questions when she was learning the materials. She wanted "step by step" descriptions of what the CAI materials had done in each example.

Terry, thought that greater interaction in conjunction with the examples might have been useful for students who have difficulty with certain concepts. He would have placed these examples in a section which was not required by all students. He would force students with problems to go through these examples and base the decision as to which students were having problems, on their need for hints in answering questions and the number of errors made in answering questions. He would not make this interaction compulsory for all students, because it would increase the amount of time necessary for the more capable student to complete the course and in so doing may frustrate the student.

Paul and Carol thought that questions within the examples would have kept them more involved and therefore, would have been helpful. Cindy also expressed this opinion. She commented that in the last topic there were some examples with embedded questions and she liked those "because that way I got involved. I was participating with the computer. I wasn't just reading and not really digesting what I was reading. ... It had me paying attention more to what was going on." Mark, however, liked the program the way it was.

Dan thinks "a detailed example is appropriate without requiring input" upon initial introduction to a method. He clarified "If two examples are given, the second one might have been interactive in some way."

Other Solutions

Students were asked "If more than one way of solving a problem is possible, would you like to see these other solution instead of just one solution?" Both Donald and Jan thought this would be helpful but their reasons were different. Jan thought that one solution may seem simpler than another, so showing more ways to solve the problem might help. Donald thought that this would be useful because sometimes a student may think of a correct solution that is different from the computer solution but may think this solution is wrong because the computer doesn't display this particular solution. Showing more than one solution may alleviate this problem. Barb thought it would be helpful but might increase the length of the program and the amount of time it takes to complete the course. Martin wanted the quickest solution.

Terry thought that the section on synthetic division was a good example of how more than one solution could be used to solve a problem. This section "showed both methods and then just concentrated on one. If you show both of them [solutions] all the way through, students who are trying to learn these things, will just be confused."

Carol thought that one solution may sometimes be confusing but another may be more clear. Both Mark and Paul thought the presentation of more than one solution would be useful but emphasized that the exact same question must be used when showing different methods. Cindy also reacted positively but emphasized that the program must "clearly state that this is just an optional way of doing it." Dan agreed with Cindy that these different solutions must be alternatives. He would have placed these extra solutions "in an appendix possibly. ... An approach taken by some of the commercial software is just to provide an option for some screens which leads to a more complicated or alternate approach. If they [the students] don't want it, they don't have to look at it."

Navigator

The navigator is a portion of the program which allows a user to move backward in the program either one page or to any previous page. As part of this facility, the student can leave named bookmarks to 'jump back' to. The student can also enter remarks anywhere in the CAI materials; these are saved by the CAI materials for use by the researcher.

The navigator was used by Donald to move back in the material to look at previous examples so he could correctly answer the questions. Barb used the navigator to review material she had just read or if she did not understand the material, to move back and reread the material. Martin tried to use the navigator to go forward, but since this was not permitted he did not try to use it again. Jan did not make use of the navigator. Neither did her teacher, Terry.

Of the students at school one, none left bookmarks and only Donald left remarks on those occasions when the program wasn't working as he had expected. Terry also did not use bookmarks and left remarks when he encountered problems.

All four students at school two used the navigator to move backwards to previously encountered material. However, Mark used it only when he had finished and "was messing around." Carol, Cindy and Paul all used the navigator to go back one page. Carol went back to reread material she had read previously. She navigated back upon restarting the program to review material encountered the previous day. She also used it to go back and read information she missed when the computer skipped ahead on occasions when she hit the return key an extra time. Cindy also used the navigator when the program skipped ahead. Paul used the navigator to review and move about in the program. He completed each example and then, if he didn't understand the example, he went back and read it over again.

Dan used the navigator to assist students. When they encountered a problem, the students often continued with the program before Dan arrived to assist them. Dan then had them go back to the page where the problem occurred. He noted that he "didn't notice them [students] using it [the navigator] all that much on their own, except when they forgot what they were doing or when they picked up from the previous day."

At school two only Cindy left remarks, on two occasions, to note problems with questions. Dan commented on student use of remarks noting that the students used the remarks option "when encouraged. ... Initially they were making more use [of the remarks option] than later to point out things that they considered needed changing in the program. Not so much to point out improvements in approach but to point out things they considered errors that were not necessarily wrong, but that were confusing to them. Later they considered their available time was going to run out and they were more concerned with their own progress rather that anything else."

Dan did not make use of the bookmarks option and did not know if the other students did or not. Of the four students interviewed at school two, only Mark and Paul left bookmarks. Mark wanted to keep track of where he ended the program each day. Paul used the bookmarks to see how they worked. He entered two bookmarks and then went back just to see if that particular screen would be displayed.

Introduction and User's Guide

At school one, the researcher demonstrated the CAI materials to the students. All four students thought they had learned enough from this demonstration to use the CAI materials. However, Martin had some trouble using the local-area network on subsequent days and suggested that some notes be provided that students could follow to accomplish the startup procedure. His teacher, Terry, was provided a copy of the User's Guide. Terry said "I sat down a couple of times, thinking I would read the whole thing [User's Guide] this time, but I never got past about a page and a half of it." He used "a little bit here and a little bit there" but never did use the entire guide but said he didn't need to because "so much of what's in the guide is actually available on the computer so you don't really need it [the guide]."

At school two, the students were given a students' version User's Guide to help them get started with the program. As mentioned earlier, this student version was like the original User's Guide but had a series of diagrams at the beginning to indicate the startup procedure. In addition, much of the information provided in the original User's Guide which was not needed by students was removed from the student version. All students at school two, thought the information provided in the Guide was sufficient. Mark said he didn't even need the Guide because a friend helped him start using the CAI materials. The only suggestion for change came from Cindy, who thought an explanation of how to use the calculator in the computer should be provided so that students could make greater use of this feature. Their teacher, Dan, did go through the User's Guide, probably because he was not introduced to the program by the researcher. Dan said that the Guide "was useful for anyone who had not used the Mac[intosh] before for parts that weren't program specific. It was not essential." He commented regarding the student version of the User's Guide "The modification that you made to produce a couple of introductory pages I think would be appropriate because if someone were to start this from scratch they would have to start somewhere."

Reaction to the Materials

All students were asked a series of questions about their reaction to the materials. The reactions to the materials were quite different for students from school one as compared to those in school two.

All students were asked whether or not they enjoyed using the Mathematics 30 CAI materials. Barb, from school one, responded "Not really", adding that she found the material "hard to understand. I had to go home at night and reread everything in that little book and take notes myself." By "little book", she refers to the print correspondence materials, provided to students, which contained most of the same material as in the CAI materials.

When asked if the CAI materials affected her feelings toward mathematics, Barb responded "Yes. I was getting frustrated." She added "I just need somebody to show me step-by-step. ... I just can't relate to a computer teaching me." When asked it she thought a computer was a good way to teach and learn Mathematics 30 she answered "no". She said "the teacher just does it step-by-step instead of having everything printed out. ... They write it gradually so that you can see the steps."

Would Barb recommend the use of the CAI materials to friends who wanted to complete Mathematics 30? She said that if her friends really wanted to use the CAI materials then she would recommend it, but not if they were struggling with mathematics. Barb struggled with the CAI materials despite the fact she is a strong mathematics student. She responded that she may have struggled because she had not taken mathematics for one and one-half years and may have forgotten a great deal. Barb thought she needed to review her previous notes from Mathematics 20. She thought that the CAI materials did not provide enough review for her, especially in the areas of factoring and expanding polynomials. She thought the program "jumped right in" to the mathematics material and she was left saying "Wow! Where am I?"

Jan, also from school two, reacted to the program differently than Barb. On the first day, she found the program difficult although "kind of neat". The graphs were enjoyable, but after a while she "got kind of sick of [the CAI materials]." She thought the CAI materials were "good" because she "could get help" but there was a lot to work through, so she was required to make notes. She also made notes from the book. She thought the program was a good way to teach and learn Mathematics 30, as long as help was available from the mathematics teachers or other students. She also thought that student help was not always sufficient because students don't always know the answers; teacher help was deemed necessary. She would have preferred regular classroom instruction over the computer CAI materials because she finds mathematics difficult and found she needed someone to help her learn mathematics. She explained "the computer can't sit there and try to explain it to you in different terminology. It just has this one explanation. That's why a teacher can help." She would recommend the use of this program to friends wanting to complete Mathematics 30 only if they were good at mathematics. She said "It can be fun if you are good at math[ematics]."

Martin, also from school one, did not enjoy the use of the Mathematics 30 CAI materials. He said he "felt tempted to just whiz through it and then you have to work harder to try to understand." He said "he didn't really enjoy mathematics that much this week". He usually enjoys mathematics more than he did while using the CAI materials. He missed the one-to-one relationships developed in a classroom and also had some difficulty visualizing the concepts. He thought that using the computer was a "good way to review [material] and [to receive] help but ... it's not a substitute for a teacher". He did not feel that the computer was a better way to teach and learn Mathematics 30 than the regular classroom. However, he would recommend the use of this program to friends wanting to complete Mathematics 30 for home study, for continuing education, or for review. When asked if the CAI materials could be used instead of a class in Mathematics 30, he replied "it would need a better textbook to go with it." Rereading one explanation over and over again is not what is needed when student misunderstanding occurs. Alternate explanations, or the same ones reworded, are what is needed.

Donald, from school one, thought the program was "okay. There wasn't anything wrong with it" except for some programming errors which he mentioned several times. He said he "never really did like mathematics but [the program is] a change of pace instead of sitting there and listening to a teacher. ... It was a refreshing change". He thought the computer was a good way to teach and learn Mathematics 30 "as long as there was a teacher there who knew how to use the computer and who could help you out in trouble spots."

Since Donald had taken Mathematics 30 in a regular classroom he was asked to compare this to the computer experience. He thought this experience with the CAI materials was easier for him because he'd taken Mathematics 30 before and he "knew basically what [he] was supposed to do." He wasn't sure it would be easier if he used the Mathematics 30 CAI materials after only taking Mathematics 20. He would recommend the use of the program to friends for "extra help". He also said "you could use it instead of a teacher as long as there was a teacher who knew what was supposed to be going on and could help you out with questions. ... I'd like it." He also thought that it could be used alone if a user's manual or reference guide were provided to "tell you what you are supposed to be doing".

It appears that this group of students did not get much enjoyment from the program and thought that assistance from a teacher was essential to effectively use the CAI material. However, they all would recommend the use of the materials to others, provided teacher assistance was available and those using it wanted to do so and were sufficiently capable in mathematics to handle it.

Carol, a student at school two, enjoyed the use of the CAI materials and thought "it was fun. I could understand it." This resulted in a more positive reaction to mathematics which she says is "usually boring". She thought that the computer was a good way to teach and learn Mathematics 30 "as long as a teacher [was] there to help in understanding." Carol thought that using only the computer to complete Mathematics 30 might also get boring. Possibly doing both, that is, using a computer and being in a regular classroom, would be the best arrangement. She recommended the use of the CAI materials to friends. She said "it's so different. It gives you a new perspective and a new way of thinking about doing it."

Paul thought the program was "all right". He said "the computer way [of teaching and learning Mathematics 30] is pretty good. With computers it's pretty well self-explanatory." He preferred using the CAI materials to the regular classroom because he could "go back and review" material which would be less possible in a classroom. Paul would recommend the use of this program to other students because he prefers it to regular classroom instruction.

Mark thought the program was "pretty good". He thought that he paid attention when using the computer, but often was distracted by other students when in a regular classroom. The program made "it a bit more fun to come to math[ematics] class." He thought the computer was a good way to teach and learn Mathematics 30 and he would like to do another unit by CAI materials rather than do the unit in a regular classroom. He thinks he'd possibly do better with the CAI materials because he'd pay attention.

Cindy liked using the CAI materials to learn mathematics. She liked working at her "own speed". She said "I like to have a teacher around to help but I liked doing most of it on my own." She liked having help when she needed it because she "might have gotten frustrated" if she had to do it all at home. She said that the method of computer presentation "might be a better way for students who like to work on their own, but for students who need constant teacher supervision they might not like it." She also said "I think it would be neat to possibly do the whole course [this way]." She would recommend the program to friends wanting to complete Mathematics 30. "Instead of taking it by correspondence [she'd] say [to] take it by computer, it's better."

The reaction of students in school two was positive toward the CAI materials. All four students would recommend the use of the computer to friends and all would like to do more of Mathematics 30 by using the CAI materials. It seems that despite differences in students' mathematics background and perceptions of computers, these students were positive about the experience.

Both Terry and Dan, the teachers at the two schools, thought that using the CAI materials to teach their classes was a good and positive experience. However, both thought the CAI materials could not be used exclusive of classroom teaching.

Terry said "It's a nice supplement." In his discussions with students he felt students "didn't seem that keen on it. They actually prefer, by their voice count, traditional spoon feeding to having to read it off the screen...They didn't like having to do the work on their own. They said they had to rush through it too fast." Despite student reactions, Terry would use the unit again with his class but in a modified form. He feels he would "pull pieces" of the program together with his teaching and use it "for a couple of periods or half-periods." Terry also commented about his students

> I would say, in this group, maybe one student in five is a self-motivated and disciplined student who is probably at least as well off and maybe better off to do it on the computer. He can take it in his own time frame. He can take it by himself and he can work through things at his own speed. It does cater to a person that has those kind of motivations and abilities but for the student that doesn't really accept that, doesn't want the challenges or basically needs the verbal feedback to any questions he has, the computer doesn't offer it.

Dan thought that a "percentage of the time" in Mathematics 30 could be used for computer presentation of information. He said he "would be uncomfortable with an entire five month block to do the entire course." He added that he thought

> the computer was as good a way to teach and learn Mathematics 30, if not a better way, given a fairly structured topic. I think some interaction, doing some sections in classroom time would help and then maybe doing more [by computer]. I base that on some of the questions I am getting. These students have gone through sections of the program and obviously have missed a primary or secondary point and yet are still working on questions and doing reasonably well. In class we could catch thi[illegible] to get the best of both worlds should be the focus. ... For some instances, for some individuals, [using the computer] would be better [than regular classroom instruction] but not for all. For kids who like to work at their own pace and are sufficiently literate [this would be better]. ... This is always a concern with any materials of this kind. The reading ability determines the success.

Dan would use the CAI unit again in whatever form seemed to fit his course because he thought that his students reacted positively to use of the materials, but some students expressed concerns. Although these students were frustrated while using the CAI materials, they were some of the same ones identified by Dan as frustrated in his regular classes.

Open-Ended Questions

Likes. The students and teachers were asked what they liked most about using the Mathematics 30 CAI program. Jan said she found it fun sometimes and liked doing the graphing. Barb also found it fun and "different from the classroom work." Martin and Donald did not answer this question. Terry "liked it" and thought the CAI unit was "a good attempt to take the polynomials unit in Math[ematics] 30 and put it into a sequenced, self-directed learning [package] available to students. I think it's a good opening but it definitely needs some work yet. ... For those kids who ... work through the program, for whatever reason, on their own ... it's a nice option available to them. ... I don't know how useful it's going to be in a regular classroom" but for "a school where you have totally individualized instruction time" it may be more suitable.

Mark thought the program "broke the monotony of sitting in class and writing notes [copied] off the blackboard. It made it more exciting to go to math[ematics] class. We were doing something nobody else is [was]. It was fun." Carol thought it was different. She was not used to using a computer, but found it enjoyable. She liked some of the graphics and the things that made it fun. Cindy liked working at her own pace and doing it her own way but also emphasized the teacher's help when she "got stuck". She wouldn't want to use it without teacher assistance. Paul thought mathematics was easier to do on the computer using the CAI materials and liked the fact that it was "up to me to get the information and make sure I learn."

Dan "liked the students' ability to move at their own pace and to be forced, for the bottom third [of the students when grouped by ability], into doing and following sequentially through a thought to get through a particular idea or topic as opposed to just going to exercises without being concerned about what they were learning or supposed to be doing. ... Even though it seemed that there is a fair bit of teacher input as far as individual questions, they do have the opportunity to have their questions answered directly by the program--whether moving backward or forward or having to sit there and think for a few minutes to answer their question. That is the strength of CAI in general."

Dislikes. Students were asked what they disliked about the CAI materials. Barb said she disliked the amount of reading and "not really understanding the concepts." She also missed "having a teacher giving notes on the blackboard." She found it was necessary to take home the book, which accompanied the computer materials, and make notes from it in order to understand the materials. She thought she would not have learned as much if she had not done this.

Jan thought that there was "too much writing and unnecessary stuff in there." She also disliked the program when it presented an entire problem all at once. She preferred a step-by-step approach. She discussed the program with her mother who thought that it was "kinda neat". But Jan's concern is simply to "do well in the course."

Terry said "I was disappointed by the [amount of] time [spent] waiting because the network is [was] slow. Also the bugs in the program were a problem. There wasn't anything else. It was basically well done." However he would recommend the use of this program to his students "as a resource. ... They may enjoy using the computer to do the math[ematics]. I would want to let them use it instead of the text[book]. It would also be useful for students on vacation if the student can do the program on his own. It might also be used as another option for students who want more [mathematics instruction]. It basically would be useful for individuals, but not [for] classes larger than 10 [in size]. In those situations, there will be stronger learning in class." He was also concerned that "students spent so much time learning about the program [CAI materials], not the math[ematics], and this assumes a knowledge of the math[ematics] which is probably not there."

At school two, Paul could not think of anything he disliked about the program. He "thought it was really good." He enjoyed the experience. He would be willing to do another unit by computer if asked to do so.

Cindy disliked the fact that the program "gave a lot of information that you didn't really absorb. ... I found that I was just beginning to get the hang of it and we went on to a new topic or more examples. ... I could have used more practice." She also would complete another unit by computer if asked to do so because she "liked this unit."

Mark disliked the fact that the computer was slow, but feels he may be comparing the speed of the program on this network with twenty-five users, to a computer at home which he alone is using. However, despite the slowness of the CAI materials, he would recommend the program to friends in Mathematics 30 and would "definitely" be willing to do another unit of the CAI materials.

Carol also criticized the program for being a "little bit slow. ... The computer takes so long for your reaction, for your answers to be in. You just sit around waiting and then it goes on." However, she would be willing to do another unit by computer. She also would recommend the program to others in Mathematics 30 because she says "Students in class would benefit from it." She bases this on the fact that "Students in the other class didn't know some of the stuff and it was surprising I knew all this stuff. They asked me questions and I knew the answers. It's a good way to learn."

Dan said "I don't have any major dislikes. The program works quite well. Nothing really stands out. There are a few errors, rough edges, I guess, but nothing serious." However, he made recommendations for the use of the program: "As far as for individual students, it would depend a lot on the student. Some would make out better than others and get more out of it. I would certainly think that if I have the opportunity to do a portion of the course on computer that I would use it." He would suggest it to a student who couldn't fit the course as opposed to recommending correspondence. He thought it was better than correspondence materials "without question! Any student that was working individually for any reason, [for example, if] they were sick for a month or were trying to fit in a course that wasn't available to them, this would be far superior to correspondence lessons. . . . If available, it would be very appropriate" to use this unit with students who had been away from school, even if the class weren't doing this unit on the computer. "Given the chance, I would make sure that all students in the course were comfortable with the program so that they could use it" and had the necessary skills to make use of the program independently. He would then use it "for certain students" who needed the extra material. "It would be useful for remedial, as well as first time exposure. Its [the CAI materials] major strength in comparison to other things that are available is that it's matched to the curriculum very well. There are other things out there, but by the time you figure out where they fit in and try and convince the kids this is the same topic that they are talking about, only discussed from a different vantage point, the point is lost. This will be very useful." The interviewer then asked if there was anything else Dan wanted to add about the experience. He said "Are you doing this for physics? Can I get a job doing this?"

Chapter V

Conclusion

As part of the purpose of formative evaluation, interviews were conducted with students and teachers to determine their opinions of the Mathematics 30 CAI materials. A summary of student and teacher opinions follows. Pretest and posttest scores of students using the CAI materials, as well as the time taken to complete the CAI lessons, were also summarized and discussed. Other factors potentially affecting this study and future research are also discussed. Concluding statements, including suggestions for further research are made as a part of the final section in this chapter.

Summary of Student and Teacher Opinions

The student and teacher opinions, of particular interest, dealt with the types of assistance required by students, the influence of graphics and animation, questioning and types of feedback, sequencing of instruction and questioning, amount of textual material, use of examples, use of more than one solution, use of the Navigator, Bookmarks, and Remarks, and finally, student recommendations to other students.

Assistance required by students. Various types of assistance were required by students to use the CAI materials. All students required some assistance to begin using the CAI materials on the computer. Some of the students acquired this assistance from friends while others made use of the User's Guide prepared by the researcher. Most students obtained assistance, which was provided by the teacher, to solve problems with both the computer usage and the mathematics concepts. Students' opinions indicated that a teacher would be required for future use of the materials. This has implications for implementing these materials in other schools or distant sites where individual students are using the materials. The provision of support for students, for both computer use and mathematics concerns, must be considered when implementing the CAI materials.

Influence of graphics and animation. Most students were impressed by the graphics and animation sequences incorporated into the lesson. The students statements indicated that these sequences either functioned to help them learn the material or as a 'break' from the textual presentation. These sequences were deemed by students to be effective. The majority of the students interviewed were not experienced computer users and the newness of the experience may have influenced this result. Graphics may have been 'less impressive' to more experienced users but this is not verifiable from the data.

Questioning and types of feedback. Most students indicated that they were generally satisfied with the questions asked; however, some students indicated that more questions would have been beneficial. Feedback was deemed effective by some students. A common theme which ran through comments by students indicated that feedback consisting of the display of a numeric answer without a complete solution was ineffective. A student which the researcher observed stated that she felt insulted by this form of feedback because it appeared to her that the CAI designer assumed she was incapable of solving the problem and so was reduced to telling her which key to press.

Sequencing of instruction and questioning. Although the reaction of students regarding the instruction was generally positive, there appeared to be a number of students who desired the sequencing of instruction and questioning to be altered. These students expressed preference for short sequences of instruction followed by questioning before proceeding to further instruction. The assumption made by students was that this would enhance their ability to remember the material and would provide students with corrective feedback earlier in the learning process.

Amount of textual material. There appeared to be a student concern with the reliance of the CAI materials on textual presentation. Students reported that this made the instructional sequences seem long and boring. Students indicated that shorter sequences of text, incorporating graphics, animation and questioning, improved the CAI materials presentation of information.

Use of examples. Although some students felt that the amount and type of examples were appropriate, others expressed a need for a greater number and variety of examples in the instructional sequences. The divergence of opinion may be a reflection of individual learning styles. One way to accommodate this divergence is to incorporate additional examples of varying types. The choice to view or bypass these additional examples could then be given to students. This would allow for the varying needs of the students.

Use of more than one solution. Students expressed favorable opinions regarding the incorporation of a number of possible solutions for each example where this was possible. This might provide additional strategies for students to use when solving problems on their own. One student cautioned, however, that the exact same example must be used so that comparisons between the two solutions could be made. The teachers cautioned that this might confuse weaker students and must be used cautiously and possibly not for all students but only as an alternative for some students who are capable of taking advantage of this option.

Use of the Navigator, Bookmarks, and Remarks. Students did not make extensive use of the Navigator, Bookmark, and Remark menus during their use of the CAI materials. This was possibly due to the fact that students were working under some time constraints and were inexperienced CAI users. More experimentation and possible use of these menus may have occurred if students had used additional units of the CAI materials and for an extended period of time.

Student recommendations. Despite the less positive reactions of students at school one compared to students at school two, all students indicated they would recommend the use of these materials in some form. Responses ranged from recommendations which would restrict the CAI materials to only those students who had strong mathematics skills and really wanted to use the materials to recommendations that the CAI materials be used without restriction.

The CAI materials, as they currently exist, appear to provide adequate instruction to be useful in an educational setting but modifications to the materials need to be made based on concerns expressed by students and teachers that participated in these schools. Through further development of these materials, changes can be incorporated which will optimize their effectiveness.

Student Achievement

Since the mean achievement scores of the students in the two schools were 42.1% on the pretest and 57.7% on the posttest, it could be presumed that some learning took place as a result of the treatment. These results are not conclusive, however, because alternate explanations are possible for this increase. These include 1) attrition- some students who wrote the pretest failed to write the posttest and these tended to be poorer students, 2) greater motivation to do well on the posttest since the teachers 'counted' the marks toward their final grades, and 3) information on the pretest required recall from past mathematics courses which may have been a year and one-half ago compared to the immediacy of recall of information on the posttest. The increase in scores provides impetus for further research in the area of achievement gains due to the CAI materials. More research is needed in this area.

Other Factors Potentially Affecting this Study and Future Research

Many factors affect research when it is conducted in a real world environment. These factors are often considered confounding variables when conducting experimental research. But when a formative evaluation is conducted, it is the purpose of the investigation to discover some of the many influences, or factors, which affect the experience and which may alter the data. These factors, listed below, were not verified by the data but are based on the observations made by the researcher and should be interpreted as such. The factors are deemed important to further research in this area and the interpretation of this study. These factors include: laboratory setting, speed of network and influence of waiting time, teachers' computer experience, student computer background, student personality factors, curriculum placement, and time pressure.

Laboratory setting. In school one, students were grouped together by the computer desk alignment; students interacted with other students in close proximity to them. The amount of interaction between students varied but seemed to be mainly within these computer groupings which may also have been friendship groupings. In school two, the computers were located further apart and in rows; this appeared to have restricted or reduced student interactions. These laboratory specifications may have affected the experience and perceptions of students.

Speed of the local-area network and influence of waiting time. The local-area networks in the two schools were identical before the research project began but between the implementation in school one and in school two the local-area networks were changed by the county. This meant that the local-area network in school one was far slower than the new faster local-area network in school two. The reduction in waiting time when starting a new topic, and when starting and shutting down the computer each day in school two may have meant less frustration for the students. This may have resulted in more positive student opinions of the CAI materials.

Teachers' computer experience. The teachers in the two schools had different levels of computer experience. The teacher in school one had less experience and appeared less comfortable and confident in using the computer. He seemed to be more negative about the project and the experience. In this school, the staff decided to implement the program and this teacher was the only one who had a class of Mathematics 30 students at a time when the computer laboratory was available. As a result, he became involved in the project because of timetabling convenience rather than personal choice. The teacher at school two was interested in and involved with computers and appeared to have a sincere desire to be involved with the project. This difference in the teachers' opinions of the project may have affected the project outcomes. The teachers' opinions seemed to be reflected in the opinions of their students. Students in school one expressed less positive opinions toward both the CAI materials and the study than students in school two.

Student computer background. The majority of the students at both schools did not seem to have extensive computer background. They needed assistance to get started using the local-area network. There may have been some computer anxiety which may have reduced the effectiveness of the CAI materials for those students who experienced this phenomenon. The students also appeared to be very impressed with the animations and graphics. More experienced users may have been less impressed by these animations and ics.

Student personality factors. The students seemed to have different personality eristics and different agendas in the two schools. The students in school one o be somewhat more dependent on the teacher, while the students in school two o be more self-directed. This may have influenced the reaction to the CAI materials in school one in a less positive way and in a more positive way in school two. The students in school one seemed to be more concerned with achievement of grades; students in school two appeared more interested in the experience and learning the material.

Curriculum placement. Students at school one were just beginning Mathematics 30 and had not completed any units from Mathematics 30 before beginning the Polynomials unit as part of the research project. Students in school two had completed two Mathematics 30 units prior to beginning the Polynomials unit used for the study. As a result, students in school one may have felt less secure when beginning the unit because of lack of security in the course. Students in school two participated in this research after completing two other Mathematics 30 units so they had had time to get their 'heads back into mathematics' and appeared more ready for the experience. Since they had been in a classroom with a teacher from whom they had taken notes and learned for several months, they may have been more ready for a change of pace than students just beginning the course.

Time pressure. In school one, students were placed under time constraints to complete the CAI unit in the teacher defined time line rather than being encouraged to take the time necessary to learn the material. This meant that many students in school one probably did not finish and did not carefully consider the material while using the CAI unit because they were conscious of the time constraint. There was also a lack of individualization due to the confines of this time pressure. Instead of individuals being allowed to complete the CAI unit at their own pace, they were required to complete the CAI unit on the teacher specified time schedule. This meant that they could not take more time when they needed it but instead were encouraged to use a steady and hasty pace.

Progression through the materials. The use of the CAI materials involved using five separate topics. When students quit a topic, the following day the CAI materials started again at the same point where the students had stopped, provided that the students started the same topic the next day. If a student was working on topic 2 on Tuesday and on Wednesday, when the student signed back on, the student started on topic 2 then the CAI materials would start the student on the same page as the student had quit the previous day. However, if the student started up topic 3 on Wednesday, before completing topic 2, the computer would allow this action. There were students who did not complete a topic before proceeding to the next topic. This may have been an error on the part of some students. No matter what the reason for the error, the logical progression through the materials would not have been followed. It would be advisable to incorporate a 'driver' which would automatically re-start the materials where the student had stopped and which would move the student forward in the logical sequence. This would alleviate the need for students to remember which topic they were last working on. The addition of an option to move outside the prescribed sequence could be incorporated. This would mean that deviating from the prescribed sequence would then be a matter of choice for a student rather than a mistake. This would help avoid the unfortunate situation in which a student misses material because the student forgot which topic was worked on during the previous day. It would then be interesting to investigate how students use choices about progression through the material. From the results of this research, it is uncertain why there was a lack of linear progression; it is also unclear whether students are even aware of the path they have followed.

Version of the CAI materials. The version of the CAI material used by the two schools may also have affected the opinions of the students because two different versions of the CAI materials were used for this study. When the first was used in school one, certain problems were identified by the students and the teacher. Changes, based on the identified problems, were incorporated into the later version of the CAI materials. The second school used this modified version of the CAI materials. This version, as a result of the modifications, may have been more effective than the earlier version and may account for the more positive opinions of the students and the teacher toward the materials. However, considering the variables which have just been noted above, it cannot be stated conclusively that the changes in the materials produced the effect. Therefore, there is a need for further research to identify whether changes in the materials may account for the perception of more positive opinions of students and teacher. Further research is also needed to determine the effect on students' opinions by the other variables identified above.

Recommendations For Further Research

This research, although preliminary, was of benefit to the researcher even though it was restricted by a limited convenience sample and a lack of control over many factors. Each of these factors which were identified earlier, needs study to determine if the factor has an effect on opinions of users of the CAI materials and to identify the type of effect. Also, a larger and more representative sample of subjects would have enhanced this research project. In addition, the ability to determine, more conclusively, whether achievement gains occur when using the CAI materials would be useful. To study these effects would necessitate access to one or more comparison groups. A research design which enables the use of representative samples for comparison purposes, would enhance future research efforts in this regard. The assessment of attitudes towards the CAI materials would be useful and might be made possible through the use of the semantic differential. Several questions, such as the following, might be answered through future research: 1) Does the type of laboratory setting affect student interactions and thereby affect the use of CAI materials?, 2)What is the influence of the speed of the local-area network and user waiting time upon user achievement and opinion?, 3) Does the teachers' computer experience, or lack of computer experience, influence the way the students react to CAI materials?, 4) Does a student's computer background influence the way the student reacts to the CAI materials?, 5) Does a student's ability to act independently increase the probability of the student achieving greater gains when using the CAI materials?, 6) Does a student's ability to act independently increase the likelihood of a student having a positive opinion toward the CAI materials?, 7) Do reactions of students to CAI materials depend on their placement and use within the curriculum and, if so, what are these reactions?, 8) Do externally imposed time limits negatively influence student opinions of CAI materials?, 9) Does linear progression through CAI materials influence student achievement?, and 10) What effect does the improvement of CAI materials from one version to the next have upon students' reactions to the material?

Implications

Many factors have been identified by this research project which may be important both for teachers who use the current CAI materials and for the developers of future CAI materials. Whether an educator is planning to implement current CAI materials, or modify existing CAI materials, or develop new CAI materials, several factors should be considered. These factors include the needs expressed by students in this project to receive assistance from a teacher, when necessary. In addition, teacher inservice training may assist others in the implementation of new CAI materials.

It appears that the current Mathematics 30 CAI materials are likely not sufficient to be used without a teacher's support. One factor seems clear, teacher intervention during the use of the CAI materials is important. In addition, a comprehensive workbook or instructional material to accompany the CAI materials may enhance use of CAI materials.

Other factors which may appear as less positive elements of the CAI materials include inadequate feedback and insufficient numbers of questions and examples. The students in this study desired brief instructions, followed immediately by questions to help the students to clarify the concepts. Reliance on textual presentation alone for concept development may be a problem, however, greater emphasis of graphics and animation may enhance the materials. In addition, the students in this study indicated a desire for a greater number of examples, and the provision of more than one possible solution to a problem. Use of special features by students, such as the Navigator, Bookmarks and Remarks features, was limited but these features need further study before conclusions about their benefits can be more accurately assessed.

Students in this study 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. The reaction of many students to the CAI materials was one of excitement and interest. This positive reaction, in itself, provides reason for further study and use of these materials. Another reason for interest in further study and use of the materials are the achievement gains students made while using the CAI materials.

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Appendix A

Results of the Quantitative Analysis

All data collected through the pretest, posttest and time calculations were entered into a file on the University of Alberta's academic computing system. The data were analyzed using the SPSSx software program. The descriptive statistics are shown in Table 1 for the time data, and in Table 2 for the pretest scores, and the posttest scores. The time data are also graphically represented in Figure 3.

Table 1

Mean (in minutes), Standard Deviation and Number of Subjects For Time Data From Performance Recordings For All Students in Schools One and Two

Variable	School One:			School Two:			Composite:		
	$\bar{x}$	(sd),	n	$\bar{x}$	(sd),	n	$\bar{x}$	(sd),	n
Lesson 0	6.45	(2.37),	28	5.72	(2.54),	23	6.12	(2.45),	51
Practice 0	16.78	(4.72),	28	22.25	(6.77),	24	19.3	(6.33),	52
Total 0	23.22	(5.29),	28	27.72	(8.18),	22	25.21	(7.01),	50
Lesson 1	25.74	(8.51),	28	35.39	(16.30),	26	29.59	(13.36),	54
Practice 1	34.15	(10.18),	26	38.38	(13.45),	25	2.89	(11.97),	51
Total 1	59.72	(12.69),	26	71.58	(22.94),	25	65.54	(19.21),	51
Lesson 2	11.13	(7.61),	26	12.85	(8.53),	22	11.92	(8.00),	48
Practice 2	21.45	(12.08),	25	31.22	(13.29),	21	25.91	(13.43),	46
Total 2	32.70	(18.12),	25	44.88	(16.48),	19	37.96	(18.28),	44
Lesson 3	12.19	(8.06),	22	30.00	(11.39),	19	20.44	(13.16),	41
Practice 3	41.58	(18.10),	23	39.28	(12.18),	16	40.64	(15.80),	39
Total 3	51.70	(21.56),	20	69.60	(20.57),	15	59.37	(22.69),	35
Lesson 4				28.44	(8.74),	16			
Practice 4				71.64	(19.32),	15			
Total 4				100.42	(24.25),	15			
Total Unit Time				314.20	(92.42)				

Table 2

Mean, Standard Deviation and Number of Subjects For Pretest and Posttest Scores For All Students in Schools One and Two

Variable	School One:			School Two:			Composite:		
	$\bar{x}$%	(sd),	n	$\bar{x}$%	(sd),	n	$\bar{x}$%	(sd),	n
Pretest Scores	45.2%	(13.6),	24	39.1%	(11.2),	25	42.1%	(12.7),	49
Posttest Scores	52.2%	(14.3),	26	64.8%	(14.9),	20	57.7%	(15.7),	46

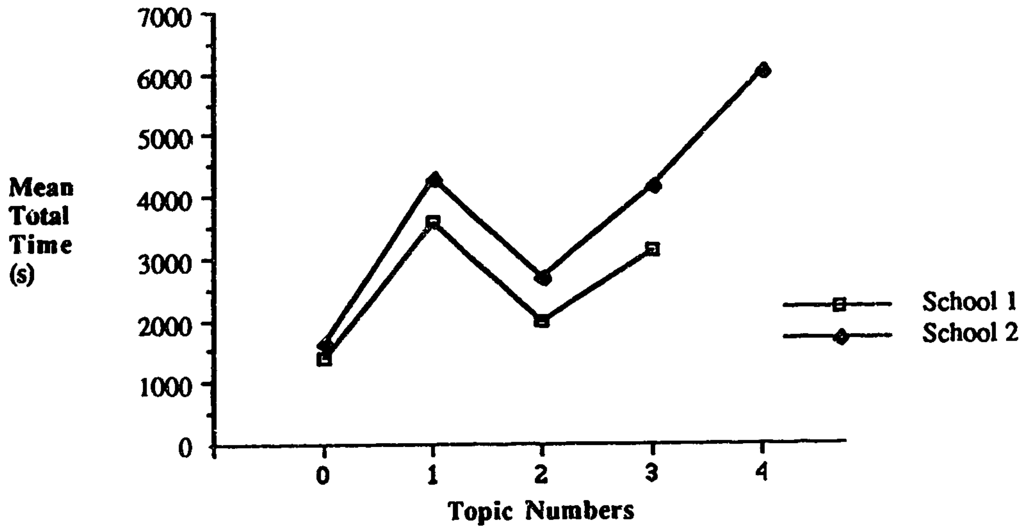

Figure 3. Mean topic total times for all subjects in schools one and two

New descriptive statistics data were calculated based on the restricted sample of only those students who completed all topics in the unit. The descriptive statistics are shown in Table 3 for the time data, and in Table 4 for the pretest scores, and the posttest scores. The time data are also graphically represented in Figure 4.

Table 3

Mean (in minutes), Standard Deviation and Number of Subjects For Time Data From Performance Recordings For The Restricted Student Sample in Schools One and Two

Variable	School One:			School Two:			Composite:		
	x	(sd),	n	x	(sd),	n	x	(sd),	n
Lesson 0	6.44	(2.34),	18	6.09	(2.64),	11	6.31	(2.42),	29
Practice 0	17.17	(4.56),	18	22.06	(7.71),	11	19.02	(6.30),	29
Total 0	23.61	(5.70),	18	28.15	(8.79),	11	25.33	(7.23),	29
Lesson 1	24.68	(8.74),	18	37.16	(13.05),	11	29.42	(12.05),	29
Practice 1	36.17	(10.64),	18	33.37	(13.00),	11	35.11	(11.45),	29
Total 1	60.83	(13.29),	18	70.53	(19.86),	11	64.52	(16.46),	29
Lesson 2	10.23	(4.24),	18	13.94	(10.34),	11	11.63	(7.24),	29
Practice 2	18.69	(10.42),	18	30.15	(15.89),	11	23.04	(13.72),	29
Total 2	28.92	(12.94),	18	44.08	(18.53),	11	34.67	(16.75),	29
Lesson 3	11.37	(8.19),	18	28.44	(13.87),	11	17.84	(13.44),	29
Practice 3	40.67	(17.79),	18	37.04	(12.79),	11	39.30	(15.93),	29
Total 3	52.03	(22.24),	18	65.49	(21.92),	11	57.14	(22.72),	29
Lesson 4				28.80	(9.64),	11			
Practice 4				68.80	(19.66),	10			
Total 4				98.14	(27.08),	10			
Total Unit Time				306.39	(96.18)				

Table 4

Mean, Standard Deviation and Number of Subjects For Pretest and Posttest Scores For The Restricted Student Sample in Schools One and Two

Variable	School One: x% (sd), n	School Two: x% (sd), n	Composite: x% (sd), n
Pretest Scores	44.2% (12.1), 17	47.0% (11.2), 10	45.2% (11.5), 27
Posttest Scores	52.9% (14.6), 17	69.0% (14.9), 8	58.0% (16.3), 25

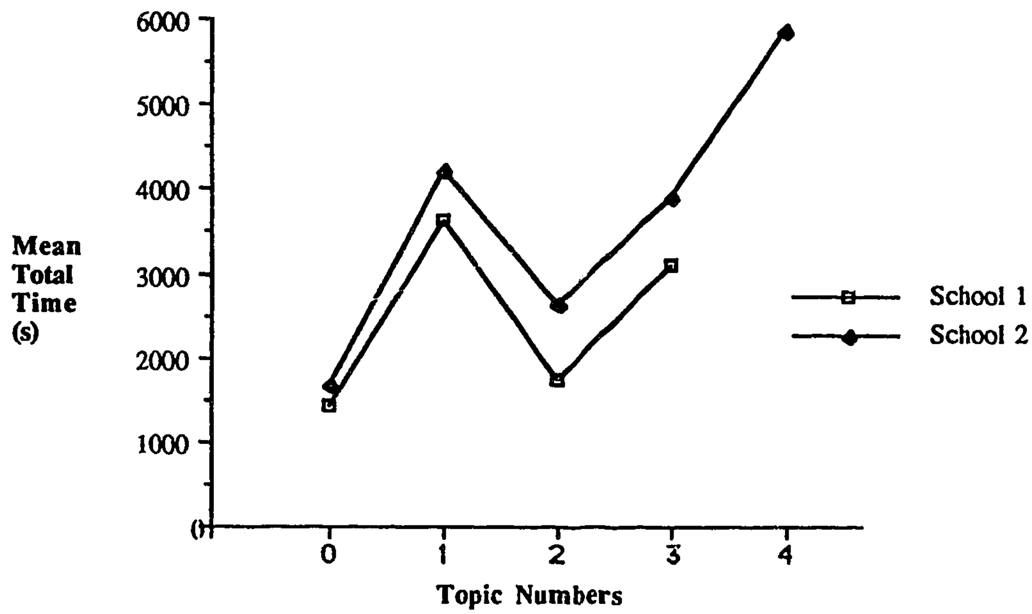

Figure 4. Mean topic total times for restricted sample of subjects in schools one and two

Appendix B

Review of Literature: Attitudes Toward Computers

Introduction

To fully understand the use of computers and their efficacious use for instructional delivery, one must understand user attitudes toward computers because negative attitudes towards computers could inhibit their use of computers and their ability to learn from CAI. There are many influences upon attitudes toward computers. These include one's position in the educational environment -- whether teacher or student, gender -- whether male or female, state of anxiety -- whether anxious or not, and many possible personality factors which may influence one's attitudes.

A variety of attitude measures have been developed; many of these are reviewed here. This review examines attitudes of various groups toward computers in educational settings. Cited are studies from many countries and many educational settings. Various age levels are also considered in this review. However, the use of computers by the elderly has not been dealt with here.

Validating Attitude Scales

Abdel-Gaid, Trueblood, and Shrigley (1986) made the statement that "attitude is ... a construct that must be measured indirectly by self-report of respondents. Therefore, establishing a valid attitude scale is a complex process of statistical procedures and human judgement--both a quantitative and qualitative process" (p. 824). The purpose of their study was to design a systematic procedure for construction of Likert attitude scales.

Generally, the first step in establishing a valid scale is to define the attitude object of interest. A look at the literature should provide a basis for this. Trial statements can then be generated based on the literature. Other statements may added which are based on the researchers' experience with the attitude object.

In the Abdel-Gaid, Trueblood, and Shrigley (1986) study, 70 trial five-choice Likert statements were constructed and administered to 281 teachers similar to the target population. The data were analysed using Likert's item analysis. In order to validate the items on the scale two conditions must be met: "1) Distribution of the data of all respondents on each statement should spread across Likert's continuum in both directions with a low percent responding at the midpoint ... 2) For an item to be discriminating, the distribution of data generated by positive respondents should agree and negative respondents should disagree" (Abdel-Gaid, Trueblood, & Shrigley, 1986, p. 826). Only 23 of the original 70 items met these criteria.

The second step in validating the scale was to correlate each respondent's item scores with the corresponding total score. This procedure was used to select homogeneous items. Using this procedure the 23 items were found to be homogeneous and reliable. As a result, this scale failed to meet the criterion of unidimensionality. This implied that the scale was measuring more than one attitude and posed a threat to content validity of the scale.

To test the divergent validity of this scale, the researchers hypothesized that there would be no relationship between this scale and a Askov-Trueblood Reading Attitude Scale (cited in Abdel-Gaid, Trueblood, & Shrigley, 1986). This hypothesis was upheld with a correlation coefficient of r=.02. To test the convergent validity of this scale, the researcher hypothesized that a moderately positive correlational relationship would exist between this scale and the Trueblood-Suydam Mathematics Attitude Scale (cited in Abdel-Gaid, Trueblood, & Shrigley, 1986). A correlation coefficient of .20 was found, which supports this hypothesis. These two techniques were used to establish the construct validity of the scale. A final step-by-step summary of the procedure for validating a Likert Attitude Scale was presented.

Ellsworth and Bowman (1982) conducted a study to determine if attitudes toward computers items, developed by Ahl (1976), could be used to devise a score of belief about computers. The study involved 38 undergraduate students majoring in computing science who were assumed to have positive attitudes toward computers. The students were asked to respond to the 20 item Likert scale developed by Ahl (1976). Based on the responses of these computing science students, only 17 items were retained as valid. One-hundred and nine students from an introductory biology class were then given the reduced scale. Of the 109 students, 82 took the test a second time to ensure test-retest reliability. The "test-retest reliability for this scale was found to be .85, while internal consistency on the first testing using coefficient alpha was .77" (p. 33). The procedure attempts to validate the items and provide some measure of reliability but more work is needed if these items are to be used to determine beliefs about computers.

Another study which attempts to validate a computer attitude scale was conducted by Bannon, Marshall, and Fluegal (1985). The computer attitude scale was based on six items of their own design and eleven items drawn from Ahl's (1976) study. A five-point Likert scale was used for each item. Respondents to the survey included 2525 participants drawn from 15 urban and rural school districts and one urban university. The sample consisted of 1811 students and 714 educators. It is unclear if this was a random sample. The factor analysis which followed produced two factors, cognitive and affective computer attitudes, with loadings ranging from .30 to .67. No evidence was presented regarding the external validity of this instrument. The data from students, teachers and administrators were combined; therefore, the representativeness of this data is questionable.

The use of unreliable and/or invalid scales of measurement makes the results of any study questionable. The preceding studies have attempted to establish validity and reliability but have not succeeded in the attempt. If research into attitudes towards computers is to proceed by using scales, then the scales must be validated and shown to be reliable before results can be generalized.

Koslowsky, Lazar, and Hoffman (1988) developed an instrument to measure attitudes toward computers based on findings of Lee (1970), Morrison (1983), and Peace and Easterby (1973). A 34 item Likert scale was first employed with 50 subjects in a pilot group in an attempt to establish the validity of the scale. Data are not reported to validate the items. Based on this pilot sample, modifications in wordings were made. The number of items and intent of the items were not changed. A factor analysis was used to group similar items. Names were given to each cluster. Two major factors were identified, the computer as a controlling device and the computer as a challenging machine. However, without further attempts to establish validity and reliability of these items, the results cannot be considered conclusive.

The sample for the main study consisted of 162 first-year students at a university in Israel. Students were asked to complete the revised attitudes toward computers scale. A computer usage measure was determined for each student based on the number of times the computer was used by the student during the following twelve week semester, the total amount of time elapsed in these sessions, and the student-computer interaction time on the computer. Correlations between the three measures were low. The correlations of these three measures with the controlling factor on the attitudes toward computers scale were not statistically different from zero. The only correlation coefficient which reached significance between the challenge factor on the computer scale and the three measures was student-computer interaction time. The results indicate that computer attitudes as measured in this study were, at best, a moderate predictor of actual usage. However, since the validity and reliability of this scale is questionable, the results must be interpreted with caution.

Loyd and Gressard (1984) created a six-response Likert instrument, called the Computer Attitude Scale (CAS), consisting of 10 items for each of the following three subscales: 1) Computer Anxiety, 2) Computer Confidence, and 3) Computer Liking. The validity and reliability of this instrument are not reported and are assumed not to have been established. From a large school district, 155 grade eight and twelve students were selected from computer-based education classes. The strategy for selection of students is not described (but is assumed by this researcher to be non-random). The students were administered the CAS by their teachers. Means and standard deviations were calculated and internal consistency measures were estimated for the three subscales and the total score. "Classical factor analyses with a three factor solution and a varimax rotation were conducted" (p. 503). Without access to the items it is difficult to critically assess the results of this analysis. The validity and reliability of the CAS was attempted, but not established, by this procedure.

Loyd, Loyd, and Gressard (1987) examined three types of computer attitudes of junior high school students using the CAS (Loyd & Gressard, 1984). Five-hundred and sixty-one students in seventh and eighth grade were drawn from three school systems in Virginia. No description of the sampling strategy is provided. The CAS was used to produce scores for subjects on 10 items for each of the three subscales: 1) Computer Anxiety, 2) Computer Confidence, and 3) Computer Liking. Information regarding the students' gender and previous experience with computers was also collected. Factorial analysis of variance procedures were conducted using the factors gender and computer experience (4 levels). Main effects for gender and computer experience were found. Students with more experience were less anxious and females were less anxious than males. Those students with more experience also liked using computers more than did less experienced users. Males with more than one year's experience liked using computers significantly more than did females with the same amount of experience.

The results of this study are interesting in that they indicate that females using computers were less anxious than males. Females, with less than one year of computer experience, liked working with computers more than did males with the same amount of experience. This trend reverses when users have more than one year of computer experience. However, it must be noted that the sample was not a representative one and subject selection may account for these differences. Also, these results cannot be applied to any group outside the confines of the school jurisdictions from which the sample was drawn. The scores used to generate these results are based on the CAS which has not been validated nor shown to be reliable. The results of this study must be interpreted with great caution because of these facts.

Bear, Richards, and Lancaster (1987) used the Bath County Computer Attitude Survey (BCCAS), a 38 item, three-response Likert scale, to assess attitudes toward computer use, computer assisted instruction, programming and technical concepts, social issues surrounding computer use, and computer history (p. 209). The instrument was first administered to 392 students in grades four to twelve attending elementary or high school in a rural school district in western Virginia. The BCCAS was judged to be unidimensional for both high school and elementary school groups of children. A revised survey instrument was constructed of the 26 items with the highest item-to-total correlations. The external validity and reliability of these items however, has not been established.

The revised BCCAS was then administered to 197 elementary and 354 secondary students attending schools in Bath County, Virginia. Means, on the BCCAS, of the elementary children were significantly higher than those of children in secondary school; however, no significant grade level effect was found within either group. Computer experience and attitudes combined to have a relationship with grade levels. Stronger relationships were found in higher grades. Those students in the secondary schools who selected science or computing as their favorite subject and those who planned computer related careers showed more positive attitudes toward computers on the BCCAS. This information supports the validity of the BCCAS.

A random sample was not used so the external validity is questionable. The researchers attempted to validate the items in the survey but their efforts were not sufficient to establish its validity. Therefore, the results of this study must be considered with caution.

Since the preceding studies all are based on samples which are not random and instruments which have not been shown to be valid and reliable, the resulting measures of attitudes towards computers are questionable. The results must be studied further, with valid instruments, in order for statements to be made about student attitudes toward computers.

Anxiety

Campbell and Dobson (1987) described the development of The Computer Anxiety Scale - Short Form from the CAS (Newman & Clure, 1984). A nonrandom sample consisted of 422 students enrolled in four rural and one urban Oklahoma school district in grades four to eight. Classroom teachers administered the CAS and a personal information questionnaire to students in each selected classroom. A factor analysis was completed for responses to the CAS. Two major factors composed of 18 of the 30 items in CAS were identified: fears related to computer-usage skills, and self-concept based on computer skills. Using Cronbach's coefficient, an alpha coefficient of .87 and standard error of 6.08 were calculated. A t-test comparing the mean computer anxiety of boys and girls showed no significant difference. An analysis of variance of the CAS - SF revealed no significant differences among the anxiety levels of the students by grade level. However, since the results were based on a non-random sample, and determined using an instrument which has not been validated, the study results must be considered with caution.

Rosen, Sears and Weil (1987) stated that "past research on computerphobia has been limited to a study of computer attitudes, which are assumed to be directly linked to computer anxiety" (p. 169). These authors question this assumption and devised five studies to investigate this relationship.

CARS (anxiety). However, age was significantly related to the anxiety scale. Having previously taken a programming course was not related to ATCS or CARS. Having taken a non-programming course that used computers was correlated with lower levels of anxiety and more positive attitudes. An extensive analysis was undertaken using analysis of covariance across gender, ethnic group, and academic major, and involving individual item comparisons. The results of this analysis show that the scales have respectable reliability and internal structure. A second result is that although anxiety and attitude are related they are not identical.

A second study was reported by Rosen, Sears and Weil (1987). This study involved 145 students from courses (problem solving and logic, psychological testing, and business computers) requiring extensive computer interaction. All subjects were administered the CARS, the ATCS and the CEDQ as in the first study. In addition, the Bem Sex Role Inventory (Bem, 1984), the State Trait Anxiety Inventory (Spielberger, Gorsuch, & Lushene, 1970), and MARS (Richardson & Suinn, 1972) were administered. These instruments were selected by the authors to detect gender-role identity, state and trait anxiety, and mathematics anxiety. The entire battery of instruments was administered twice, with a ten-week time period between the administrations.

Further evidence for the reliability of the CARS and ATCS was added by the results of this study. The CARS and the ATCS correlated negatively with each other ($r=-.29$). This indicates that those students with the most positive attitudes had the least anxiety. The ATCS, but not the CARS, correlated significantly ($r=.31$, $p<.01$) with the self-rated knowledge score. This indicates that self-rated knowledge is significantly correlated with computer attitudes but not with anxiety. Both the CARS and the ATCS had significant ($r=.62$, $r=.58$, $p<.05$) test-retest reliability. Correlations between computer anxiety, computer attitudes, and physical discomfort subscales indicate that computer anxiety and computer attitudes were related but not identical. Both computer anxiety and attitudes were significantly correlated ($r=.30$, $p<.001$, $r=-.22$, $p<.01$) with physical discomfort; however, only computer anxiety was correlated with math anxiety ($r=.33$, $p<.001$) and feminine gender-role identity ($r=.17$, $p<.05$). Computer attitudes was related to computer knowledge ($r=.16$, $p<.05$), state and trait anxiety ($r=-.17$, $r=.22$, $p<.05$), and masculine gender-role identity ($r=.28$, $p<.01$).

An interaction of gender and major was found for computer anxiety. Males who were science and business majors exhibited more anxiety than did male who were social science majors. The opposite trend is true of females. However, feminine-identity students had higher levels of computer anxiety and were more negative towards computers than did masculine-identity students. These results may simply be due to sampling conditions.

Comparing the pretest to posttest scores resulted in some interesting comparisons. Self-reported computer knowledge increased significantly but no change was evident in mathematics anxiety, state anxiety, trait anxiety, or physical discomfort. No significant changes were seen on the computer anxiety or computer attitudes measures although some of the subscales did change significantly.

Students who expected poorer grades had greater discomfort while using a computer than those who expected higher grades. They also had more negative attitudes, more mathematics anxiety, and more trait and state anxiety but no more computer anxiety.

Studies three and four (Rosen, Sears, & Weil, 1987) investigated the "relationship between computerphobia and computer literacy" (p. 175). Both studies used the CARS, ATCS, and a revised CEDQ (as in study 1) as well as the Computer Aptitude, Literacy and Interest Profile (Poplin, Drew, & Gable, 1984). Subjects were also asked to rate the importance of computer literacy to them, to rate their own ability to use a computer, and to rate expectations of computer usage in future careers and personal life.

Subjects for study three included 105 students from introductory biology, and English courses, as well as from art and psychology classes. Subjects for study four included 60 students from computer science classes. The scales, listed earlier, were administered in a single class period at the beginning of the term. A between-study comparison of results was made. This was a problem since the samples were not equivalent and differed in number of students in each category of age, gender, and demographic group. It is unclear as to which factor the differences found should be attributed.

Students in the two studies had equivalent levels of computer attitudes and self-rated computer discomfort. Students in study three showed lower levels of computer literacy, ability, and interest, and higher levels of anxiety when compared to students from study four. It appears that the two populations were very different. Students in study three showed a negative relationship between computer anxiety and aptitudes and a positive relationship between computer attitudes and computer interest. Students in study four showed a positive relationship between computer aptitude, literacy and interest and computer anxiety. Women showed significantly less interest in computers than men, even though they do not differ in aptitude and literacy. This relationship held even when experience was covaried. It was clear that the two groups were different. If women in science and business were chosen for the study, it is possible that the same results for women as for men would have resulted. It may not be gender that was significant in these results, but the fact that the two groups were very different in their interest and involvement with computers based on their expected career path.

Study five involved 69 students from a psychology class and a computer class. The CARS and a demographics questionnaire were administered to the students. In addition, the CTS (Computer Thoughts Survey) was created. This survey included 28 self-statements about human-computer interaction. For each item, students were asked how often they had the thought described in the item while using the computer or thinking about a computer. Unlike the CARS, the CTS was normally distributed. The two measures were significantly correlated but not identical. The problem with this method was that the CTS may not be representative of the scope of thoughts actually occurring during these activities. It may be that the particular choice of the items created the desired results.

The results of the five studies taken together reflect a complex relationship between gender and computers. Gender was found not to be related to computer anxiety or thoughts but was significantly related to computer attitudes. Gender interacted with the major area of study on the anxiety and attitude scales. Feminine- and masculine-identity, regardless of gender, influenced anxiety. This may indicate that gender-role identities, possibly culturally based, have an influence on computerphobia. However, the non-representitiveness of the sample limits the generalizability of these results and indicates that although these results are interesting they must be interpreted cautiously because of the sampling constraints. More research is needed into the constructs of anxiety and attitude before more conclusive statements can be made.

Glass and Knight (1988) investigated the relationship between computer anxiety and trait, mathematics and test anxiety. Fifty nine undergraduate students participated in the study. Subjects were selected to be involved in the study based on their scores on the Computer Anxiety Rating Scale (CARS). Thirty subjects with the highest scores and 30 with the lowest scores were selected. Students completed 1) the State-Trait Anxiety Inventory (Spielberger et al., 1970), 2) the Math Anxiety Rating Scale (Richardson & Suinn, 1972), 3) the Computer Attitudes Scale (Loyd & Gressard, 1984), 4) the Computer Experience Questionnaire (Heinssen et al., 1987), and 5) the Test Anxiety Scale (Sarason, 1978). In addition, students reported their SAT scores. Expectations during computer interaction were reported by students. This involved subjects being seated in front of a computer. Subjects were asked to rate, on a scale of 0 to 100, how confident they felt. Half of each group was then given the Checklist of Bodily Sensations (Galassi et al, 1981), a Subjective Units of Disturbance Scale (as cited in Glass & Knight, 1988), and the Self-Statements About Computers checklist (SSAC) (as cited in Glass & Knight, 1988). The other half of the groups were given these measures after completion of the task. Students completed three computer tasks which increased in difficulty but required no previous experience. The SSAC consisted of four types of self-statements: "1) positive evaluations of oneself or the task, 2) on-task thoughts, 3) negative evaluations, and 4) off-task thoughts" (p. 355).

Results of a multivariate analysis of variance to examine gender and group differences on the measures found that the highly computer-anxious had less computer liking, confidence, and experience and less mechanical interest. They also reported more mathematics anxiety and higher levels of trait anxiety and expected to have poorer performance than low anxious students. They also experienced a higher level of on-task thoughts, negative evaluations, and off-task thoughts. They reported significantly more bodily sensations. Low computer-anxious men had lower levels of test anxiety that the other groups. Gender did not appear to be significant in other cases. The validity and reliability of the instruments used for measurement are questionable, as a result, so are the results.

In a study by Morrow, Prell, and McElroy (1986) ten potential correlates of computer anxiety were examined. The subjects for the study were 174 undergraduate college students enrolled in a management class. Attitudes associated with computer anxiety were measured by a computer anxiety scale developed by Raub (1981). The potential correlates considered were 1) computer experience--a single question developed by Raub (1981), 2) computer knowledge--a ten-item questionnaire developed by Howard (1983), 3) ownership avoidance--a single question developed by Morrow, Prell and McElroy (1986), 4) locus of control--a 29-item Locus of Control scale developed by Rotter (1966), 5) rigidity--a 24-item true-false scale developed by Rehfisch (1958), 6) anxiety about mathematics--the Mathematics Anxiety Scale is a 12-item Likert scale developed by Fennema and Sherman (1976), 7) automatic bank teller card use--a single-item developed by Morrow, Prell, and McElroy (1986), 8) typing speed--a single item developed by Morrow, Prell, and McElroy (1986), 9) video game ownership--a single item developed by

Morrow, Prell, and McElroy (1986), and 10) video game avoidance--two five-point Likert item developed by Morrow, Prell, and McElroy (1986).

Correlations between these potential correlates and computer anxiety were calculated using a regression analysis (no details of this procedure were given). Eight of the ten potential correlates were significantly related to computer anxiety ($p < .05$). Only typing speed and video game ownership showed no relationship. Computer knowledge, computer experience, mathematics anxiety and locus of control exhibited the strongest relationships and accounted for 31% of the variation. Although these findings tend to show a relationship, they do not imply causation. A problem with this procedure is the reliability of the instruments and measures which may confound the results. The non-representativeness of the sample means that these findings only can be applied to the group being studied and cannot be applied to any larger population. This restricts the use of this research to develop other studies.

Marcoulides (1988) investigated the relationship of computer aptitude, computer achievement, and mathematics anxiety to computer anxiety with a group of 72 student volunteers in a university computer information course. He measured computer aptitude using The Computer Aptitude Literacy and Interest Profile (CALIP). Computer achievement was established by counting the number of completed computer homework assignments. This may or may not truly represent achievement and may actually be more an indication of time restraints or computer access than achievement. The Mathematics Anxiety Rating Scale (MARS) was used to determine students' perceptions of their anxiety towards mathematics.. A Computer Anxiety Scale (CAS) was used to measure students' perceptions of their anxiety. The means, standard deviations, and correlations of all variables were calculated. The correlation between computer anxiety and computer aptitude was significantly negative. The correlation between computer anxiety and mathematics anxiety was positive. The correlation between mathematics anxiety and computer aptitude was also negative. A problem with this procedure is the lack of data confirming the reliability of the instruments and measures which confounds the results. The non-representativeness of the sample means that these findings only can be applied to the group being studied and cannot be applied to any larger population. This limits the use of the research results.

Since these studies all use instruments with questionable validity and reliability, the results must be interpreted with caution. The lack of random and representative samples also limit the interpretation of the results.

Personality Characteristics

Lieskovsky (1988) conducted a study to investigate the relationship between attitude toward computers and personality characteristics and social determinants. For his preliminary study, Lieskovsky selected 100 Britislave University students (faculty and sampling strategy were not specified) in order to develop an attitude scale. A factor analysis of the data with varimax ortogonal rotation was used. Two factors represented 28% of the data. These factors were fear of computers and rational acceptance. Rational acceptance "represented a tendency to support and use the computers actively. ... The final version of the attitude scale ... [had] chosen items whose loading in these factors was more than 0.40"(p. 118).

Lieskovsky then selected 100 students from the Electrotechnical faculty and 100 from the Philosophical faculty enrolled in the first year of Britislave University. In addition to Lieskovsky's attitude survey, the students were administered 1) the Spielberger questionnaire for the measurement of state and trait anxiety, 2) the Eysenck and Eysenck personality questionnaire to measure impulsivity, adventurousness, and empathy, and 3) the Self Monitoring Scale (Snyder) for measuring social desirability. There appeared to be a significant difference between the two groups of students on attitude, with the electrotechnical students having more positive attitudes. For all students, there existed a significant negative correlation between attitude scores and empathy scores and between attitude and social determination. However, it should be noted that, although these relationships were significant for both groups of students, the relationships were stronger for the philosophy students than for the technical students. No significant relationships were found between the computer attitudes and the level of anxiety. Gender differences were not calculated as the data were confounded by the fact that 86% of the philosophy students were female and 77% of the technical students were male. The differences between the two groups may be explained by gender.

The author noted that the technical students differed significantly from the philosophy students in the level of anxiety, impulsiveness and empathy with the technical students displaying lower scores on each measure. It should not be surprising that the two groups had different scores on the attitudes toward computers because they were chosen to be different. The author has not shown that the personality factors cause the differences in attitude toward computers, only that as one changes, so do the others.

Abler and Sedlacek (1987) conducted a study to determine possible student computer attitude differences depending on their gender and their Holland types. The Holland types involved here are the Investigative and Realistic types (Gottfredson, Holland, & Ogawa, 1982). From a large university, 289 freshmen were selected to complete the Computer Attitude Scale (CAS) (Loyd & Gressard, 1984). The selection of students was not described but is assumed to be non-random. Students also responded to a question which asked them to list their top three vocational goals. Based on these responses, trained recorders assigned students each a Holland code: "Realistic, Investigative, Artistic, Social, Enterprising, or Conventional" (p. 165). Interjudge agreement was 94% and a list of three references were provided to show that valid results can be obtained using this method of assigning Holland codes. However, since the CAS had not been validated, the methodology was flawed.

A multivariate analysis of variance (MANOVA), for the three subscales of the CAS, was completed using gender and Holland code as factors. Significant main effects for the three subscales (Computer Anxiety, Computer Confidence, and Computer Liking) were revealed through the MANOVA. No interaction effect was found. Table 5 shows the Holland type percentages.

Table 5

Percentages of Holland Types For Males and Females

Gender	Realistic	Investigative	Artistic	Social	Enterprising	Conventional
Male	40%	30%	7%	4%	18%	0%
Female	20%	28%	14%	11%	27%	0%

The Computer Anxiety scores showed that women were significantly more anxious than men. Enterprising and Artistic type students were significantly more anxious than Realistic types. Enterprising students were more anxious than Investigative students. The Computer Confidence scores showed that men were more confident than women. Students with Realistic Holland type were more confident than Enterprising, Artistic, and Social types. Investigative type students were more confident than Enterprising and Artistic students. The Computer Liking scale indicated males liked computers more than females. Realistic and Investigative students liked computers more than did Enterprising and Artistic students.

These results were based on students selected by unspecified means, and based on an attitude scale which has not been validated. The method of assigning Holland codes may have been valid but these were based on the answers to one question, which has limited reliability. Interpretation of these results must be made cautiously.

Self-efficacy

Vasil, Hesketh, and Podd (1987) investigated gender differences in computer self-efficacy expectations, computing experience, computer access and application, and intentions to enrol in computer courses. Three-hundred sixty-three students with an average age of 15 years were selected from seven secondary schools in the lower half of the North Island of New Zealand. Two classes of form five at each of the schools were selected. All students who were enrolled in these classes were involved in the study. The schools were chosen to include three co-educational schools and two each of single gender schools. Because of this non-random method of sampling, subjects are not representative of any population. Application of these findings to other populations must be made with caution.

Each student was asked: 1) how likely it was that she would enrol in a computer course in the future, 2) do you have a computer at home, 3) how often do you use a computer, and 4) do you think there is a relationship between ability in mathematics and ability in computers. Student self-efficacy expectations were assessed by the student indicating that she would be able to learn how to perform each of nine computer tasks. Past computer experience was assessed by the student indicating which of the nine computer tasks she had performed. Notice here that the tasks were defined by the investigator and represent a small number of possible tasks that students may have accomplished using a computer. It is possible that this select sample of tasks will bias the results.

Results showed no significant gender differences in self-efficacy. However, significantly more females than males intended to enrol in computer classes. Significantly more males than females reported completing the computer tasks identified in the questionnaire and more males than females had computers at home. Males also had greater access to computers and more frequent use of computers. Despite this significant finding, both males and females believed they had equal access to computers. When asked if ability in mathematics was related to ability in computers, 65% of the students responded no. There were no significant differences between male and female responses to this question. However, since the sampling was not random and the instruments without validation, these results are tentative at best.

Miura (1987) investigated differences between male and female college students in their perceptions of self-efficacy regarding computer-related activities. Students, 368 in total, in a general education course at a large university in California, served as subjects. Gender, year in school, age, major of study, microcomputer ownership, and nonschool computer use were assessed in a questionnaire. Students were asked if they had ever taken a university level computer course. On a scale of one to five, students were asked to rank plans to take a computer course at university, importance of computer skills in their own future careers, and interest in learning how a computer operates. Students were also asked to rate their ability to perform a task, and confidence in this ability (on a scale of 10 to 100). The 15 items were classified as computer programming, computer coursework, or personal use of a computer. Perceived self-efficacy for each of the three sections was calculated by dividing the total confidence rating by five (number of items in each section). Results of this method must be interpreted cautiously as reliability and validity of this method have not been determined.

No significant differences were determined for age or year of school so these groupings were combined for analysis. For gender, no differences were found for access to a home computer or computer use outside of school. The self-efficacy composite score had a significant positive correlation with plans to take a computer science course, importance of computer skills in future careers, and interest in learning how a computer operates, as well as with completion of a high school or university computer course. Men had higher ratings on self-efficacy than women. Males felt computers would be more important to their future careers and had more interest in learning how a computer works.

However, males and females reported significant differences in their reported college majors which may account for different perceptions of career use of computers. Fifty-three percent of men had majors in business or engineering while 51% of women had majors in social sciences and applied arts and science. Males and females had significantly different past and present enrollments in computer classes, with 53% of males and only 23% of females stating past or present enrollment in computer classes. Twenty-seven percent of the variability in the self-efficacy measure was accounted for by college major, high-school computer course, and past or present enrollment in computer science class. The main predictor for women was high school computer classes and computer ownership. These results may be accounted for by the sampling of an intact class of students but cannot be applied to students outside this class, as they only represent this class. In addition, the data collection methods have not been validated and may also account for the results.

Computers and Mathematics

Collis (1987) conducted a study which explored gender differences in attitudes toward computers and mathematics in secondary school students. She used 1818 students in grades eight and twelve enrolled in a school district in British Columbia. Subjects were not randomly chosen but taken from intact school populations. A survey instrument with 28 items was developed for this study based on earlier research conducted by the author (Collis, 1985, 1986) and also on Sandman's (1974) Mathematics Attitude Inventory (Self-Confidence in Mathematics subscale). The instrument was divided into two parts: twenty-four computer attitude items and four mathematics attitude items.

Canonical correlations analyses between the computer and mathematics attitude variables were performed. In each of the four gender by grade groups a significant relationship between the variables was found. This is not surprising since the sample was very large and representing a population of students in the school jurisdiction. For twelfth grade students, 19% of the variance in computer variables was explained by the mathematics variates. For the eighth grade students 12% of computer variance was explained by mathematics variates. Although this level is significant, due to the large sample, it is unlikely that these low levels would be useful in making predictions. Collis failed to report the standard error of the values and did not report the canonical correlation, so it is impossible to determine if the analysis is a valid one. The nonrandom sample which is likely a population means that these results cannot be generalized to jurisdictions other than the one used in the study.

Collis (1987, p. 399) stated "The first canonical variate for the male students indicated that those who expressed feelings of frustration toward mathematics were also likely to express a disinterest in computers." For male students, feelings of self-confidence in mathematics were related to feelings of pleasure in computer use. The Grade twelve female students' feelings of self-esteem in mathematics were related to a mixture of variables including computers were not boring and it would not be hard to learn to program a computer. Analysis of the data for the Grade eight female students produced a relationship between attitudes toward mathematics and computers that was not interpretable due to insignificant results. As with the previously reported studies, the results of this research are questionable.

Gender Differences

Drambrot, Watkins-Malek, Silling, Marshall, and Garver (1985) explored gender differences in computer attitudes and experience (including course completion, knowledge of computer language, intentions to major in computer science, and use of computers). Subjects were 540 student volunteers in a university psychology class. Four instruments were used in this study. These included 1) A Computer Attitude Scale (CATT) which including 20 items on a five point Likert scale developed during this study from general statements about computers taken from previous research and observations; 2) The Fennema-Sherman (1976) Math Anxiety Scale (FS) consisting of 12 items in a five point Likert scale; 3) The Computer Aptitude Scale (CAPT) which consisted of 19 items taken from Konvalina, Wileman, and Stephens (1983), six of which "require a respondent to fill in the missing segment of a series of numbers or letters, four logic word problems, four calculator simulation problems, and five mathematical word problems" (Drambrot et al., 1985, p. 75); and 4) The American College Testing Program Mathematics Test (ACTM) as a measure of mathematics aptitude. The ACTM was not described in the study. Data to show that these instruments were valid and reliable were not described in the study. It is possible that no data exist in support of these instruments.

Scholastic achievement was taken as the high school grades (HGPA) and the college cumulative grade point average (CGPA). These measures are based on a variety of courses taken by subjects and given by a variety of instructors. The reliability of these measures is questionable. A mathematics experience score (EMATH) was tabulated by adding the number of mathematics courses a student had completed in high school.

A computer experience score (ECOMP) was devised by determining if students had a computer-related course, knowledge of a computer language, or neither course nor language. This measure does not represent the full spectrum of computer experience possible. The student who used computer applications (as opposed to languages) extensively on his/her own would be considered inexperienced by this measure.

A multivariate analysis of variance on all measures and a univariate analysis of each variable was completed. The multivariate analysis yielded significant effects for gender. The univariate analyses were significant for all measures except gender. "Males had significantly higher scores on computer aptitude, mathematics aptitude, experience in mathematics courses, and experience with computers. Females had higher mean high school and college scholastic achievement and held more negative attitudes toward computers" (Drambrot et al., 1985, p. 76). Mathematics experience, mathematics aptitude, and scholastic achievement were highly related to the Computer Aptitude Test (CAPT). This is not surprising since the CAPT "was operationally defined as a test to assess the likelihood of success in computer science courses" (p. 75) and it is not unreasonable that success in a computer science course is related to mathematics experience and aptitude and scholastic achievement. Mathematics Anxiety, Computer Aptitude, and Computer Experience were significantly related to computer attitude for the total sample. In terms of computer experience, more males had knowledge of computer languages and more males had taken a computer course. There appear to be gender differences in this sample, however, since the sample is not representative of any group other than this first year psychology course, applying these results to other samples would be unreasonable. In addition, these results were based on instruments with undefined validity and reliability and as a result are questionable.

Drambrot et al. (1985) made the statement that "Women seem to be more negative and more fearful toward computers" (p. 83), but a measure of computer fear was not incorporated into this study. The authors then question whether "negative attitudes have led women to avoid computers and ... explain the greater number of males enrolled in computer classes" (p. 83). There seem to be other plausible reasons, besides negative attitudes, as to why more males than females would have enrolled in computer classes. One possible explanation might be that more males than females are enrolled in programs that require their participation in computer classes.

Chen (1986) surveyed high school students in five high schools to determine computer uses and attitudes. "A random systematic sample of 1,138 students completed the questionnaire. The questionnaire incorporated four categories of information: 1) use of computers in school or out-of-school settings, 2) attitudes toward computers including perceived skills, gender equality, and interest in using computers, 3) interest in, knowledge of, and encouragement of computers among family members, and 4) student background and demographic data." (p. 270).

Based on "bivariate relationships between gender and measures of students' uses of computers" (p. 271), a higher percentage of males than females enrolled in programming courses in secondary school and as the level of difficulty of the course went up, so too the ratio of number of males to females rose. Significant differences were not found in the number of males versus the number of females in courses which used computers, nor were differences found in percentages of computer use before coming to high school.

It appears that access to computers may be different for males than for females. Significantly more males than females reported having a home computer, while no significant differences were found in the number of other electronic technologies in the home. Males used their home computers an average of 6.1 hours per week which was significantly more than females, who averaged only 3.6 hours per week. Males reported higher percentages of use of a friend's computer and of belonging to computer clubs. However, no differences were found between males and females in use of a computer in a public library or a parent's office.

A factor analysis was performed on the attitude items which confirmed the presence of five dimensions of computer attitudes. Males reported more positive attitudes toward computers on the following four dimensions: Computer Interest, Computer Confidence, Computer Anxiety (lower levels here), and Respect Through Computers. The only dimension on which girls scored more positively was Gender Equality in Computer Use. There appeared to have been a contrast in female attitudes between feelings that females should be as capable as males and more negative feelings regarding involvement with computers. However, when experiences were taken as predictors of attitudes, the findings indicated that interest in computers was similar for both males and females. This appears to have indicated that males had more positive attitudes toward computers because of their greater experiences with computers and that when this variable was held constant, no differences were found between males and females. However, when "controlling for similar amounts of experience, males still were more self-confident about their abilities with computers...These findings are consistent with studies of adolescents' attitudes toward mathematics, where males often report higher levels of confidence in their abilities than do females [(Chipman & Wilson, 1985; Fennema & Sherman, 1977)]"(p. 277).

Lower female participation in mathematics is often explained as the perception that mathematics is a gender-typed domain (Chipman & Wilson, 1985). Males undertake its study because of their belief in superior ability and females avoid its study because they believe males are more successful than they will be. If such a belief was held by females in the domain of computer use, then one would expect lower participation in this domain. Both males and females agreed with gender equality of computer use, but females agreed more strongly. When asked if encouragement was received from friends and family, males responded significantly more often that they had been encouraged by friends but no difference was found in encouragement by family.

Kass and Kieren (1986) reported on a large study done in Canada to investigate the nature of computer impact on Canadian youths. The study investigated three main questions: "1. What is the nature of access to microcomputers among Canadian youth?... 2. What is the nature of the values, feelings and important social issues of young persons with respect to computers? How are these related to conditions of access?... [and] 3. Are the experiences with computers and computer related values different at different age levels of youth?" (p. 1-3). The study involved three types of data collection which were inter-related: a large scale survey, interviews, and situational observation interviews.

During 1985, a pilot study was conducted on all three types of data collection. Pilot Study One was used to develop survey items to assess values toward and access to computers. Two versions of the survey instrument were created to allow for a wide range of items. The surveys were administered to junior high school students in Alberta, Newfoundland, Quebec and Ontario. Extensive analyses were completed for each survey based on the data collected.

Based on Pilot Study One, a revised version of the survey instrument, now referred to as Computer and Canadian Society Survey, was developed. It was divided into five sections related to access, feelings, values and social issues. A five item response scale was used. Pilot Study Two was conducted to further refine this instrument. Further data were collected from a convenience sample of 216 Alberta students and 164 Ontario students. Although the sample made it impossible to make inferences, it was used to determine clusters that would be of interest in a national study.

The researchers reported results of this pilot in four sections. Under Access a significant difference was found between access to computers for students enrolled in rural schools as opposed to students enrolled in urban Alberta schools. Rural students had less access to computers than did their urban counterparts in Alberta. Home access to computers appeared to be equal for urban/rural comparisons and male/female comparisons. Under the heading Recreational Use it was found that female students made less use of computers than males only in arcade type settings, but that males were more interested in recreational use of computers than were females. All other differences were not significant. Under the heading Creating and Organizing, it was found that significantly more use of computers was for the purposes of creating and organizing in urban settings than in rural settings and that significantly more of these types of uses were made at school than at home. Females made greater use of the computer for these purposes than did males. Under the heading Learning, significantly more urban students used the computer for learning than did rural students and this use was significantly made more at school than at home. All students saw computers as valuable for learning in Canadian society with no significant differences found between urban and rural students or males and females. In looking at these results we must keep in mind that the sample was one of convenience and no attempt at representative sampling was made. It is possible that the differences that were found in this pilot were simply due to differences in subjects drawn for the sample and not due to urban vs. rural characteristics or gender.

In addition to the pilot of the survey items an Interview Pilot was conducted. A subset of students involved in completing the survey were used for this pilot study. A standardized elaborative technique of interviewing (Pothier and Sawada, 1983) was used to gain information to enhance the information gained through survey techniques. From this information it was possible to determine that students were able to interpret items on the survey; however, these interpretations were not always what the investigators had intended. "Differences in interpretations verify the need for the interview phase in the national study proposed" (p. 6).

The interviews were established to explore the subjects' interpretations of use of computers for recreation, creating, organizing, and learning. To the subjects, recreation seemed to mean the playing of games and boys seemed to indicate that they made greater use of computers for this purpose and got greater satisfaction from these endeavors. Programming was seen by these students to be a creative task and included things like graphics generation and word processing. It was also seen as r[illegible]iring organizational skills. Learning by using a computer was seen by one student as difficult because pressing a button made things happen that were not always well understood by the student. However, drills that were easy to use were considered helpful. Students who had computers with tutoring packages at home felt that they were helpful and liked being able to learn in a relaxed environment at home. There seemed to be the greatest amount of variance in reactions to this question for different students which seemed related to very different experiences of how a computer could be used to assist in learning.

A national study (Kass, Kieren, Collis, & Therrien, 1987) followed the completion of the pilot studies. A national sampling scheme was used to access 120 classes of Grade 11 students (average class size of 25) from urban centers across Canada. The representative sample consisted of 2,808 students. The principle instrument used in the study was a questionnaire based on the pilot studies (Kass & Kieren, 1986).

The results of this research indicated students reported post secondary plans, reported frequency of home computer use, perceived dominant user of home computers, patterns of reported recreational use of home computers, frequency of reported school computer use for recreation, frequency of reported home modem use, reported patterns of home programming, reported task-type use of home computers, frequency of reported use of school computers, reported satisfaction with frequency of use of school computers, reported satisfaction with frequency of use of school computers, reported educational contexts of school computer use, reported quantity of school computers, reported location of school computers, students' perceptions of free-time access to school computers, reported uses of school computers, reported feelings about using a computer for recreation during free time, perceived competence at using a home computer for tasks, expectations of success with school computer use, affective responses to using a school computer, affective responses to using a home computer for tasks, comparisons of feelings when using computers in different contexts, perceptions of social interaction while engaged in computer use, perception of computer competence compared to classmates, stereotypes of computer users, relationships between gender, computer usage, and stereotypic thinking about computer users, and male/female ability stereotypes. It is beyond the scope of this review to discuss the specific data presented in this national study. However, a general summary indicates that:

> computers are truly a ubiquitous phenomenon for Canadian urb[illegible] adolescents. ... Grade 11 urban Canadian young persons are characterized as [illegible] who can and to a certain extent do access computers both at home and at sch[illegible] [Computer] use models for males and females do not differ appreciably in s[illegible] did differ in strengths and orientations. ... Gender differences [illegible] ales use computers more than do females and that more males than female[illegible] continuing computer users. This is the case across the types, at hom[illegible] school. ... Canadian young persons generally have a positive attitude t[illegible]

computers. Furthermore, they generally do not hold gender and social stereotypes with respect to computer users and uses. ... Computers are used for a variety of purposes and in a variety of social environments. There is not a uniform image of the "lone user," with two thirds of Canadian urban youth seeing recreational use occurring in groups in contrast to sixty percent who see the computer being used alone for recreational home tasks. ... In terms of social concerns with respect to computer, the differentiation between concerns adolescents talk about with others and concerns they indicate are of personal importance was supported. ... There are regional differences in their reported levels of computer use and in the personal and social concerns held by Canadian adolescents. (p. 344-346)

Smith (1987) conducted a study to examine attitudes of teachers and students about computers. Subjects were 318 students (from grades one to twelve) and 173 teachers all from a single school district. Intact classroom groups of students were randomly selected for the sample. Elementary and junior high school classes were tested in these intact groups. High school students were selected from intact English classes they attended. As these classes may have been stratified, it is unlikely that this truly was a representative sample of students in the district. The teacher questionnaire explained the purpose of the study and how it was to be completed. Distribution of the questionnaires to teachers was not described. However, teachers submitted their completed questionnaires to the principal of the school. No arrangement for privacy of this information was made.

Two subscales of the Minnesota Computer Awareness and Literacy Test (Minnesota Education Computing Corporation, 1979) were used as the instrument in this study. It was validated using factor analysis with relatively high levels of reliability (Anderson, Klassen, Krohn, & Smith-Cunnien, 1982). The Efficacy subscale was related to enjoyment of, anxiety toward, and educational use of computers. The reliability of this subscale is $\alpha=0.68$. "The Sex-typing scale was selected to measure attitudes reflected in reports of computer access and usage" (p. 482). The reliability of this scale was 0.74.

Questions were also asked to determine grade level, gender, and experience with computers.

A factorial design with three factors was used to assess the data. The three factors were grade level, gender, and group (teacher or student). Based on the Efficacy scale, two significant main effects for group indicated that teachers were less confident in their ability to use computers than were students; elementary students felt a higher sense of efficacy than junior high students and high school students. No gender differences were found. Regarding the Sex-typing scale, a significant main effect was found for gender difference in stereotypes of and attitudes toward computer abilities. Males more often believed in male superiority over females in computer and science abilities. Females held fewer stereotyped views of potential computer abilities and believed more in equity of genders regarding potential computer ability.

A follow-up study is reported by Smith (1987). This study used the same methodology as Smith's first study. Ninety teachers and 331 students from a rural area participated. Schools with cooperative administrators were involved. The sampling involved intact classroom groups and all teachers in the selected schools but no further description is provided by the author. Again the instruments used were the Sex-typing and Efficacy subscales of the Minnesota Computer Awareness and Literacy Test. Results of a factorial analysis indicated that elementary students were significantly more confident than their teachers and students in junior high or high school. In the elementary school male teachers were less confident in their abilities than female teachers. Female students and teachers were more equality minded than males and teachers were more equality minded than students. Two significant relationships occurred as grade level increased: confidence and gender role stereotyping decreased. These findings were based on limited samples which are not random and must be interpreted with caution.

Teacher Attitudes

Madsen and Sebastiani (1987) used a pretest-posttest control group design to investigate "the effect of computer literacy instruction on teachers' knowledge of and attitudes toward microcomputers" (p. 68). Sixty secondary teachers were randomly selected from 90 secondary teachers "in a suburban northeast Pennsylvania School District" (p. 68). The teachers were randomly assigned to one of two groups, experimental or control. The experimental group received a 15 hour long computer literacy training course; the control group did not. The Minnesota Computer Literacy and Awareness Assessment, Form 8 (Anderson, Hansen, Johnson, & Klassen, 1979) was administered to each subject before the treatment started with the experimental group and then again after the treatment was completed. It was used to provide a cognitive and affective score for each subject. The cognitive and affective test items were validated in an earlier study (Klassen, Anderson, Hansen, & Johnson, 1980) by factor analysis and resulted in internal consistency alphas ranging from .39 to .68 for the cognitive subtests and .60 to .81 for the affective subtests.

The analysis of the current study consisted of a two-way analysis of variance and correlations between cognitive and affective gains. Results showed that attitudes of teachers toward computers and knowledge about computers significantly improved for teachers who participated in the inservice training. Subjects who scored high on the initial measure also tended to score high on the posttest, regardless of group. Because of the way the items were assigned values, a higher score for anxiety means less anxiety. For the experimental group, the mean subscale score for anxiety was 3.09 and the posttest score was 4.70. This showed a gain of 1.61 which is a substantial reduction of anxiety. No significant correlation was found between improvement in attitude and gain in knowledge. These results may be generalized to the population of teachers in the county in which the research was conducted. However, generalization outside of this county would be questionable.

Elkins (1985) surveyed 39 special education teachers and eight special education teacher's aides to assess their attitudes toward computers. The items for the survey used a five-point Likert scale developed from ideas taken from the Minnesota Computer Literacy and Awareness Assessment, Form 8 (Anderson, et al., 1979) and from Williams and Williams (1984). The author used percentages to present findings. The unequal number of individuals in each group and the small number of respondents made the use of more stringent methods impossible. The items in the survey were divided into three categories for presentation: Using Computers, Feelings about Computers, and Computers in Education. A higher percentage of teachers than aides were interested in learning more about computers. More teacher's aides than teachers felt computers controlled people. Teacher's aides were less positive than teachers about the use of computers in education. Feelings about computers seemed to be related to experience with use of computers with teachers having had more experience and also feeling more positive. These findings were general impressions but were not verified statistically so interpretations from them are not possible.

Student Attitudes

Bird and Chung (1986) conducted interviews with 48 males and 48 females from classes in a junior high school in Wellington, New Zealand. The students were asked whether they would be able to learn if a computer gave them feedback on a test instead of a teacher and which they would prefer, a teacher giving feedback or the computer giving feedback. The method for collecting this data was not discussed. However, if teachers collected the data, then the results may be simply due to teacher expectations of students. Ninety-four percent of children preferred the teacher giving feedback. Fifty-seven percent indicated that the reason for this preference was the teacher's superiority in explaining. Twenty-seven percent mentioned the importance of the teacher-student relationship. Sixteen percent of this group preferred the teacher because of the students' negative reaction to computers. The importance of the teacher as explainer, helper, and expert in knowledge was emphasized in the affective nature of these interviews.

Computer Assisted Instruction (CAI)

Gray (1987) conducted a study to determine the effect of sequence control in which students had control of branching in a linear progression or to branch to any place in any order while using a CAI program. Students with greater control over sequencing performed better on comprehension tests than students with less control. Gray (1988) conducted a follow up study to this earlier work. The purpose of the study was to compare student achievement and attitudes using two types of sequence control menus (broad versus deep) and two types of decision categories (locational and symbolic). Broad menus presented all options on one menu. Deep menus presented options in three narrowly defined menus. Locational decision categories included a list of the order of the decisions made. Symbolic decision categories assigned a meaningful name to each category. Ninety-six students from undergraduate university sociology courses, as part of their course work, were involved in the study. Subjects were randomly assigned to one of four groups, each having a different menu and decision category type: 1) broad and locational, 2) broad and symbolic, 3) deep and locational, and 4) deep and symbolic.

Each student spent 40 minutes using a software package related to concepts of poverty and inflation in which policy-related decisions were required. Each student received feedback on poverty and inflation in response to his/her decisions. At the end of the session each student was asked to rate the CAI exercise on a five-point scale for each of the following statement pairs: boring-interesting, enjoyable-not enjoyable, educational-not educational, and challenging-not challenging. These measures were combined to form an attitude measure. A multiple choice test on the content of the lesson was also given.

Scores on the multiple choice test were higher for students in the two groups with meaningful menu choices. No significant differences were found between groups using menus that were broad and those using deep menus. Scores on the attitude toward the CAI indicated a main effect for symbolic and locational decision categories but no main effect for broad and deep menu types. Attitude toward the CAI was significantly correlated with the multiple choice test.

The select sampling of subjects and limited amount of time to interact with the program must be considered confounding variables. It is possible to explain the results by any of these two factors and therefore one must be cautious in interpreting these results.

Skinner (1988) measured the attitudes of 36 college undergraduate students in a course taught by three instructional strategies. These strategies included 1) textbook supplemented by CAI which was required, 2) textbook supplemented by CAI which was optional, and 3) textbook alone. The students were divided into two groups with equivalent achievement on a prerequisite course. The first group completed the initial three units using the text and required supplemental CAI while the second group used text and optional supplemental CAI. The next set of two units were completed by text and CAI, but the groups were reversed with respect to required or optional CAI. After completion of these five units, students were given an attitude questionnaire which had five Likert scale questions with additional space for inclusion of comments by students. Students completed the last four units of the course by text alone at which time they were given the final exam and then complete a second questionnaire which asked them to rank the methods by preference. Students indicated, based on percentages of responses to the second questionnaire, that CAI was preferred to text delivery and mandatory CAI was more useful in learning than optional CAI. However, in comments made on the questionnaires, some students indicated that a choice in using all or some of the CAI materials would have been preferred.

This research was confounded by the fact that students were grouped, by matching, on achievement in a prerequisite course which involved the presentation of information by CAI. It is possible that this method of grouping and thus the attitudes determined in this study were influenced by the preceding course and were not truly a result of the instructional differences. Also, it is difficult to accept these findings because they represent a small number of individuals; only 18 students were members of each group. Another problem is that this number represented the entire population of students. There is no group to which these findings can be generalized.

Perkins, Donaldson, and Zimmerman (1988) conducted a study to determine the effectiveness of small group computer-assisted instruction. Mathematical word problems in the form of a CAI lesson called "Read and Solve Math Problems #1" (p.408) were used as content for the lessons used by 92 students. The selection procedures for these students was not stated. Workbooks were created by taking the content of the computer programs and replicating it on paper so that the sequencing and content of the workbook was identical to the computer program. All students were given the Minnesota Computer Literacy and Awareness Assessment Scale (Anderson, et al., 1979) to assess their attitudes toward microcomputers both before and after completion of the lessons. A 15-question test which accompanies the computer program was used to measure achievement both before and after students used the lessons. The validity and reliability of these instruments were not established, thus the data and analysis results must be interpreted with caution.

The students were placed into one of four groups through a matching procedure, based on the attitude survey and the achievement test. The four group were 1) CAI individual - one person using the machine, 2) CAI dyad - two people on the machine, 3) workbook individual - one person using the book, and 4) workbook dyad - two people using the book. Brief instructions were given to students as to their instructional conditions. It must be assumed that these instructions were not constant since some students had to learn to use the computer while others did not. This variance in instruction and possible variance in the instructor and the instructors attitudes must be considered a confounding variable. Students were provided with many classroom sessions as necessary to complete the lessons. There was a large variance in completion time which ranged from three to six weeks. This difference in the amount of time to complete the task is another confounding variable. The computer program recorded the number of correct student responses. Students using workbooks handed in their responses and the responses were marked by the experimenter. There is a potential difference between the two groups in the amount of interaction students had with the experimenter and also in the immediacy of feedback, which are two more confounding variables.

The data collected from the attitude surveys and the achievement tests were analysed using analysis of variance techniques. The mean scores of the two students working together (CAI dyad) were compared to scores of students working individually. This method is questionable and creates difficulty in accepting the results. A significant interaction effect (instruction by grouping by testing) was found for the attitude scores, but when the test condition was held constant, no significant interaction was found on the pretest scores but significant differences were found on the posttest scores. It is understandable that no significant differences between groups were found on the pretest since this instrument was used to match students and create groupings. Post-hoc pairwise comparisons of means using a Tukey test were conducted. It was not specified whether this was a Tukey A or Tukey B test. CAI dyad subjects had significantly more positive attitudes than the CAI individual subjects. This trend was reversed for the workbook users. For subjects involved in dyads, no significant difference was found in attitudes. No significant interactions or differences between instructional conditions were found on the achievement tests. The number of confounding variables present in this research makes interpretation of these results difficult. To what should these differences be attributed, to the treatment of the confounding variables?

Duin (1988) conducted a study to determine if differences in design features in a CAI lesson could influence students' attitudes toward CAI. One hundred and sixteen students, enrolled in a college writing course, were randomly assigned to one of four groups (each with 29 subjects): 1) well-designed CAI, 2) poorly-designed CAI, 3) paper version of well-designed CAI, and 4) paper version of poorly-designed CAI. Although the sampling procedure was not described the author states that prior to treatment "no significant differences were found among the groups on age, teacher ratings, quality of their previous writing, or level of previous computer experience" (p. 49). The author provided a list of guidelines that are generally followed in the well-designed CAI and not adhered to in developing the poorly-designed CAI. The paper versions of the instruction were printouts of the screens of the CAI material. Students using the CAI materials entered their compositions from the keyboard upon a request of the CAI materials. Students using the paper versions wrote their compositions on sheets of paper placed between the screen printouts.

All students were introduced to the computer system to be used in the study by instructors in the course, but no mention was made of controls on the instructors' effect on the outcomes and learning. It is possible that different instructors had different effects on the outcomes or that the same instructor had views that may have influenced the success of students in different instructional groupings.

Observations of students' computing behaviors were recorded by two trained observers with an inter-rater reliability of .88. Scores on students' prewriting were tabulated by trained independent raters. These raters placed papers into four nearly equal groups of poor, satisfactory, good, and excellent prewriting and gave each paper a score of 1 to 4 based on the pile they were in. The prewriting was marked holistically based on the suggestions of Cooper (1977). It is possible that the results found in this study were simply reflective of the different modes of composition and not the CAI at all. It was not stated whether the papers which were handwritten were typed so that they appeared the same as the students' typed responses. It may be a confounding variable if markers were given both typed and hand-written compositions and asked to rate them. It would be obvious to raters, in this instance, which treatment condition the paper came from and thus the ratings may have been effected. Students responded to a questionnaire which asked students to circle responses concerning the CAI or written materials usefulness to their later compositions, the visual effectiveness of the materials, and the conceptual level of the materials. The questionnaire was not validated by others, so this may effect the validity of the findings.

The students using the well-designed CAI worked through the exercise with a faster response time, enjoyed working with the CAI significantly more, and had significantly higher quality prewriting than did students using the poorly-designed CAI. "All groups indicated that they had received understandable instruction and that the level of the information, writing tasks, and tone of the exercise were understandable and appropriate" (p. 53). However, 86% of students receiving the well-designed CAI responded that the visual representation was good or excellent, while only 31% of those using the poorly-designed CAI responded favorably.

Conclusion

These many studies reviewed have found interesting results. However, caution must be used in applying the findings as most studies did not report sampling frames or use random sampling. Many instruments were specifically designed for the study and did not include validation and reliability data. As a result, conclusions of a summative nature seem inappropriate. If the lack of controls and instrumentation controls were ignored then general conclusions could be drawn. These conclusions might include statements like the following: Computer attitude and anxiety are related but not identical. Both of these factors are related to physical discomfort when using a computer. Those students who expected poorer grades had more discomfort than those expecting higher grades. The highly computer-anxious liked computers less but also had less experience with computers. They also showed higher levels of math anxiety.

Abler and Sedlacek (1987) showed that women were more anxious than men. Vasil et. al. (1987) found no significant differences in self-efficacy, but Miura (1987) found men had higher scores on self-efficacy than women.

Experience with computers was different for men and women (Drambrot, 1985; Miura, 1987; Vasil, 1987) with women generally having less experience in programming and less access to computers at home. Chen (1986) reported males had more positive attitudes toward computers but when their greater experience was covaried out, there was no difference in attitude.

Kass and Kieren (1986) found rural students had less access to computers as compared to their urban counterparts in Alberta. Females made less use of computers in arcade settings but greater use of computers at school for creating and organizing. Urban students used computers more for learning than did rural students.

Teachers were less confident in their ability to use computers than were students (Smith, 1987). Elementary students were more confident and had a higher sense of efficacy than junior high and high school students. Male elementary teachers were less confident than females (Smith, 1987). Teacher attitudes toward computers were improved by participation in inservice training (Madsen & Sebastiani, 1987). A reduction in anxiety also resulted.

Elementary students felt that the teacher-student relationship was important and would not be enhanced by computer usage. This was of concern to them (Bird & Chung, 1986).

Computer usage for CAI was perceived positively (Gray, 1987) but control of its use was preferred by students (Skinner, 1988). CAI was also perceived more positively by students working in pairs than by those working alone (Perkins, Donaldson, & Zimmerman, 1988). This may be dependent on the task. Not surprisingly, well designed CAI was more well received than poor CAI (Duin, 1988).

These are general statements based on specific findings of limited samples from studies using methodologies with poor control of confounding variables and using study instruments for which validity and reliability data are generally not reported or not present. The results of these studies cannot be applied to populations outside those which were studied. However, no evidence of negative attitudes have been provided by the research reviewed.

The methodologies used in these studies are flawed in most cases so are not useful in the design of future research. As a result, this researcher has decided to use other means, besides quantitative study using survey or measurement instruments, to determine the perceptions of students and teachers toward CAI. Given the state of the field, based on the reviewed research, this seems to be a reasonable decision.

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