IMPLEMENTING COMPUTER ASSISTED INSTRUCTION IN THE MATHEMATICS CLASSROOM: EFFECT ON STUDENT ATTITUDES AND THE TEACHING PROCESS

BY

KATHARINE D. TETLOCK

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A Thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

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Abstract

This study investigated the effects of using a curriculum-based CAI program in the mathematics classroom. The study examined how the teaching process changed when implementing such a program, and the effect that such a program had on students' attitudes toward computers and toward mathematics. Teacher report forms were developed to help the teachers reflect on their teaching behavior, and on the impact that the software had on their teaching, as well as on the students. These reports were qualitative in nature and were completed throughout the duration of the study. Questionnaires, consisting of Likert-type statements, were developed to assess students' attitudes toward computers and toward mathematics. The students also responded to two open-ended questions where they indicated what they liked the most and what they liked the least about using the software in their mathematics class.

A major change in the teaching process was that of a significant role change - the teacher became a facilitator in the learning process. Another major change in the teaching process was in the type of preparation that was needed. Extensive time was spent previewing the software before using it in the classroom. Also, teacher activities focusing on hardware and software issues in the classroom were new additions to the teaching process. Decisions on pacing and when to supplement the software with instruction presented new challenges to the teachers. The students' attitudes toward computers did not show any significant changes over the course of the study. However, student attitudes toward mathematics showed some significant improvements at the completion of the study compared with the beginning of the study.

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Chapter One

INTRODUCTION

There have been recent developments in computer assisted instruction (CAI) software for mathematics which have radically changed the delivery of mathematics in some classrooms across the country. Notably, this software is curriculum-based, i.e., based on an established curriculum for a specific subject and grade level, one of the characteristics which Kaput (1992) says was missing in earlier CAI software. The software puts the student in control of his/her own learning (in a pre-defined course of studies), one of the important goals put forward by the National Council of Teachers of Mathematics (NCTM) in Curriculum and Evaluation Standards for School Mathematics (Standards), 1989. Thereby, students are actively engaged in the learning of mathematics, rather than passively listening to a teacher lecture, as so often occurs in high school mathematics classes (Everybody Counts, 1989).

There is no question that technology has dramatically changed our world, and no one can accurately predict what the future will look like. But according to Kaput (1992), few mathematics classes use technology on a regular basis. A careful look at the sessions being offered at NCTM's Central Regional Conference in March of 1994 might make one believe that technology is not a top concern of mathematics educators. Nevertheless, one extremely important factor in the level of implementation of technology in the classroom is the degree of acceptance by the teacher (Ellis, 1984). How to increase that degree of acceptance is an important question that needs to be addressed.

Purpose of the Study

The statement that students learn more and do more mathematics with a computer is, according to Kaput (1992), not worth questioning since "computational aids overall do a better job of converting a child's intellectual power to mathematical achievement . . . The real questions needing investigation concern the circumstances where each [type of technology] is appropriate" (p. 518). The purpose of this study was to examine the effects of using a curriculum-based software package in the mathematics classroom. Accordingly the investigation sought answers to the following two questions:

1. What changes take place in the teaching process when a program of computer assisted instruction is implemented?
2. What is the effect on students' attitudes toward mathematics and attitudes toward computers when exposed to mathematics teaching using curriculum-based CAI materials?

A Description of the Software

The software that was used in this study was Level 4 Mathematics (Level 4), developed by Alberta Education (1994). It is based on the Alberta curriculum for the grade 12 university entrance mathematics course. The software has four major components: 1) tutorial material, 2) teaching examples, 3) practice exercises, and 4) test banks. The software allows for student interaction, in varying degrees, within all of the mathematical topics. The test banks allow students at any time, to test themselves on a particular topic and will direct them back to topics on which they appear to be having difficulty with. The software also includes four "explorers" which allow the student to explore the relationships between functions

and their graphs. The four explorers are: 1) Polynomial Explorer, 2) Quadratic Explorer, 3) Trigonometric Explorer, and 4) Exponential Explorer. These Explorers allow for what Kaput (1992) refers to as "Linked Representation", - that is, where students are continually making the link between algebraic and graphical representations. The explorers allow the student to change parameters defining a function easily and to immediately see the effect those parameter changes have on the graph. Further, the software allows the student to proceed through the material in any topical order and the student can very easily go back to a particular item to review, or may omit a particular item. The pace of instruction is under the complete control of the student.

Rationale for the Study

Change is never easy. It can often be painful for many. Change in educational practices is very slow as teachers are often very reluctant to change their teaching practices (Akker, Keursten & Plomp, 1988). The integration of a computer based mathematics program into the classroom requires a change in the practices and philosophy on the part of the teacher (Ellis, 1990). Fullan (1982) and Mecklenburger (1990) both feel that teachers must perceive a need for the change in order to be willing to change.

One of the obvious changes that takes place when implementing such a program is the role of the teacher in the classroom (Fulton, 1988; Akker, Keursten and Plomp, 1988). The teacher is no longer the source of all information, but is rather a facilitator in the learning process. This role change is very difficult for some teachers to accept. In the traditional classroom, the teacher is seen as being in complete control of every aspect of the classroom, whereas in this new classroom the students have more control. This change in the mathematics classroom is one of the

goals proposed in the Standards. It is assumed that providing teachers with information regarding the implementation process of such a program will help to increase the degree of acceptance of CAI programs similar to Level 4 and the acceptance of technology in general into the mathematics classroom.

Limitations of the Study

This study is limited by the fact that it is very difficult to assess what was the cause of the changes in students' attitudes toward mathematics and attitudes toward computers. There are many variables which can affect attitude such as achievement in the course of study, the student-teacher relationship and personal problems.

Another limitation is that the data have been collected from a very small sample - two classes of mathematics students and three teachers. The results offer limited generalizability.

One final limitation of the study is that it makes use of a particular piece of software. The results of the study are specific to the software used and may be generalizable only to other very similar types of software.

Significance of the Study

This study could help facilitate changes in the mathematics classroom with respect to incorporating CAI. Looking at the implementation process that the three teachers in this study went through, as well as the effect of the CAI program on students' attitudes toward mathematics and computers, may help in facilitating that change and increase the degree of teacher acceptance of similar programs. The information provided by the teachers in the study will inform other teachers contemplating the same type of change and could be used to help design teacher training programs aimed at assisting teachers in implementing similar programs.

Further, complete CAI programs which cover a particular course of study and are shown to be successful, have important ramifications for providing viable forms of learning alternative to traditional classrooms (Ellis, 1984). Small rural high schools are very interested in this type of CAI program in order to enable them to offer a wide variety of course selections to their students. Mecklenburger (1990) asserts that a nation that is committed to educational equality for all students must be aware of the potentials of electronic learning.

Chapter Two

REVIEW OF THE LITERATURE

The review of the related literature has been organized into three sections. The first deals with student achievement using Computer Assisted Instruction (CAI) materials. The second deals with student attitudes toward mathematics and computers. The issue of teacher change when using technology will be the focus of the third section.

Achievement and CAI

What does the research say about students' achievement when exposed to CAI? It depends on who you read. In Kaput's (1992) opinion, CAI has not paid off in mathematics education yet. But other researchers report differently. Kulik (1983) reported on several meta-analyses that have been done and found that students achieve just as well or somewhat better when using CAI material (Hartley, 1977; Burns & Bozeman, 1981; Kulik, Kulik & Cohen, 1980). Kulik (1983) performed another meta-analysis on 51 studies and found that 48 of the studies described effects of computer based instruction on achievement test scores. Although the size of the effect was moderate, it did vary from study to study, ranging from highly positive to moderately negative. While it is recognized that these are older studies, it is the range of effect found here, as well as the differences in effects in using Level 4 described in Chapter Three, that led the researcher to believe that it may not be the software that is directly the cause of the effects, but rather how the software is implemented in the classroom. Kulik also found that effects on achievement scores were somewhat greater in studies of shorter duration, which Krendl & Broithier (1992) assert is most

likely due to novelty effects. Kulik & Kulik's (1987) meta-analysis on Computer-Based Instruction concluded that "most programs of computer-based instruction have had positive effects on student learning" (p. 229). One other conclusion which is worth noting here is that they found that computer-based instruction has not been uniformly successful in its various forms and at all instructional levels.

More recent studies on achievement when using CAI confirm the results found in the meta-analysis cited previously - the use of CAI is as effective or more effective than traditional classroom instruction (Tilidetzke, 1992; McCoy, 1991; Sterling & Gray, 1991).

Attitudes Toward Mathematics and Toward Computers

The question of students' attitudes toward mathematics and toward computers has been looked at in a variety of settings. Alkalay (1993) studied college students who used computers for independent exploration in "Precaclulus". The computer was used in conjunction with traditional instruction. Alkalay found no changes in students' attitudes toward mathematics or computers when using the computer in this way. She does state that the students started the study with moderately positive attitudes and the interesting point in this study is that students' attitudes toward mathematics and toward computers did not deteriorate with the use of the computers.

One area of mathematics that has made substantial use of computer software is statistics (Bland, 1984; Dambolena, 1986; Gordon & Hunt, 1986; Kersten, 1983) but very few studies in the area of statistics have examined student attitudes. Sterling and Gray (1991) found that students had positive attitudes toward using simulation software in their introductory statistics course. A majority of the students felt that the software increased their ability in statistics and in their use of computers but only a minority showed an increase in their interest in statistics or computers. One

explanation for not seeing a large attitude change may have been due to the fact that the students using the computer resented having to put extra time on the computer - time the other classes not using the computer did not have to spend on the course. Sterling and Gray caution that well designed software is important, but that it is also very important to carefully implement the software in order to positively affect student attitudes.

Krendl and Broithier (1992) think that much of the research on attitudes toward computers is misleading because of the short-term nature of most studies. They argue that many studies are "vague about the details of the application being used - characteristics and content of the software, degree of student control, role of the teacher, description of the learning environment, and so on" (p. 216). They found from a longitudinal study of three years that there was clear evidence of novelty effects with respect to students' preferences for computers and their perceptions of learning from computers. Clark (1985) has suggested that the favorable results in student attitudes reported in much of the research may be attributable to a variety of uncontrolled effects, such as novelty effects, and differences in instructional content, rather than the computer itself.

In general though, researchers have found that students' level of confidence with technology increases as a result of practice and experience (Griffin, Gillis, & Brown, 1986; Koohang, 1989). The meta-analysis performed by Kulik (1983) found that for those studies which looked at student attitudes, the results were all the same - students' attitudes toward computers were more positive in the computer-based instruction class compared to the traditional classroom. But Kulik reports that "computer based teaching had only small effects on academic attitudes of students" (p. 20) where "academic attitudes" refers to students' attitudes toward specific subjects.

Martin, Heller and Mahmoud (1992) report that there is not much research available on students' attitudes and computer use, and what research there is focuses on the effects of gender on computer attitudes. They found in their study, which looked at students from America and from the former Soviet Union, that students' attitudes toward computers were similar to each other and mostly positive. Martin, Heller and Mahmoud believe that further studies need to look at specific uses of the computer, be it drill and practice, tutorials, simulations and so on, and how these specific uses of the computer affect students' attitudes toward computers.

Teacher Change

It is difficult to move teachers to change their instructional practices and any significant change of teacher behavior takes several years, according to Hord (1987). On the important issue of how to move teachers toward integrating computers within their own instruction, Trollip (1988) believes that teachers must be sufficiently motivated to make this effort. Mecklenburger (1990) argues that teachers must perceive a need for computers in the classroom or they will not be used. Akker (1988) believes that inservice programs need to de-emphasize the technical aspects and put more emphasis on the actual integration of computer uses into daily classroom practice. Judson (1991) provides some practical advice to teachers on the establishment and management of a mathematics computer lab suggesting that: (1) teachers should have a lab assistant available to them for the first few classes, and (2) print materials should be meticulously prepared well in advance, and tested before they are used. Similarly, Ellis (1990) believes that science teachers need specific training in how to apply educational technologies in the science classroom. The same might be said for mathematics teachers and the mathematics classroom. In any case, as Ellis (1984) states "the most important factor in determining the level of

implementation of educational computing will likely be the degree of acceptance by the teacher" (p.206).

In her article "Preparing Teachers to Integrate Computers into Mathematics Instruction", Janice Flake (1990) describes her four years of working with preservice secondary mathematics teachers in helping them integrate computers into their mathematics instruction. She concluded that three critical steps should be part of all teachers' training. According to Flake, teachers should: 1) reach a level of comfort in using computers; (2) experience learning in a meaningful way using computers as an instructional tool, and (3) work with students and observe them learning with the computer as an instructional tool. Also, Kaput (1992) has identified some important conditions which should be in place in order to effectively implement technology in the mathematics classroom. First, there must be outside support for the changes that must take place in the classroom, that is, teachers need extra materials and collegial and administrative support. Also, teachers need to be flexible in using the software, i.e., they must be able to use it in a lab setting as well as in a teacher-directed discovery class and they must learn to cope with matters such as hardware problems and scheduling of the computer lab.

One of the most important ideas to make teachers aware of is that their role will change when they use computers in the classroom (Fulton, 1988). Largely, the teacher's role is seen to change from an expository role to more of a guide to the student. Attempting to change the role of the teacher can be difficult for both the student and teacher alike (Akker, Keursten & Plomp, 1988).

One final point is worth noting. According to Anderson (1989), one of the key factors in the degree of acceptance of CAI mathematics software in the classroom is the alignment of the software's pedagogical principles with those of the teacher's.

This is a crucial factor in affecting implementation, and one this researcher hypothesized would arise in the study.

In summary, the research basically supports the statement that students achieve as well or better using CAI, compared to traditional classrooms. Students' attitudes toward mathematics and computers are moderately affected by CAI programs, and these effects may be attributable to novelty and how the CAI material is actually implemented in the classroom. The teacher change research leads one to conclude that teachers must be supported during the change process and that collegial support, technical support, material support and administrative support will likely help to determine the pace and effectiveness of the change.

Chapter Three

PRIOR EXPERIENCES WITH LEVEL 4 MATHEMATICS SOFTWARE

The purpose of this chapter is to provide some details about previous teacher and student experience with the Level 4 courseware. The chapter consists of two major components, first a section dealing with students' achievement when utilizing the software and, secondly, a section looking at prior teacher experience in implementing the software in mathematics classrooms.

Level 4 Courseware and Student Achievement

The Level 4 courseware has been utilized in some Alberta schools for the last four years. All Alberta grade 12 students enrolled in Mathematics 30 (the Grade 12 university entrance mathematics course) must write a provincial departmental exam, referred to as the diploma exam. It is because of this diploma exam that some comparisons can be made with respect to those students who used the CAI material and those who did not. The researcher requested information from the Alberta Distance Learning Centre regarding the effects on student achievement of using the software. The following two examples were provided by Rik Hall (1994), Manager of Instructional Technology and Media at the Alberta Distance Learning Centre.

The first example is from a large urban high school in Alberta (see Table 1). During the 1990/1991 school year, one grade 12 class used the CAI software while the remaining grade 12 classes were taught in "traditional" mathematics classrooms. The students were in the CAI class by their own choice.

Table 1

Level 4 Mathematics: June 1991 Results

Urban Alberta High School

Type of Student	# of Students	Mean	Std Dev
CAI (in school)	23	65.9	23.8
Non-CAI (in school)	79	57.1	19.2
Provincial	10 278	59.4	20.4

In Table 1, "# of Students" column refers to the number of students who wrote the diploma exam and the "Mean" is the average final mark of the students. The diploma examination counted for half of each student's final mark. In the second year of utilizing the Level 4 software, the instructional conditions changed slightly. In this year, a teacher had two classes of grade 12 mathematics; the students had no choice as to what class they would be in, and the computer lab was available during one of the classes (see Table 2).

Table 2

Level 4 Mathematics: June 1992 Results

Urban Alberta High School

Type of Student	# of Students	Mean	Std Dev
CAI (in school)	23	61.8	17.3
Non-CAI (in school)	129	54.2	15.3
Provincial	10 749	57.8	17.2

What conclusions can be made from this data are uncertain since there are many variables that are not taken into consideration. One thing that is certain - the students in the CAI class achieved just as well as those who were not in the CAI class.

The second example is from a small rural school. In this case, a grade 12 mathematics class of five students used the Level 4 Mathematics software and had a mathematics teacher available for assistance, although the teacher was not a Grade 12 mathematics specialist. Table 3 shows a comparison of the students' grade 11 mark with their grade 12 mark.

Table 3

Level 4 Mathematics: June 1992 Results

Five Alberta Students - Small Rural School

Student	Mark - Grade 11	Mark - Grade 12
A	50	80
B	66	76
C	65	65
D	51	59
E	64	69

The Grade 11 mark is totally school given, and according to Hall (1994),"can tend to be inflated". The Grade 12 mark was an average of the class work (50%) and the diploma examination (50%). Again, no absolute statements can be made about the effectiveness of using the CAI software, since there are many variables not taken into consideration in the two examples cited. Generally though, it can be concluded that students do learn with this program.

Teacher Experiences with Level 4

The classroom procedure when utilizing Level 4 is a radical change from the traditional high school mathematics classroom. The three teacher investigators taking part in this study felt it would be wise to interview teachers who had been successful in utilizing the Level 4 courseware in their classroom in order to question them about their experiences. The teachers were deemed "successful" in that they were convinced that there were advantages in using the software and were continuing to use the software in the upcoming school year. Additionally, there had been positive feedback from the students who had used the software in their classroom. Two teachers were interviewed at School A. They were in their second year of using the Level 4 software at the time of the interview. The researcher herself also had some additional information from a survey administered by Manitoba Education and Training (1993) at a different school (School B) where teachers had piloted the same software. The experiences reported from these two Manitoba schools with regards to implementing the software differed dramatically; indeed, teachers in School B were deemed "unsuccessful". It was these differences in results that interested the researchers. How could the same CAI program have such different results in its acceptance by teachers and students?

An attempt was made to determine the difference in the implementation process at the two schools. There were several things which appeared. In School A (the successful school), the teachers provided print support material for the students prior to starting a particular topic on the computer. The print support consisted of notes and examples on the particular mathematical concept being discussed. The notes closely paralleled the software. In this school, students could not opt out of the class using the CAI material.

In School B (unsuccessful school), no notes were given to students, which then resulted in many students copying notes into their notebooks from the computer screen. In this school, students where given a choice of how they wanted their instruction - either the traditional method, or the CAI method. This choice was made at the beginning of each major unit to be studied. The number of students who chose the CAI method of instruction decreased significantly throughout the term that the software was being piloted. School B was designated as unsuccessful in the implementing of the software since the following school year resulted in the teachers choosing to decrease their use of the software in the classrooms.

The investigators involved in this study met with the two teachers from School A. The purpose of the scheduled meeting was to ask the teachers about their classroom procedure: to have them explain what they learned from their first year experience, and what they were doing differently in their second year of implementation. One teacher summed it up very well. In their first year they tried to do too much. They tried to implement CAI in the mathematics classroom as well as to allow students to proceed at their own pace. They found that some students would never complete the required course of studies if left on their own time frame. The second year they decided to set deadlines for the completion of each unit and all students wrote the test on the same day (those students who proceeded more quickly were allowed to write the test ahead of schedule if they preferred). The teachers decided to hand out a review sheet to the students prior to any major test, something which was not done on a regular basis during the first year of implementation. Also, it was found by these teachers that it was very important to allow students time in the computer laboratory in their spare periods as well as at lunch and after school. The investigators also observed the classroom in action. One major difference that was noticed in this classroom, compared to a traditional mathematics class, was the role of

the teacher. The teacher was working individually or with pairs of students during the entire class period.

This information on prior experience with the Level 4 software, both from the examples of student achievement and the differences in teacher experience with it, was taken into consideration in this study. The student examples from Alberta provided some assurance to the teacher researchers that students have shown that they can learn using the Level 4 courseware and their achievement is not negatively affected. The difference in teacher experience in School A and School B was used by the investigators to assist them in making decisions regarding the operation of the classrooms and the type of support needed for the students to try to ensure a "successful" implementation of the Level 4 CAI program.

Chapter Four

METHOD AND PROCEDURES

The purpose of this study was to examine the changes in the teaching process when implementing a CAI program in the mathematics classroom. The study looked at the effect on students' attitudes toward mathematics and attitudes toward computers when using the CAI program in their mathematics class.

The Subjects

The teacher subjects in this study consisted of the researcher herself, plus two experienced high school mathematics teachers. The three teachers were also investigators in the study. The other teachers (Alan and Ruth) were chosen because of their desire and interest to be involved in such a study, and because their school had the necessary computer hardware to implement the program.

Alan has thirty-three years of teaching experience, the majority of those years at the high school level. He has taught all levels of mathematics courses at the high school level. Alan has been actively involved in curriculum development and has given inservices on the Standards. Alan has had minimal experience with using computers in any way. He had no previous experience in implementing such a program as Level 4 prior to the commencement of the study.

Ruth has thirteen years of teaching experience, nine of those years at the high school level. She has taught mathematics and physics at all levels. Ruth has delivered inservices on geometry and the metric system. Both Alan and Ruth have given an inservice on Cabri geometry, a geometry software tool, and both were

members of Project Prometheus, a project involving the University of Manitoba and selected public schools, funded by IBM Canada.

The student subjects consisted of two classes of grade 12 students enrolled in Mathematics 300, the Manitoba grade 12 university entrance course. These students were not pre-selected. The two classes were from two suburban high schools in Winnipeg. These students were taught a mathematics program over a 5 month (1 semester) period, using the CAI program as described in the section on Procedure One class was taught by Alan and Ruth, the other by Kathy (the researcher). Appropriate permissions were sought from participants and schools (Appendices A, B, and C).

Instrumentation

The data obtained from and on the teacher subjects in this study is qualitative in nature. As Levine (1990) points out, there does not seem to be any generally accepted observationally based procedures in place which look at the consequences of learning and teaching by and with computers. Thus the instruments utilized by the teachers were designed by the researcher. Some of the particular categories in the instruments came from O'Neill's (1988) article "Teaching Effectiveness: A review of the Research".

The first instrument utilized by the three teachers involved with this study was the Weekly Teacher Report Form (Appendix D). This form provided a framework for collecting data on the teaching process. The questions were designed to help the teachers reflect on their teaching behavior, and the impact that using the software had on their teaching, as well as on the students. Additional notes were taken when the teachers met to discuss what they had written.

purpose of this form was to provide the teachers with some overall questions to help them summarize their findings with regard to implementing Level 4 into their mathematics classroom.

For investigating the second question, regarding student attitudes, two Likert-type attitude scales, the Mathematics Attitude Scale and the Computer Attitude Scale (both in Appendix E) were developed. The Mathematics Attitude Scale consisted of twelve statements that were responded to on a five point scale. This scale was adapted from one developed by Aiken (1979). The questions deal with Enjoyment of Mathematics and Freedom from Fear of Mathematics. The Computer Attitude Scale was an adaptation of Gessard and Lloyd's (1986) attitude scale. Woodrow (1991) did a comparison of four computer attitude scales and found that the Gessard and Lloyd scales are among the most reliable measures of attitudes toward computers and their use. The scale for this study consisted of two components: Computer Anxiety and Computer Confidence. Each component consisted of ten statements.

Another instrument for the study was the Course Evaluation Form (Appendix E) which was administered to the students at the completion of the course. The purpose of the evaluation form was to determine students' opinions about using the CAI program as part of their mathematics instruction. The Evaluation Form consisted of six Likert-type statements that were responded to on a five point scale. Two additional open-ended questions were included, asking students what they liked the most, and what they liked the least about using the CAI materials in their mathematics class. The results from the Evaluation Form assisted in explaining the results from the Mathematics Attitude Scale and the Computer Attitude Scale and helped in interpreting the teacher data.

Procedure

The procedure section consists of two components. The first part is a description of the classroom procedures. The second section is a description of the data collection procedures.

Classroom Procedures

After meeting with two teachers experienced in using Level 4, the teacher investigators in this study agreed on how the classrooms in the study were to initially operate. The general procedure involved providing a package of notes that consisted of definitions and explanations of the mathematical content to be covered in the particular topic on the software. The notes also included some examples. This package of student notes was provided by the two teachers from School A who had previously used the software. Depending on the particular topic, the students went directly to the computers, or the teacher provided some introductory comments about the particular topic before the students proceeded through the material on the computer. Exploratory Exercises were developed for some topics where students made use of a software program called Agrapher (Arnold, 1991), a graphing tool. A specific time line was set when a particular set of topics was to be completed. At the completion of the topics, a review sheet was handed out to students based on the material covered. This was followed by a test. The teachers allowed the students access to the computer lab on their spares and during lunch hour as much as possible.

Data Collection Procedures

To answer the research question about the teaching process, the teachers were given multiple copies of the Weekly Teacher Report Form to think about and respond to with regard to the implementation process. The teachers completed the form once

a week, and then met together once every two weeks to discuss the items on the form. These meetings were taped and then transcribed. These transcriptions assisted in explaining and enhancing the written submissions by the teachers. The sessions looked at all aspects of the implementation process, be they hardware problems, concerns about students, or teacher concerns. The discussion looked at things that seemed to work well in the classroom, and those things which did not work well. The teacher investigators also completed the Final Teacher Report Form at the conclusion of the study.

To answer research question number two, the students involved with the study completed the Mathematics Attitude Scale and the Computer Attitude Scale at the beginning and at the conclusion of the study. The students also completed the Course Evaluation Form at the conclusion of the study.

Interpretation of the Data

The data collected from the teachers through the Weekly Teacher Report Form, scheduled meetings and the Final Teacher Report Form were summarized in a descriptive manner. The analysis of the teacher data attempted to answer these questions: What are the changes in the teaching process when implementing a program such as Level 4? What were the major problems that arose, and what were the major successes?

With regard to the Mathematics Attitude Scale and Computer Attitude Scale that the students completed, percentage responses were calculated for each category to determine if any noteworthy changes had taken place in students' attitudes toward mathematics and toward computers. Given the small number of students, more sophisticated statistical analysis was not warranted.

The Course Evaluation Form administered to the students consisted of six Likert-type questions where percentage responses were again calculated for each question. The responses to the two open ended questions were summarized in descriptive form.

Chapter Five

ANALYSIS OF THE DATA

The data collected was from two sources - the teachers and the students. The analysis will look at the teacher and student data separately.

Teacher Data

The teacher data comes from two sources: (1) Weekly Teacher Report Forms, and (2) Final Teacher Report Form. The analysis will deal with each separately, and then summarize.

Weekly Teacher Report Forms

The Weekly Teacher Report Form was completed by the three teacher researchers weekly throughout the term. The analysis of the data was done on a question-by-question basis and looked for the commonalties that occurred in the various categories throughout the study. The notes transcribed from the taped biweekly sessions with the teachers were used to provide more detail in each of the categories of the Weekly Teacher Report Form.

Student/Teacher Activity

Throughout the term there was not a lot of variation in the teacher or student activity. The majority of the time the students worked through the topics using the software. When given a paper assignment, some students would leave the computer and work on the assignment by themselves or in a small group. The students were given the responsibility of deciding how much time to spend with the software as

compared to the assignments. The teachers circulated throughout the room answering student questions. Occasionally a question would be raised that was important enough to explain to the whole class at once and this was done. However, the teacher role was primarily one of a facilitator in the learning process.

Occasionally the teachers would lecture on a topic that was not covered in the software. Some of the topics in the software were taught using a different approach than suggested in the provincial curriculum. The development of some topics in the software was more in-depth than what the teachers needed or wanted, so occasionally these topics were taught without the software. For some topics, exploratory exercises were developed where students used the software program called Agrapher, a graphing tool, to complete the exercises.

The student activity was significantly different than in a traditional mathematics classroom. Students were *doing* mathematics even during the first class, rather than copying notes off of the board. All three teachers agree that the students were more actively involved in their own learning. Ruth stated:

> I really appreciate how much math the kids are doing. Without my having said so the kids know stuff. On identities they can do most of the problems with only four questions or so that they need help on, which is better than when I taught it. In a traditional classroom they sit and watch the teacher do it - they love it. They say "you do it so well - do another one for us".

Print Material

The most significant print material that was used throughout the term was the package of notes given to each student at the beginning of each unit. These notes were provided by two teachers from School A who had previously used the software. The notes contained key concepts and ideas, with some examples. The notes closely

paralleled the software. The extent to which these notes were used varied from student to student. Some students faithfully read the notes prior to starting to use the software, highlighting important formulas, etc. Other students read the notes as they proceeded through the software. Some students did not appear to use the notes at all during class time. When questions were raised by students the teachers referred to the notes or to the software. The notes were sometimes faster to use, since it was difficult to know exactly where to look in the software to find something specific. As Alan noted, an outline of the software would have been useful.

A second type of print material was the Assignments that were based on each topic of the software. These were constructed by the teachers from School A plus the researcher and were used by the majority of students. The final type of print material used were the Exploratory Exercises which made use of the graphing software - Agrapher. These were used by all students, since class time was usually given to complete them.

Preparation Time

The preparation time varied among the three teachers. The researcher had a computer at home with the software and spent on the average, four hours a week going through the software as a student would. During this time any errors or problems with the software were noted as well as any sections that were to be omitted. This information was then passed on to the students. The other two teachers did not go through all the software prior to the students. They did say that they would have preferred to have done so. It was noted by all three teachers that there was less day-to-day lesson preparation required since you were not lecturing each day. The teachers had to be very comfortable with the mathematical content since students'

questions were from a variety of places within the software. Time was also spent constructing the Exploratory Exercises, Topical Assignments and Unit Tests.

When the time spent preparing for teaching using the software was compared to preparing a course that had not been taught before, the teachers reported that preparation time was probably about the same. Therefore, if one compares the CAI preparation time, the first time through, to the preparation time for a course one had previously taught, the preparation time would be more for the CAI class. However, the Level 4 software used in this study had no prepared print support materials for teachers or students. As a result the teachers from School A spent many hours constructing the student notes to be used with the software. But once the print support materials are constructed, and one is familiar with the software, preparation time likely decreases dramatically. Alan, one of the teachers in the study, feels that a teacher would spend less time preparing using the CAI software compared to a traditional class, once support materials are developed or available in ready to use form.

Teacher Role

The teacher role was one of a facilitator in the learning process. For the most part, this role was maintained throughout the study. The teachers' comfort level with this new role changed as the term progressed. All three teachers felt a little uncomfortable initially with letting go of control. Alan said near the beginning of the study "I am beginning to feel comfortable with the switch from 'sage on the stage' to 'guide on the side' ". During the same time period Ruth observed that "I feel at times, as if I should be more in control of what each student is doing". The researcher felt that it was sometimes difficult to let the students learn from the software and that along the way, it was very easy to fall back into the expository role. However, as the

term progressed the teachers became more comfortable with their new role. Near the conclusion of the study Alan writes: "The new role of 'guide on the side' is so superior to 'sage on the stage'. Finally kids are in control of their own learning."

The two classes that took part in the study were quite different in size. Alan and Ruth's class was composed of 8 students at the end of the term. Both teachers were in the room during the mathematics class. Kathy's class was composed of 23 students at the end of the term and she was the only teacher in the class. Understandably, more problems occurred with keeping students on task in the large class than in the small class. The atmosphere in both classes was definitely more relaxed compared to traditional mathematics classrooms. The challenge for the teacher was to manage the class in such a way that students were not wasting time, but were remaining on task. Having deadlines in place helped to alleviate some of these problems.

Teaching Style and Strategies

Classroom Management. Alan and Ruth's class tended to get right down to work with little extraneous discussion. Kathy's class was also very good at getting to work, although a few students needed encouragement. Many students came in to the lab and got to work before the class began, and if they did not have another class following mathematics they would remain to complete more work using the software. Alan thinks that classroom management is made easier when using the Level 4 software.

Instructional Mode. The instructional mode is more of a tutorial approach. This guiding role of the teacher keeps one very busy in the classroom, moving from student to student. In the larger classroom it was difficult to always answer all students' questions. The teachers' diagnostic role was more prominent in the CAI

classroom in that more time was spent analyzing students' progress since very little time was spent lecturing to the entire class.

Direct Instruction. There is still a need for direct instruction, to deal with topics that are not covered in the courseware, or to provide some additional teaching on topics that students are having difficulty with. Most of the direct instruction was done on a one-to-one basis, or with small groups.

Monitoring and Pacing. It was very easy to determine where each student was in the courseware. With a quick two minute walk throughout the lab, the teacher could determine where each student was by looking at the "Navigator" on the computer screen. The "Navigator" indicates what Unit, Topic, Objective and Page the student is on and displays which objectives and pages have been completed. Encouragement to those students who were behind could then be provided. If the entire class was behind, adjustments to deadlines could then be made. Because not all topics took the same amount of time to complete, it was difficult to know how much time the students required to complete each topic. The teachers referred to other colleagues in their school teaching the same course, to help them stay on schedule.

Teacher Flexibility. Relying on technology for the delivery of instruction or using software as a mathematics tool comes with some risks attached. Hardware or software problems may force teachers to deliver the lesson in a different way than was expected. Alan thinks that, as a teacher, you must be flexible in these types of situations, and be able to "change gears" quickly. Another area where the teachers found flexibility to be important was in the way the mathematics concepts were taught by the software. One must be flexible in accepting new ways of doing things, and will most likely have to learn new methods. The attitude "I don't teach it that way", must be gradually changed into "that is not the way I usually do it but let's take a look at this approach". The conclusion may be that "my way" is superior, but the

teachers in this study believed it was important to not make that assumption in order to be receptive to new methods.

Feedback. The immediate feedback provided by the software was appreciated by both the teachers and students. Students did not have to wait to discover if they had answered the question correctly and this made individual rates of progress a genuine possibility.

Student Role

The teachers involved in this study thought that students were taking on more ownership with regard to their own learning in the CAI classroom than they would have in a traditional mathematics classroom. Students attempted the difficult material and some even covered enrichment topics.

Student/student interaction. The student-to-student interaction generally increased as the term progressed. Generally, the students helped each other with problems, but in the larger class, not all interaction was productive. In Alan and Ruth's class, one pair of students spent a great deal of time at one computer helping each other.

Student/teacher interaction. Student-to-teacher interaction had increased in the CAI classroom compared to a traditional classroom, especially one-to-one interaction. It was noted in the large class that some students did not ask any questions and others continually asked questions throughout the term.

Nature of students questions and teacher responses. Initially student questions were about the operation of the software, or a minor hardware problem. Very quickly the questions changed to ones where the student needed some further explanation about a mathematical problem. Occasionally students needed assistance with a concept that they did not understand. As teachers, we tried to refer the students to

sections in the software or notes which would help to clarify the problem, but many times it was quicker to show the students directly. The teachers tried to respond in such a way that students would come to rely more and more on the software and less on the teacher. This was very difficult to do consistently.

Attitudes. Attitudes of teachers and students remained positive throughout the term. The students soon came to realize that it still took a lot of work and concentration on their part to be successful in the course.

Outside Contact

Before the study began, a parent called the principal asking about one of the mathematics classes in which her daughter was enrolled. The parent asked whether the course would be more difficult because of the use of computers, stating that her daughter had no computer experience, and wondered if that would be a problem. The principal reassured the parent that it would not be more difficult and that anything the students needed to know about operating the computer would be shown in class.

Throughout the duration of the study various teachers and administrators came to observe the classrooms operating. The teachers who visited were considering using the Level 4 software the next year in their classes and wanted to observe a class using it, and to ask questions of the students and teachers involved. All outside contact was positive in nature.

Software/Hardware

The errors in the software caused some irritation among teachers and students but, generally, the software ran smoothly. No major problems were encountered with the software which caused major disruptions. According to Ruth, the graphing tool - Agrapher - was easy for students to use. Alan noted that Agrapher does not display

the points of discontinuity of a graph, which is also true of most graphing calculators. Alan and Ruth's classroom of computers were networked, whereas Kathy's lab was not networked. When the network was "down" for a class , it caused some disruptions and forced the teachers to teach the "traditional" way for that class. In the non-networked class there were few hardware problems. Occasionally a mouse would not work or a student would inadvertently unplug a computer. As long as the teacher downplayed the problems, the students did not appear to be bothered by hardware problems.

Final Teacher Report Form

The Final Teacher Report Form consisted of seven open ended questions to help the teachers summarize their findings in implementing Level 4 in their mathematics classroom. A summary tabulation of comments is presented in Figure 1. The analysis and discussion which follows is on a question-by-question basis.

Teacher Role

The three teachers all agreed that their role as teachers in the classroom using the software was quite different compared to the role in a traditional mathematics classroom. There was less emphasis on lesson preparation and presentation and less direct control over pacing. There was less emphasis on teacher initiated lessons, and more emphasis on student initiated learning. There was more student-to-teacher interaction, with the majority of that interaction being one-to-one, that is, you became an assistant to the student if he/she had trouble with a concept or problem. Since there was more student-to-student interaction occurring in the classroom, the teacher had to spend time ensuring students remained on task. The teachers' diagnostic role was more prominent in the CAI classroom in that more time was spent analyzing

Figure 1

Final

Teacher Report Form

1. Describe the differences you perceive in your role as a teacher in a traditional mathematics class compared to the classroom using the computer software. Consider both the instructional and managerial aspects of teaching.
   In the CAI classroom:

Ruth's Comments:

- Less emphasis on lesson preparation/presentation
- Less direct control over pacing
- Less emphasis on teacher initiated lessons. more on student initiated learning
- More individual (one-on-one) discussion
- More student contact during class

Alan's Comments:

- The student becomes much more responsible for his fate
- You are no longer the imparter of the knowledge as teacher, rather you are the guide
- You are there to assist the student if he has trouble with the concept
- The student has to involve himself or herself or become immersed in the process
- Each student has the opportunity to work at their own rate
- Students do have the opportunity to help each other so classroom management involves keeping the students on task

Kathy's Comments:

- As a teacher one must feel very comfortable and confident with the content of the mathematics course, since students questions can be from different places within the software

Figure 1 Continued

- Having taught computer science, I felt my role in the math class was similar to my role in a computer science classroom
  (1) helping students on a one to one basis,
  (2) having to think on ones feet - not knowing what the question will be that the student has and (3) troubleshooting
- The whole idea of pacing the course was different using the software compared to a traditional classroom. It was sometimes difficult to judge how long students should take to complete a section of the software
- An area that is not relevant in a traditional classroom that arose in teaching using the software, was when and where to provide some additional teaching to supplement the software. One had to look at the software as a teacher, and be convinced that students could achieve the required objective. If you thought that some additional teaching was required to achieve that objective a decision had to be made as to when, where and how to provide that additional teaching.

2. In your opinion, what impact did the use of the Level 4 courseware have on student attitudes towards mathematics and towards computers? Justify your response.

Ruth's Comments:

- Students generally appreciated the individualized aspect of the computer study. They seemed more at ease with questions (asking and answering)
- At times students were frustrated with the difficulty of the questions asked and the necessary details required by the computer for the answers to be acceptable
- Some students found the reading level difficult and did not want to put the effort into understanding

Figure 1 Continued

- In general I feel the attitude was very positive. Students were often working at the computer before class began and often stayed after

Alan's Comments:

- For the most part students were less fearful of getting wrong answers
- They didn't seem to be afraid of the computer technology
- They didn't appreciate mistakes that were in the software as a reason why they obtained the wrong answer
- The students in our pilot group were students who hadn't achieved well in math in high school. They didn't seem to blame the computer if they didn't achieve well

Kathy's Comments:

- I don't feel I observed any significant changes in students attitudes towards mathematics because of using the software. Those who had disliked math before, still disliked it. Those that liked math before, still liked it.
- I feel that students came away feeling more comfortable in using a computer, especially those who had little or no experience in using a computer. An example of the tension that was felt initially by students in using computers in math class is the following: The principal had a parent call asking about the course before it even began. The question asked was "will it be more difficult?" and "my daughter has never used a computer before - will this cause a problem?" My observations during the term was that students felt very comfortable in using the computer. They adjust to change a lot quicker than adults

Figure 1 Continued

3. In your opinion, what impact did the use of the Level 4 courseware have on the achievement of your students? Justify your response.

Ruth's Comments:

- Noting the circumstances of our group, the late start, early exams, repeater students, I feel our students did at least as well as they would have done in a traditional class and perhaps better for some. Reviewing past math grades and present subject marks, the Level 4 math grades were certainly comparable

Alan's Comments:

- Because the students quickly realized that they were in control of their learning, they realized that their achievement depended upon using the software. One or two learned the hard way when failure to complete the courseware resulted in low achievement on evaluation. All students in the project passed the course.

Kathy's Comments:

- Because of the students having more responsibility on their shoulders for their own learning, I felt that <u>some</u> of the bright students didn't achieve as well as they would have in a traditional classroom. I think this is because they were used to getting "spoon fed" in a traditional classroom. Here they had to work harder.

- The hard working student achieved just as well or better in the computer classroom. This is because they had the opportunity to go at their own pace, review a lesson they didn't understand, practice writing tests using the Test Banks, put extra time in on the software before and after school plus on their spares during the day.

Figure 1 Continued

4. Describe the major frustrations in implementing the Level 4 courseware

Ruth's Comments:

- The major frustration was the securing of equipment suitable for running the Level 4 software. We (as teachers) had to lobby for computers and even with administrative and superintendent support received only 11 computers that were no longer needed by the board office
- Time tabling was also a source of frustration. We were given an unsuitable lab because other courses take precedence
- The network available in our school had insufficient memory space to install the complete Level 4 program. Therefore we had to continually ask to have topics installed and removed

Alan's Comments:

- Not having the correct hardware
- Getting a 3 week delay in starting the project
- Every aspect should be in place before proceeding
- all topics should be previewed before starting
- not being able to get into the computer room in the correct period
- not having enough ram to put the entire courseware on the network

Kathy's Comments:

- Initially there was some resistance to me coming into the lab to use the software. The lab had not been used by any teachers other than the computer science teacher and business teacher. It was perceived as if I was coming in and taking over
- Requests that I made to the principal were not always communicated effectively to the teachers who would be affected by these requests. For example, I talked to the principal and explained how important it was for the students to have access to the lab during their spares, which would mean that

Figure 1 Continued

the students may want to use an idle computer while another class was in the lab. The principal said this was not a problem. The teacher had some difficulty with this decision initially

- Poorly set up lab was frustrating to the students as well as teacher. For students, there was no desk space available beside each computer. For the teacher: when I wanted to explain something on the board in the computer lab, it was very difficult to have access to a chalkboard since there was computers all around the perimeter of the room
- The errors in the software were frustrating - wasted valuable time. Because of my experience as a courseware developer I found it very frustrating when errors, or problems arose in the software since I knew that most of the problems could easily be rectified

5. Describe the major achievements in implementing the Level 4 courseware.

Ruth's Comments:

- We received new equipment for the school
- The administration became involved and very supportive
- Other staff members acknowledged the course
- Students showed an interest, asking about the course
- My own knowledge and interest has increased

Alan's Comments:

- Gradually scrounging enough hardware to run the program
- After the first month, the drop out rate was 0%
- Establishing a very successful network with other teachers using the software
- Being able to continue the project next year with 2 classes at the Math 300 level and being able to continue and produce support materials

Figure 1 Continued

Kathy's Comments:

- In the school I was teaching at, the fact that I was using the computer lab for math spread throughout the staff and caused the staff to become more interested and involved with using technology in their own classrooms. Eleven teachers from the school applied and were accepted to the divisions "Adopt-a-Computer Program" which allows a teacher to have a new computer at their home for one year. During the first part of the year, the board office provides training to the teachers which is compulsory for those involved in the program. Following that year, the computer resides in the teacher's school. The staff was made aware that the computer labs in the school were not just primarily for computer science, and that they had a right to use the equipment as well.
- Another major achievement was how smoothly the course ran throughout the term. No major hardware or software problems occurred.
- How quickly the students caught on to using the software, and to the radical change in which their math program was being delivered compared to their previous years of taking math courses

6. Outline the major antecedents and supports that you feel must be in place in order to successfully implement this type of program into mathematics classes.

Ruth's Comments:

- Must have administrative support for proper time tabling and student placement
- Must have collegial support
- Must have technical help for installation and maintenance
- Must have proper equipment (appropriate computer levels and memory)

Figure 1 Continued

Alan's Comments:

- Cooperative administration who wants to see change
- Cooperative networking with teachers who have used the courseware or are using it at present
- One computer per student
- Willing teachers to use it
- Willing students to benefit from the experience

Kathy's Comments:

- Supportive administration and staff
- Adequate equipment

7. In general, what advice would you offer to other teachers using the Level 4 courseware?

Ruth's Comments:

- Make sure supports are in place
- Go through the software as a student
- Allow students to rely on the computer as teacher
- Supply students with notes, but have students make some notes on their own (e.g. Key Ideas)
- Suggest students copy questions and work out some examples in their notebooks
- Give deadlines for testing periods

Figure 1 Continued

Alan's Comments:

- Changing your approach from "sage on the stage" to "guide on the side" is not an easy one to give up since we have usually adopted the "sage on the stage" approach in high school
- This is an alternative approach, the results of which depend upon the learning style of the student you have.
- I think that as a teacher, you have to allow students to try it (using the software) before concluding that it is a boring way to do the course
- The conics section uses a different approach than the Manitoba curriculum at present
- Time guidelines for each topic have to be adhered to
- An extension of the project could be:
  - a) using 1 computer to demonstrate certain concepts
  - b) using the courseware to do remedial work
- make certain you have the correct hardware available
- Contact the people at Manitoba Education (Kathy and Don) if you have problems or other people who have used it
- Make sure you have a computer (at home)

Kathy's Comments:

- Try to become more flexible in your teaching. There may be other ways of teaching a mathematical concept than your way.
- Don't view the software as being perfect. Use your judgment based on your experience as a mathematics teacher as to when to supplement the software.
- Try not to view the software as an "add on". The software should help to drive your curriculum.
- Have a computer at home with the software on it. Go through the software before your students do, noting any sections you want to omit

students' progress since very little time was spent lecturing to the entire class.

The teacher had to be able to think on his/her feet, since student questions were not always from the same mathematical content. This meant that the teacher had to be very comfortable with all the mathematical content. Pacing of the course was a new challenge in the CAI classroom. It was sometimes difficult to judge how long students should take to complete a section of the software. Another difficult task for teacher was deciding when and where to provide additional teaching to supplement the software. One had to look at the software through the eyes of a student, and be convinced that students could achieve the required objective through it. If the teacher then thought that some additional teaching was required to achieve that objective, a decision had to be made as to when, where and how to provide that additional teaching.

Student Attitude

We perceived that students generally appreciated the individualized aspect of the software. They seemed at ease in asking and answering questions. They were less fearful of getting wrong answers. They did not seem to be intimidated by the computers and did not tend to blame the computer when they did not achieve well in the course. At times, students were frustrated with the difficulty of the questions asked and the necessary details required by the computer for the answers to be acceptable. They did not appreciate mistakes in the software as the reason why they obtained the wrong answer.

Kathy did not feel that there were any significant changes in students' attitudes toward mathematics because of using the software. Those that had disliked mathematics before, still disliked it; those that liked mathematics before, still liked it. With regard to students' attitudes toward computers, it was agreed by the teachers

that most students felt more comfortable with using computers at the conclusion of the study compared to the beginning of the study.

Student Achievement

What impact did the use of the Level 4 courseware have on the achievement of our students? Ruth thought that their students "did at least as well as they would have done in a traditional class and perhaps better for some." She looked at the students' past mathematics grades, plus the students' present marks from other courses. Alan stated that the students quickly realized that they were in control of their own learning, and that their level of achievement depended upon them using the software effectively. A few students learned the hard way when failure to complete the courseware resulted in low achievement on evaluation. All students in Alan and Ruth's class passed the course.

Kathy felt that some of the very bright, but not hard working students did not achieve as well as they would have in a traditional classroom. A possible explanation for this is that the students were used to getting "spoon-fed". In the class where the software was used, they had to work harder. The hard working student achieved just as well or better in the computer classroom. This is because they had the opportunity to go at their own pace, review a lesson that they did not understand, practice writing tests using the Test Banks and put in extra time on the software before and after school and on their spares during the day.

Frustrations in Implementing Level 4

One of the major frustrations that Alan and Ruth experienced was they had difficulty in obtaining the required hardware to run the program. When the hardware

was obtained, there was not enough room on the file server to install the entire Level 4 courseware. This meant that they had to continually ask for units to be deleted and new ones installed throughout the term.

One of the computer labs was poorly designed, which was frustrating for teachers and students. For students, there was no desk space available beside each computer for writing. For the teacher, when teaching needed to take place in the computer lab, it was very difficult to use a chalkboard since the computers were situated around the perimeter of the room. The errors and poorly programmed sections of the software were frustrating and they wasted valuable class time.

Achievements in Implementing Level 4

A major achievement in implementing the Level 4 courseware was that the administration in each school became involved and supportive. Also, the drop out rate after the first month, was zero and other students showed an interest in the course, asking if they could be enrolled for next year. Relationships with other teachers across the city who were using the software were established. Using the computers in the school for a subject other than computer science or business caused the investigators colleagues to become more interested and involved with using technology in their own classrooms. One special achievement was how quickly the students caught on to using the software and accepted the radical change in the way which their mathematics program was being delivered, compared to their previous experiences.

Antecedents and Supports Needed

The need for administrative and staff support was top on the list for all three teachers involved with the study. Technical support is also important, as is the proper

hardware. The investigators believe that it is important to have one computer per student in order to successfully implement this type of program in the mathematics classroom.

Advice to Teachers

Generally the advice the teachers in this study would give to others is to ensure that all necessary supports are in place. A computer at home with the software on it, or at least one in the mathematics department for teachers use only, is essential. Further, it is important to go through the software as a student would and provide deadlines for the completion of units. Also, teachers will need to consciously work at changing their role from "sage on the stage" to "guide on the side". This is a gradual change, one that most teachers will likely feel uncomfortable with at first. Finally we say: try to become more flexible in your teaching, looking at new ways of teaching a mathematical concept; use your judgment based on your experience as a mathematics teacher as to when to supplement the software and try not to view the software as an "add on", rather the software should drive your curriculum.

Summary of Teacher Data

The teacher data showed that there were major changes in both teacher and student roles when using the Level 4 program. The locus of control shifted from the teacher to the individual students. This role change, as a teacher, was difficult to maintain. Teachers' preparation time changed from developing daily lessons to previewing the software. Decisions on pacing and when to supplement the software with classroom instruction, not part of traditional teaching, became important. Major frustrations experienced were related to acquiring the computer hardware, poorly set up computer labs and errors in the software itself. A major achievement was raising

the awareness in the schools that computers can be used for other subjects than computer science and word processing. A final major achievement was the ease with which students appeared to move into their new role in the mathematics class.

Student Data

The student data came from three sources: the Computer Attitude Questionnaire, the Mathematics Attitude Questionnaire, and the Course Evaluation Form. The total number of students responding at the beginning of the study was 33. At the conclusion of the study, 31 students responded.

Computer Attitude Questionnaire

The results of the Computer Attitude Questionnaire which was administered to the students before and after the study, showed only small differences in student attitudes. Generally students' attitudes toward computers were very positive before the study and remained positive at the conclusion of the study.

Part A - Computer Anxiety

Part A of the questionnaire dealt with Computer Anxiety and consisted of ten Likert-type statements. Student responses on seven of the ten statements showed no major change when results before and after the study were compared. Three of the statements showed some differences in student opinion. The data are presented in Table 4.

The statement (item 3) "I do not feel threatened when others talk about computers" had 76% of all respondents agreeing or strongly agreeing before the study. After the study, 60% of respondents agreed or strongly agreed with the statement. More students were undecided after the study than before the study

Table 4

Computer Attitude Questionnaire

Part A - Computer Anxiety Results

Questions	Period	SD	D	U	A	SA
1. Computers do not scare me at all.	B	0 (0%)	1 (3%)	3 (9%)	8 (55%)	11 (33%)
	A	1 (3%)	2 (6%)	1 (3%)	18 (58%)	9 (29%)
2. Working with computers would make me very nervous.	B	11 (33%)	19 (58%)	2 (6%)	1 (3%)	0 (0%)
	A	12 (39%)	16 (52%)	0 (0%)	2 (6%)	1 (3%)
3. I do not feel threatened when others talk about computers.	B	1 (3%)	4 (12%)	3 (9%)	17 (52%)	8 (24%)
	A	1 (3%)	4 (13%)	7 (23%)	13 (42%)	6 (18%)
4. I feel aggressive and hostile towards computers.	B	17 (52%)	14 (42%)	1 (3%)	0 (0%)	1 (3%)
	A	11 (35%)	15 (48%)	3 (10%)	0 (0%)	0 (0%)
5. It wouldn't bother me at all to take computer courses.	B	0 (0%)	3 (9%)	2 (6%)	11 (33%)	17 (52%)
	A	1 (3%)	3 (10%)	1 (3%)	14 (45%)	12 (39%)
6. Computers make me feel uncomfortable.	B	11 (33%)	17 (52%)	1 (3%)	4 (12%)	0 (0%)
	A	10 (32%)	18 (58%)	2 (6%)	1 (3%)	0 (0%)
7. I would feel at ease in a computer class.	B	0 (0%)	2 (6%)	3 (9%)	19 (58%)	9 (27%)
	A	2 (6%)	2 (6%)	4 (13%)	16 (52%)	7 (23%)
8. I get a sinking feeling when I think of trying to use a computer.	B	13 (39%)	15 (45%)	3 (9%)	2 (6%)	0 (0%)
	A	12 (39%)	16 (52%)	2 (6%)	1 (3%)	0 (0%)
9. I would feel comfortable working with a computer	B	0 (0%)	2 (6%)	2 (6%)	18 (55%)	11 (33%)
	A	2 (6%)	2 (6%)	0 (0%)	18 (58%)	9 (29%)
10. Computers make me feel uneasy and confused.	B	11 (33%)	19 (58%)	2 (6%)	1 (3%)	0 (0%)
	A	8 (26%)	18 (58%)	4 (13%)	1 (3%)	0 (0%)

B - Before study - 33; **A** - After study - 31; **SD** (Strongly Disagree) . . . **SA** (Strongly Agree)

(Before the study: 9% , After the study: 23%). It appears that exposure to computers in the mathematics classroom caused more students to feel threatened when others talk about computers. An explanation for this result may be that the opinions students had about computers before the study were not based on actual experience, since approximately half of the students had not taken any prior computer courses in high school. Now that they have been exposed to computers they have a better understanding of some of the complexities involved.

The second statement (item 6) which showed some differences before the study compared to after the study was "Computers make me feel uncomfortable". Fewer students agreed or strongly agreed with this statement after the study than before the study. This is not surprising since the students spent many hours using the computer during their mathematics class.

The final statement (item 7), with significant differences is " I would feel at ease in a computer class". Fewer students agreed or strongly agreed with the statement after the study than before (Before: 85%, After: 75%). A possible explanation, similar to that for item 3, could be that the opinions students had about computers prior to the study were not always based on personal experience. Another possible explanation could be that students experienced computer anxiety during the course of studies.

Part B - Computer Confidence

Part B of the Computer Attitude Questionnaire was Computer Confidence. It consisted of ten Likert-type statements. The data are shown in Table 5. Four of the ten statements had noticeable differences when comparing the results before the study to the results after the study. The first statement (item 2) with noticeable differences is "Generally I would feel OK about trying a new problem on the computer". More

Table 5

Computer Attitude Questionnaire

Part B - Computer Confidence Results

Questions	Period	SD	D	U	A	SA
1. I'm no good with computers.	B	6 (18%)	19 (58%)	5 (15%)	3 (9%)	0 (0%)
	A	7 (23%)	17 (55%)	4 (13%)	2 (6%)	1 (3%)
2. Generally, I would feel OK about trying a new problem on the computer.	B	0 (0%)	1 (3%)	5 (15%)	21 (64%)	6 (18%)
	A	0 (0%)	5 (16%)	2 (6%)	18 (58%)	6 (19%)
3. I don't think I would do advanced computer work.	B	4 (12%)	5 (15%)	8 (24%)	10 (30%)	5 (15%)
	A	2 (6%)	9 (29%)	7 (23%)	10 (32%)	3 (10%)
4. I am sure I could do work with computers.	B	0 (0%)	1 (3%)	2 (6%)	24 (73%)	6 (18%)
	A	1 (3%)	2 (6%)	3 (10%)	15 (48%)	10 (32%)
5. I'm not the type to do well with computers.	B	9 (27%)	18 (55%)	4 (12%)	2 (6%)	0 (0%)
	A	10 (32%)	15 (48%)	4 (13%)	2 (6%)	0 (0%)
6. I am sure I could learn a computer language.	B	1 (3%)	0 (0%)	4 (12%)	18 (55%)	10 (30%)
	A	0 (0%)	1 (3%)	4 (13%)	12 (39%)	14 (45%)
7. I think using a computer would be very hard for me.	B	13 (39%)	18 (55%)	2 (6%)	0 (0%)	0 (0%)
	A	13 (42%)	14 (45%)	2 (6%)	2 (6%)	0 (0%)
8. I could get good grades in computer courses.	B	0 (0%)	2 (6%)	10 (30%)	16 (48%)	5 (15%)
	A	2 (6%)	2 (6%)	6 (19%)	11 (35%)	10 (32%)
9. I do not think I could handle a computer course.	B	11 (33%)	18 (55%)	3 (9%)	1 (3%)	0 (0%)
	A	14 (45%)	13 (42%)	1 (3%)	3 (10%)	0 (0%)
10. I have a lot of self confidence when it comes to working with computers.	B	2 (6%)	2 (6%)	12 (36%)	10 (30%)	7 (21%)
	A	1 (3%)	3 (10%)	12 (39%)	10 (32%)	5 (16%)

B - Before study - 33; **A** - After study - 31; **SD** (Strongly Disagree) . . . **SA** (Strongly Agree)

students disagreed with this statement after the study than before the study (Before: 3%, After: 16%). Fewer students were undecided after the study (Before: 15%, After: 6%). The statement (item 3) "I don't think I would do advanced computer work" resulted in more students disagreeing after the study than before the study (Before: 15%, After: 29%). The third statement (item 4) of interest is "I am sure I could do work with computers" resulted in more students strongly agreeing after the study than before the study (Before: 18%, After: 32%). The fourth statement (item 6) "I'm sure I could learn a computer language" also resulted in more students strongly agreeing after the study than before the study (Before: 30%, After: 45%).

In conclusion it can be said that using CAI in the mathematics class did not affect students' attitudes toward computers to a large extent. Some of the negative affects can be attributed to the fact that many students had little computer experience before the study; therefore, their opinions were not based on actual experience. However, after the study, their opinions were at least partially affected by the experience with the computer they obtained in their mathematics class, and these effects were not necessarily more positive.

Mathematics Attitude Questionnaire

The Mathematics Attitude Questionnaire consisted of twelve Likert-type statements and was administered before and after the study. Eight of the twelve statements have noticeable differences as shown in Table 6.

The first statement (item 2) "Mathematics is a very worthwhile and necessary subject" had significantly more students strongly agreeing after the study compared to before the study (Before: 21%, After: 42%).

Another statement (item 7) worth noting is "Mathematics helps to develop the mind and teaches a person to think". Significantly more students strongly agreed with

Table 6

Mathematics Attitude Questionnaire Results

Question	Period	SD	D	U	A	SA
1. Mathematics is not a very interesting subject.	B	1 (3%)	13 (39%)	5 (15%)	11 (33%)	3 (9%)
	A	1 (3%)	12 (39%)	7 (23%)	8 (26%)	3 (10%)
2. Mathematics is a very worthwhile and necessary subject.	B	1 (3%)	4 (12%)	6 (18%)	15 (45%)	7 (21%)
	A	0 (0%)	1 (3%)	3 (10%)	14 (45%)	13 (42%)
3. I have usually enjoyed studying mathematics in school.	B	5 (15%)	10 (30%)	5 (15%)	11 (33%)	2 (6%)
	A	2 (6%)	5 (16%)	5 (16%)	14 (45%)	5 (16%)
4. I don't want to take any more mathematics than I have to.	B	0 (0%)	10 (30%)	7 (21%)	9 (27%)	7 (21%)
	A	1 (3%)	13 (42%)	7 (23%)	8 (26%)	2 (6%)
5. Other subjects are more important to people than mathematics.	B	1 (3%)	7 (21%)	11 (33%)	11 (33%)	3 (9%)
	A	1 (3%)	10 (32%)	10 (32%)	8 (26%)	2 (6%)
6. I have seldom liked studying mathematics.	B	0 (0%)	14 (42%)	4 (12%)	10 (30%)	5 (15%)
	A	3 (10%)	13 (42%)	3 (10%)	8 (26%)	4 (13%)
7. Mathematics helps to develop the mind and teaches a person to think.	B	1 (3%)	1 (3%)	7 (21%)	20 (61%)	4 (12%)
	A	0 (0%)	0 (0%)	5 (16%)	15 (48%)	11 (35%)
8. Mathematics makes me feel uneasy and confused.	B	1 (3%)	13 (39%)	4 (12%)	11 (33%)	4 (12%)
	A	3 (10%)	14 (45%)	3 (10%)	8 (26%)	3 (10%)
9. Mathematics is enjoyable and stimulating to me.	B	3 (9%)	11 (33%)	8 (24%)	11 (33%)	0 (0%)
	A	4 (13%)	4 (13%)	7 (23%)	13 (42%)	3 (10%)
10. Mathematics is dull and boring.	B	1 (3%)	12 (36%)	10 (30%)	7 (21%)	3 (9%)
	A	6 (18%)	12 (39%)	5 (16%)	5 (16%)	3 (10%)
11. Mathematics is one of my most dreaded subjects.	B	1 (3%)	10 (30%)	5 (15%)	10 (30%)	7 (21%)
	A	5 (16%)	11 (35%)	4 (13%)	6 (18%)	5 (16%)
12. I like trying to solve new problems in mathematics.	B	2 (6%)	8 (24%)	9 (27%)	13 (39%)	1 (3%)
	A	0 (0%)	6 (18%)	6 (18%)	16 (52%)	3 (10%)

B - Before study - 33; **A** - After study - 31 ; **SD** (Strongly Disagree) . . . **SA** (Strongly Agree)

this statement after the study than before (Before: 12%, After 35%). A possible explanation for this change could be that students felt more responsibility for their own learning using the CAI courseware. The CAI courseware forced them to think.

The statement (item 9) "Mathematics is enjoyable and stimulating to me" was agreed or strongly agreed upon more frequently after the study than before (Before: 33%, After: 52%). A fourth statement (item 12) from the Mathematics Attitude Questionnaire worth noting is "I like trying to solve new problems in mathematics". More students agreed or strongly agreed with this statement after the study than before (Before: 42%, After: 62%).

The statement (item 10) "Mathematics is dull and boring" had more students strongly disagreeing after the study than before (Before: 3%, After: 18%). The next statement (item 4) "I don't want to take any more mathematics than I have to" resulted in more students disagreeing or strongly disagreeing after the study than before the study (Before: 21%, After: 6%).

Another statement (item 5) with noticeable differences is "Mathematics makes me feel uneasy and confused". More students disagreed or strongly disagreed with this statement after the study than before (Before: 42%, After: 55%). A possible explanation for this change may be found when analyzing the reasons students gave for why they liked using the computer software. The statement (item 11) "Mathematics is one of my most dreaded subjects" also showed some significant changes. Before the study, 33% of the respondents either disagreed or strongly disagreed with the statement. After the study, 51% of the students disagreed or strongly disagreed with the statement.

In summary, there appear to be some major changes in students' attitudes toward mathematics, when looking at their responses before the study compared to after the study. All of the changes were positive in nature. Some of these changes

may possibly be explained by analyzing student responses to why they liked using the computer software.

Course Evaluation Form

The students completed the Course Evaluation Form at the conclusion of the study. The form consisted of six Likert-type statements, plus two open ended questions.

Likert-Type Statements

The results of the six Likert-type statements are presented in Table 7. The first question from the table resulted in a perfect split between the number of students that disagreed or strongly disagreed compared to the number of students that agreed or strongly agreed. Sixty-one percent of all respondents disagreed or strongly disagreed with the second statement , "It was frustrating to use a computer in math class this year". An explanation for those who agreed with this statement can be found in the open ended question where students stated they were frustrated with errors in the software. Sixty-seven percent of the respondents said they agreed or strongly agreed with the statement that they enjoyed using a computer in Math 300.

Statement number 4, "Learning in a regular Math 300 classroom can be frustrating. It is difficult to understand what is going on", resulted in a very close split between the number of students who disagreed or strongly disagreed compared to the number of students who agreed or strongly agreed. Interestingly, 26% of the respondents were undecided. A possible explanation for this is that the students may feel that their opinion on this statement depends on who the teacher is. Fifty-one percent of the respondents agreed or strongly agreed with statement number 5. But again, 26% of respondents were undecided. A similar explanation could be given

Table 7

Student Course Evaluation Form

Likert Statement Results

Question	SD	D	U	A	SA
1. I believe that the computer-assisted method for learning mathematics was better than the traditional teacher taught method	6 (19%)	7 (23%)	5 (16%)	3 (10%)	10 (32%)
2. It was very frustrating to use a computer in math this year.	10 (32%)	9 (29%)	2 (6%)	5 (16%)	5 (16%)
3. I enjoyed using a computer in Math 300.	2 (6%)	5 (16%)	3 (10%)	10 (32%)	11 (35%)
4. Learning in a regular Math 300 classroom can be frustrating. It is difficult to understand what is going on.	2 (6%)	10 (32%)	8 (26%)	6 (19%)	5 (16%)
5. Learning in a regular Math 300 classroom with a teacher instructing is interesting.	2 (6%)	5 (16%)	8 (26%)	15 (48%)	1 (3%)
6. I would recommend the Math 300 computer software to be used in all Math 300 classes.	6 (19%)	5 (16%)	4 (13%)	7 (23%)	9 (29%)

Note. **SD** (Strongly Disagree) . . . **SA** (Strongly Agree); # respondents: 31
The number in each cell represents the number of students that chose that particular response.

here as in question #4. The final Likert-type statement, "I would recommend the Math 300 software to be used in all Math 300 classes", resulted in 52% of the respondents agreeing or strongly agreeing.

Open Ended Questions

These data are presented in Table 8 in summary point form. The number of occurrences mentioned by the students in the open ended questions is presented. A discussion of the data follows.

What did you like most about using the computer software in your math class?

This was the first open ended question of the Course Evaluation Form. The student responses to this question have been organized into four categories: 1) Pacing/Format, 2) Role of Student/Role of Teacher/Learning Styles, 3) Software, and 4) Novelty.

Pacing/Format. There were three frequently stated comments that were made in this category. The first comment, which occurred fifteen out of 31 times was that what they liked most about the software was that they could proceed at their own pace. The response in this area is interesting since the students were given deadlines as to when units had to be completed, which meant that they did have to work within the deadlines. Reflecting on how traditional mathematics classrooms operate, one can understand why this aspect of pacing was so appealing to the students. Traditional classrooms do not tend to have much flexibility built into them as far as pacing is concerned. The second comment that occurred nine times out of 31 was that what they liked most about using the software was that if they did not understand a lesson/topic they could take that same lesson over again. One student said it this way:

> If you don't understand it, the computer will go through it step by step; a teacher usually jumps back and forth and confuses you more which is frustrating.

Table 8

Student Course Evaluation Form

Open Ended Question Results

7. What did you like most about using the computer software in your math class?

	Occurrences
Pacing/Format	
1. Allows one to work at your own pace	15
2. You can go back to a certain topic and review it (if you don't understand)	9
3. If you missed a class it is not as bad (you are not lost or confused) because it is easier to catch up.	5
4. Didn't need to worry if you were a page behind the rest of the class	1
5. It is great if you are a fast learner, because you can move ahead	1
6. That there wasn't homework every night	1
Role of Students/Teachers/Learning Styles	
Independence:	
1. You are completely responsible for yourself	3
2. It teaches you independence	3
3. Taught yourself	2
4. Going through the process by your self	1
Note-Taking:	
5. Less note taking; all my notes we always on the computer; the computer always had organized notes to study from	3
6. It is more relaxing, rather than a teacher giving you constant notes	2
7. It was a lot easier than taking notes all day, because you got to do examples for the entire class, not just at the end when you get your homework	1

Table 8 Continued

	Occurrences
<u>One on One</u>:	
8. The computer was my teacher. It was always 1 on 1. In a regular classroom the ratio is usually 1:25	2
<u>Relationship with Teacher</u>:	
9. The computer doesn't lecture or get on your case	1
10. Less confrontations with teachers	1
<u>Other</u>:	
11. It is great if you can learn something just by reading it	1
12. A computer is straightforward and much less confusing than most teachers	1
13. If you don't understand it, the computer will go through it step by step; A teacher usually jumps back and forth and confuses you more which is frustrating	1
14.. For me it was easier to remember	1
15. A computer is not bias; accordingly, if a teacher does not like you, often extra instruction from the teacher is inferior. However with a computer every student gets equal instruction and can get as much help and practice he or she wishes	1
Software	
1. It was very detailed and made it easy to catch onto things (The in-depth explanation and breakdown of problems) It showed most things in a logical, step by step manner and it highlighted the most important formulas and key points	4
2. The "Test Banks" which refer you to the section from which the incorrectly answered question was from	2
3. I thought that they gave a lot of exercises, which was good because the ideas were drilled into your head	1

Table 8 Continued

	Occurrences
4. It was very easy to work with	1
5. Told you if you had the wrong answer in the practice exercises	1
6. You get problems with accurate and precise diagrams	1
7. You know how to set up a diagram, but you don't have to waste time going though the procedure for every problem	1
Novelty	
1. It was different	1
2. Using a computer in general is fun, but using one to learn math from was interesting	1
3. It was more interesting than a regular Math 300 course Time went faster and it wasn't as boring	1
4. Using a computer	1

8. What did you like least about using the computer software in your math class?

	Occurrences
Software	
1. Inflexible in the interpretation of answers	5
2. It was slow, it took time. Teacher could have taught it quicker	4
3. The software still has errors in it; causes frustrations	3
4. The ease in which a person could simply run through the program without learning anything	2
5. Often, explanations were not given for how answers were created	2
6. There should be more examples on the Math 300 software	2
7. "Test Bank" questions are hard	1

Table 8 Continued

	Occurrences
8. "Test Bank" questions should show the steps in solving a problem	1
9. "Test Bank" didn't always correspond to the lesson	1
10. Hard to understand	1
11. Sometimes the software leaves out steps so you don't really understand what is going on	1
12. I didn't like reading the long continuous pages	1
13. Some of the computer functions throughout the year never worked: like pi and ±, It made it confusing when the answer was wrong and when it was right	1
14. It can be difficult at times and hard to understand	1
15. They were very picky about how they explained the assignments and stuck with that one way	1
16. It couldn't help you with your weak points	1
17. If I didn't understand something on the computer I could not be helped by the computer. I needed a teacher's help to better explain the lesson	1
Roles of Students/Teacher/Learning Styles	
Student Role:	
1. It was harder for me to learn the material	3
2. It was a bit hard to concentrate when reading some of the information	2
3. A computer is hard to learn from	1
4. Some people need to see and hear the teacher explaining something to fully understand it	1
5. It is hard to adjust from learning from a teacher to basically just a computer	1
6. It is hard to understand if someone doesn't explain what you are doing	1

Table 8 Continued

	Occurrences
7. What they tell you on screen does not sink in, unlike when a teacher is teaching you	1
8. I can't simply read and learn. I like to take notes and ask questions, but a computer can only explain an answer one way	1
9. I need to take notes to learn	1
Teacher Role:	
10. Since there is only 1 teacher many questions went unanswered. There were so many people with questions that a lot of people just gave up asking someone because if you waited you would never get through the material	4
11. When you are in a classroom and the teacher is teaching, you can ask a question that many people may have, but on the computer everyone is at different places and a lot of time is wasted waiting for a teacher to answer your question that might have been answered sooner in a regular classroom	1
Other:	
12. During double math periods my eyes would get sore from staring at the screen for 2 hours	2
13. A teacher can make the course interesting	1
14. Not a good course for students who rely on teachers and have had a hard time with math	1
15. Not having any notes or examples in my binder to help me study for the exam. I didn't catch onto taking my own notes until halfway through the year	1
16. You get into a pattern of answering questions on the computer, but when it comes times to do the questions on paper or on a test, it is hard to answer because you are not sure what to do	1

Table 8 Continued

	Occurrences
17. It can get monotonous at times staring at the same computer screen for hours, but it is better than listening to a teacher lecture for hours	1
18. I sometimes get tired, and no one is pushing me to work	1
19. It was easier in a classroom when a teacher was nearby	1
20. A computer is too impersonal/ no interaction with other people	1
Miscellaneous	
1. If you do all the work on the computer, then you should do the test on the computer too so that the format is the same	1
2. I think the class would be better if the teacher did the teaching and we used the computer just for doing exercises or work	1
3. The fact that we were thrown into one of these kind of classes in our final year. I much rather would have taken Math 300 in a teacher oriented class	1
4. I didn't really like the graphing on the computer as much	1
5. Hardware problems	1

The third comment under Pacing/Format, which was stated by five students, was that what they liked most about using the computer software was that if they missed a class one was not lost or confused the next class. It was easier to catch up. What often happens in a traditional mathematics classroom is that a teacher delivers a crucial lesson on a particular mathematical concept only to have a number of students absent. The students then return to discover that they are very confused as to what is happening in class.

Role of Students/Role of Teacher/Learning Styles. There are four recurring themes that appeared in the student comments which fall under this category: 1) Independence, 2) Note-taking, 3) One on One, and 4) Relationship with teacher. There were nine students who said that what they liked about using the computer software was that it taught them to be independent. They were responsible for themselves. Six students made the comment that what they liked was that they did not have to spend the majority of their class time taking notes. One student stated it this way:

> It was a lot easier than taking notes all day, because you got to do examples for the entire class, not just at the end when you got your homework.

It appears as if some students felt that their time was better spent in the CAI classroom. Two students commented that what they liked was that the computer was their teacher and therefore it was always on a one-to-one basis, rather than a one-to-twenty-five ratio, as in a regular class. Two students made comments implying that they had a better relationship with the teacher in the CAI classroom compared to a traditional classroom. Another student's comment might suggest a reason for an improved relationship with the teacher in the CAI classroom:

> A computer is not bias [sic]; accordingly if a teacher does not like you, often extra instruction from the teacher is inferior. However with a computer every student gets equal instruction and can get as much help and practice he or she wishes.

Students can readily sense when a teacher does not want to provide extra help for them outside of regular class time. With the increased work load of many high school teachers this is understandable from the teacher's point of view. Very possibly the

software provides students the opportunity to receive the extra instruction that is needed without the risk of it being "inferior".

Software. There were a total of eleven comments made about aspects of the software that the students liked. Four students said that the software was very detailed and made it easy to catch onto things. Two students said that they liked the "Test Banks" which referred them to the section from which incorrectly answered questions originated.

Novelty. Four students said they liked using the software because it was different; it was interesting. After an entire semester of using the software, it was a surprise that some students would make this kind of comment. One would have thought that the novelty would have worn off.

What did you like least about using the computer software in your math class?

This was the second open ended question of the Course Evaluation Form. The student responses to this question have been grouped into two categories: 1) Software and 2) Roles of Student/Roles of Teachers/ Learning Styles.

Software. There were 29 different comments made by students referring to aspects of the software that they did not like. The most frequently occurring comment (5 occurrences) was that they did not like the fact that the software was inflexible in interpreting answers that they entered. This is how one student expressed this concern:

> The computer should be programmed to accept answers that are reasonably close. Ex: Answer is 58.96, and you enter 58.98 and the computer marks you wrong, you work out the problem again (waste time) and arrive at the same answer only to find out that you are correct - just a marginal error.

This is one of the major concerns that both teachers and students have had with regards to the Level 4 software. Some students (4 occurrences) commented that the software was slow to use. A teacher could have taught it quicker. Three students said that they did not like the errors in the software - it caused them to be frustrated. A few students said they did not like using the software because it was too easy for a student to simply run through the program and not learn anything. Two students said they did not like it when there was no explanation given as to how the answer was obtained.

Role of Student/Role of Teacher/Learning Styles. The most frequent comment that was cited (10 occurrences) in this category was with regard to students' roles in the classroom. Some students said it was harder for them to learn the material. They preferred to learn from a teacher. "Some people need to see and hear the teacher explaining something to fully understand it" was one student's comment. Another student said "it is hard to adjust from learning from a teacher to basically just a computer." This is understandable since the majority of students had received all previous instruction from a teacher. These comments reinforce the idea that not all learners find the CAI classroom to be the best way for them to learn. It also confirms the idea that the student has a different role to play in the CAI classroom than in a traditional classroom. A second comment which occurred in this category five times was that there were so many student questions that the teacher did not have time to answer all of them. This caused some students to stop asking questions.

Summary of Student Data

There appears to be little significant effect on students' attitudes toward computers when exposed to mathematics teaching using curriculum based CAI materials. Level of comfort with computers increased slightly, whereas slightly fewer

students felt comfortable when others talked about computers. Fewer students said they felt at ease in a computer class after the study compared to before the study took place.

It was found that there were significant changes in students' attitudes toward mathematics when exposed to mathematics teaching using curriculum based CAI materials. More students after the study compared to before the study either agreed or strongly agreed with the following statements: "Mathematics is a very worthwhile and necessary subject"; "Mathematics helps to develop the mind and teaches a person to think"; "Mathematics is enjoyable and stimulating to me"; and "I like trying to solve new problems in mathematics". More students either disagreed or strongly disagreed with each of the following statements: "I don't want to take any more mathematics than I have to"; "Mathematics make me feel uneasy and confused"; "Mathematics is dull and boring"; and "Mathematics is one of my most dreaded subjects". Overall there was a positive change in students' attitudes toward mathematics.

Chapter Six

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary of the Study

Questions and procedures

The purpose of this study was to examine the effects of using a curriculum based CAI program in the classroom. Two questions were posed for the investigation:

1. What changes take place in the teaching process, when a program of computer assisted instruction is implemented?
2. What is the effect on students' attitudes toward mathematics and attitudes toward computers when exposed to mathematics teaching using curriculum based CAI materials?

In order to answer these questions, a Weekly Teacher Report Form and Final Report Form were developed and used by three teachers who were implementing the software in their mathematics classroom. The forms provided some guidelines to the teachers in recording their thoughts and actions throughout the term. To answer question number two, a Computer Attitude Questionnaire and Mathematics Attitude Questionnaire were administered to students before the study as well as at the completion of the study. The students also completed a Course Evaluation Form at the completion of the study.

Results

The complete teacher data analysis can be found in Chapter Five. The teachers found that the teaching process changed significantly when implementing the Level 4 courseware in their mathematics classroom. Spending time going through the software before students did was a significant change in the teaching process. Hardware and software concerns were always present, but not a major problem. The most significant change in the teaching process was that of a new role for the teacher. The teacher became a facilitator in the learning process and the teachers' diagnostic role was more emphasized. The three teachers involved in this study came to realize that the expository role is not an easy one to give up. It was always a challenge to remain in the facilitator role, and not "take over" the class. The general consensus was that the facilitator role is superior to the expository role because students became more responsible and more actively involved in their own learning.

The Computer Attitude Questionnaire results are found in Chapter Five. Generally there were no significant changes in students' attitudes toward computers. Their comfort level with computers increased slightly, although they felt more uncomfortable when others talked about computers after the study than before. More students felt they would do advanced computer work.

The Mathematics Attitude Questionnaire results showed a significant difference in students' attitudes toward mathematics after the study than before the study. Their attitudes were positively affected in all cases.

Implications of the Results

If mathematics classrooms are to change so that students have much more control of their own learning (which is advocated throughout the Standards), the results of this study imply that teachers will need assistance in adjusting to a new role.

The teachers that took part in this study had a prior understanding about this role change but still found it difficult to remain in the role of facilitator of the learning process. Training sessions would need to be provided which allow teachers to observe and take part in this new role.

A possible explanation for why students felt more uncomfortable when others talked about computers after the study, than before the study may be that students opinions prior to the study were not based on actual experience. Nearly half of the students involved in the study had not completed any computer courses in their high school years. The exposure to computers that they experienced as part of their mathematics classroom possibly revealed complexities of computers that they were not aware of before. This implies that a specific effort must be made to increase students' comfort level with computers.

The change that took place in students' attitudes toward mathematics may possibly imply that one way to positively affect students' attitudes may be through using CAI in the mathematics classroom. The three most frequently stated reasons that students cited for why they liked using the software were: 1) they could go at their own pace, 2) they could repeat a lesson that they did not understand and 3) if they missed a class it was easier to catch up. These student comments imply that they desire more flexibility to be built into their mathematics instruction. CAI is one possible way of accommodating these desires.

Advice To Teachers

The advice that the teachers in this study would give to other teachers who are considering using CAI courseware in their classroom would be to ensure that administrative and collegial support are in place. It is crucial that the correct computer hardware is available, and that technical support for the hardware and

software are available. A computer at home with the software on it, or at least one computer in the mathematics department for teachers use only is likely essential. It is important to go through the software as a student would and to provide deadlines for the completion of units, that is, teachers should not expect the software to stand on its own. Print support materials for the students will most likely need to be developed. Conscious work at changing the teacher's role from "sage on the stage" to "guide on the side" will be necessary. Further, teachers need to become more flexible in their teaching, looking at new ways of teaching a mathematical concept and using their judgment based on experience as a mathematics teacher to decide when to supplement the software. The software should not be viewed as an "add on" it should drive the curriculum.

Recommendations for Further Research

The Computer Attitude and Mathematics Attitude Questionnaires did provide an indication of students attitudes. In this study, the changes in students' attitudes toward mathematics could have occurred for a variety of reasons. Students in their final year of high school are examining post-secondary education which may have made them more aware of the need of mathematics as a pre-requisite for many programs of study. Another explanation may be that the software tended to provide introductions to new mathematical concepts by showing how the concept could be applied to real-life situations. This may have raised students' awareness of the importance of mathematics and caused their attitudes toward mathematics to improve. These instruments, along with others, could be used in a larger study which involves a control group in order to determine what causes change in such attitudes.

The Weekly Teacher Report Forms and Final Teacher Report Form were useful in gathering information as to what the teachers did and what they were

thinking throughout the study. Since the data come entirely from the teacher researchers themselves, it may possibly be biased. Further research could involve having other researchers regularly attend a teacher's class where the software is being used, recording the actions, thoughts and experiences of both the teacher and the students. This could enlarge the answer to one of the questions of this study - "How does the teaching process change when implementing a curriculum based CAI program in the mathematics classroom?"

Conclusions

Initially the teachers in this study found that there was some resistance from other colleagues in using the schools' computers to teach mathematics. Traditionally the computers in most high schools are only used for computer science and business classes. School administrators and teachers need to work at breaking down this barrier.

It is important to establish a stable environment which allows for the smooth operation of the software. A properly designed lab, which allows for teaching the entire class, small groups, and individual work is crucial in order to successfully implement CAI in the mathematics class.

Teachers can be reassured that students' attitudes toward computers and toward mathematics are not negatively effected when they receive the majority of their instruction through CAI. This study showed an improvement in students' attitudes toward mathematics as a result of the CAI courseware.

Teachers must be prepared to significantly change many aspects of their teaching if they are considering implementing a CAI program in their mathematics class. These changes should normally include preparing print materials to support the

software, and adjusting their role from a traditional one to a strategic facilitator in the learning process.

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Appendix A

Letters to School Divisions

Katharine Tetlock

Winnipeg, MB
R

Seven Oaks School Division
830 Powers St.
Winnipeg, MB
R2V 4E7

Mr. David Coulter:

As you may be aware, two teachers at West Kildonan Collegiate, Alan Wells and Ruth Shrofel, will be utilizing Computer Assisted Instruction (CAI) Courseware in a Mathematics 300 class. As part of my Master's Program in Education, I am interested in studying the change in the teaching process when utilizing such a program. I am also looking at the effect on students' attitudes toward mathematics and toward computers when exposed to CAI in their mathematics class.

I am requesting permission from the Seven Oaks School Division to gather data from the students involved regarding their attitudes toward mathematics and toward computers. The students will be expected to complete the Mathematics Attitude Questionnaire and Computer Attitude Questionnaire (see attached) at the commencement of the study, as well as at the conclusion of the study. The students will also be expected to complete the Course Evaluation Form (see attached) at the completion of the study. The total time this will require of the students will be approximately one hour. The two teachers involved have agreed to administer the questionnaires and evaluation form, provided the division agrees.

Parent consent forms (see attached) must be completed for students to participate in the study. All of the information obtained in the study will remain strictly confidential. Upon completion of the study, a summary of the results will be made available to the Seven Oaks School Division.

Further information about this study can be obtained by contacting my Faculty Advisor, Lars Jansson at at the University of Manitoba.

Sincerely

Katharine Tetlock

cc: Mr. K. Humeny

Katharine Tetlock

Winnipeg, MB
R

St. Boniface School Division
50 Monterey Rd
Winnipeg, MB
R2J 1X1

Dr. G. McConaghy:

As you are aware I am teaching a section of Mathematics 300 at J.H. Bruns utilizing Computer Assisted Instruction (CAI) courseware. As part of my Master's Program in Education I am interested in looking at the change in the teaching process when utilizing such a program. I would also like to study the effect on students' attitudes toward mathematics and toward computers when exposed to CAI in their mathematics class.

I am requesting permission from the St. Boniface School Division to gather data from the students involved regarding their attitudes toward mathematics and toward computers. The students will be expected to complete the Mathematics Attitude Questionnaire and Computer Attitude Questionnaire (see attached) at the commencement of the study, as well as at the conclusion of the study. The students will also be expected to complete the Course Evaluation Form (see attached) at the completion of the study. The total time this will require of the students will be approximately one hour.

Parent consent forms (see attached) must be completed for students to participate in the study. All of the information obtained in the study will remain strictly confidential. Upon completion of the study, a summary of the results will be made available to the St. Boniface School Division.
Further information about this study can be obtained by contacting my Faculty Advisor, Lars Jansson at . at the University of Manitoba.

Sincerely

Katharine Tetlock

cc: Peter Janzen

Appendix B

Parent Consent Form

Katharine Tetlock
J.H. Bruns Collegiate
250 Lakewood Blvd
Winnipeg, MB
R2J 3A2

Dear Parents/Guardian:

My name is Katharine Tetlock and I am a University of Manitoba graduate student currently working on a Master's Thesis within the Faculty of Education. I am interested in studying the effect on students' attitudes toward mathematics and toward computers when exposed to computer assisted instruction in their mathematics class.

The school division has approved of the study. I am requesting your permission for your son/daughter to participate in the study. His/her participation will consist of completing two questionnaires regarding their attitudes toward mathematics and toward computers. The questionnaires will be administered at the beginning of the study, as well as at the completion of the study. Your son/daughter will also be requested to complete a brief Course Evaluation Form. The total time this will require of your son/daughter will be approximately one hour.

All of the information obtained from the study will remain strictly confidential. Your son/daughter has the right to withdraw from completing the questionnaires and Evaluation Form at any time. Upon completion of the study, a summary of the results will be made available upon request.
The school division has approved of the study. The administration at West Kildonan Collegiate has requested that this data be collected in order to help them make future decisions regarding the use of technology in the classroom. Further information about this study can be obtained by contacting myself at J.H. Bruns Collegiate,

Thank you for your cooperation.

Sincerely

Katharine Tetlock

I give my consent for my son/daughter to participate in the study as described above.

_____

Parent/Guardian Signature

Appendix C

Letters Received From School Divisions

CAI 91

DIVISION SCOLAIRE DE
ST. BONIFACE
SCHOOL DIVISION NO. 4
50 MONTEREY ROAD, ST. BONIFACE, MANITOBA R2J 1X1
TELEPHONE: (204) 253-2681 FAX: (204) 257-4805

January 27, 1994

Gerald McConaghy, Ed. D.
Superintendent and Secretary Treasurer
Directeur général et secretaire-trésorier

Ms. Katharine Tetlock

Winnipeg, Manitoba
R

Dear Kathy:

This is to acknowledge receipt of your letter received here on January 24.

I am in agreement with your request to survey students in the Mathematics 300 section that you will be teaching.

Best of luck with the study and with the completion of your Masters program.

Sincerely yours,

Gerald McConaghy
Superintendent of Schools

GM:rms
cc P. Janzen

CAI 92

SEVEN OAKS SCHOOL DIVISION NO. 10

830 POWERS STREET WINNIPEG, MANITOBA R2V 4E7

Telephone: (204) 586-8061 Fax: (204) 589-2504

February 9, 1994

Ms Katharine Tetlock

Winnipeg, Manitoba
R

Dear Ms Tetlock:

At its regular meeting of Monday, February 7, 1994, the Board of Trustees passed the following motion:

> "That Katharine Tetlock be granted permission to conduct research on the effect on students' attitudes towards mathematics and towards computers when exposed to Computer Assisted Instruction (CAI) in their mathematics class, as per her proposal."

Best wishes for a successful research project.

Yours truly,

David Coulter,
Acting Superintendent.

DC:eb

c.c. K. Humeny
A. Wells
R. Shrofel

Appendix D

Instruments for Teachers

Date:_____

Weekly

Teacher Report Form

1. Briefly describe what has taken place in your classroom during this past week. Categorize your responses into two areas - (1) teacher activity and (2) student activity.

2. Describe the type of print material you used this week. Did the students use the print material?

3. How much time was spent on your part preparing for teaching this week. Explain the nature of this time. How does this amount of time compare to preparing for a mathematics class taught using traditional methods?

4. Describe any changes in your teacher role that you have not noticed before. Consider the instructional and managerial components of teaching. How do you feel about those changes?

5. What impact do you feel the use of the Level 4 courseware has on your teaching style and strategies? Consider:
   - classroom management
   - instructional mode
   - direct instruction
   - monitoring and pacing
   - teacher flexibility
   - feedback

6. What have you observed this week about students using the courseware. How do you feel about these observations you have made about students. Consider the following:

    (i) amount of student/student interaction
    (ii) amount of student/teacher interaction
    (iii) Nature of student questions and teacher responses
    (iv) Attitudes

7. Did you have any contact with other teachers, administrators, or parents this week. What was the nature of this contact?

8. Software (Things you like/things you don't like)

   Hardware Problems (What were they and how did they affect the class)

9. Other Concerns/Comments

Final

Teacher Report Form

1. Describe the differences you perceive in your role as a teacher in a traditional mathematics class compared to the classroom using the computer software. Consider both the instructional and managerial aspects of teaching.

2. In your opinion, what impact did the use of the Level 4 courseware have on student attitudes toward mathematics and toward computers? Justify your response.

3. In your opinion, what impact did the use of the Level 4 courseware have on the achievement of your students? Justify your response.

4. Describe the major frustrations in implementing the Level 4 courseware

5. Describe the major achievements in implementing the Level 4 courseware.

6. Outline the major antecedents and supports that you feel must be in place in order to successfully implement this type of program into mathematics classes.

7. In general, what advice would you offer to other teachers using the Level 4 courseware?

Appendix E

Instruments for Students

Computer Attitude Questionnaire

Directions: Draw a circle around the letter(s) indicating how strongly you agree or disagree with each statement: SD (Strongly Disagree), D (Disagree), U (Undecided), A (Agree), SA (Strongly Agree)

Part A - Computer Anxiety

1. Computers do not scare me at all. SD D U A SA
2. Working with a computer would make me very nervous. SD D U A SA
3. I do not feel threatened when others talk about computers. SD D U A SA
4. I feel aggressive and hostile toward computers. SD D U A SA
5. It wouldn't bother me at all to take computer courses. SD D U A SA
6. Computers make me feel uncomfortable. SD D U A SA
7. I would feel at ease in a computer class. SD D U A SA
8. I get a sinking feeling when I think of trying to use a computer. SD D U A SA
9. I would feel comfortable working with a computer. SD D U A SA
10. Computers make me feel uneasy and confused. SD D U A SA

Part B - Computer Confidence

1. I'm no good with computers. SD D U A SA
2. Generally, I would feel OK about trying a new problem on the computer. SD D U A SA
3. I don't think I would do advanced computer work. SD D U A SA
4. I am sure I could do work with computers. SD D U A SA
5. I'm not the type to do well with computers. SD D U A SA
6. I am sure I could learn a computer language. SD D U A SA
7. I think using a computer would be very hard for me. SD D U A SA
8. I could get good grades in computer courses. SD D U A SA
9. I do not think I could handle a computer course. SD D U A SA
10. I have a lot of self confidence when it comes to working with computers. SD D U A SA

Mathematics Attitude Questionnaire

Directions: Draw a circle around the letter(s) indicating how strongly you agree or disagree with each statement: SD (Strongly Disagree), D (Disagree), U (Undecided), A (Agree), SA (Strongly Agree)

1. Mathematics is not a very interesting subject.	SD D U A SA
2. Mathematics is a very worthwhile and necessary subject.	SD D U A SA
3. I have usually enjoyed studying mathematics in school.	SD D U A SA
4. I don't want to take any more mathematics than I have to.	SD D U A SA
5. Other subjects are more important to people than mathematics.	SD D U A SA
6. I have seldom liked studying mathematics.	SD D U A SA
7. Mathematics helps to develop the mind and teaches a person to think.	SD D U A SA
8. Mathematics makes me feel uneasy and confused.	SD D U A SA
9. Mathematics is enjoyable and stimulating to me.	SD D U A SA
10. Mathematics is dull and boring.	SD D U A SA
11. Mathematics is one of my most dreaded subjects.	SD D U A SA
12. I like trying to solve new problems in mathematics.	SD D U A SA

Course Evaluation Form (S)

Directions: Draw a circle around the letter(s) indicating how strongly you agree or disagree with each statement: SD (Strongly Disagree), D (Disagree), U (Undecided), A (Agree), SA (Strongly Agree)

1. I believe that the computer-assisted method for learning mathematics was better than the traditional teacher taught method.

SD D U A SA

2. It was very frustrating to use a computer in math this year.

SD D U A SA

3. I enjoyed using a computer in Math 300.

SD D U A SA

4. Learning in a regular Math 300 classroom can be frustrating. It is difficult to understand what is going on.

SD D U A SA

5. Learning in a regular Math 300 classroom with a teacher instructing is interesting.

SD D U A SA

6. I would recommend the Math 300 computer software be used in all Math 300 classes.

SD D U A SA

7. What did you like most about using the computer software in your math class?

8. What did you like least about using the computer software in your math class?