Supplemental visual computer assisted instruction and student achievement in freshman college calculus

by Virgil Grant Fredenberg

A thesis submitted in partial fulfillment of the requirement for the degree of Doctor of Education
Montana State University

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Results indicated little statistically significant change in student attitudes and anxiety, and no statistically significant change in achievement. Students receiving supplemental computer labs performed as well as students who received additional homework.

Recommendations for future research include: continued research into the use of supplemental CAI in the form of computer labs; research into the use of graphing calculators in college calculus; research into long-term effects of CAI in college calculus; and research into college calculus courses which have been restructured to take advantage of technology in the classroom.

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A thesis submitted in partial fulfillment
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Montana State University
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APPROVAL

of a thesis submitted by

Virgil Grant Fredenberg

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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VITA

Virgil Grant Fredenberg was born October 15, 1954 in Kalispell, Montana. He graduated from Flathead High School in June, 1973.

He attended Flathead Valley Community College from September, 1973 to December 1975 when he joined the United States Air Force. He served in computer operations in the Strategic Air Command and the Alaskan Air Command. He was honorably discharged in July, 1980.

He returned to college and received a Bachelor of Science degree from Montana State University, Bozeman, Montana in 1983 with a major in Mathematics and a minor in Industrial Arts.

He taught mathematics, woodworking and computer science at Kenny Lake School, Copper River School District, Glennallen, Alaska from August, 1983 to May, 1985. From August, 1985 to June, 1986 he taught mathematics and computer science at Whitehall High School, Whitehall, Montana.

He returned to Montana State University as a graduate teaching assistant in the Department of Mathematical Sciences in September, 1986 and completed a Master of Science degree with a major in Applied Mathematics in June, 1988. He continued as a graduate teaching assistant in the Department of Mathematical Sciences from June, 1988 through June, 1991. During these five years, his wife completed her undergraduate degree in education and they had two beautiful daughters.

In August, 1991 he began teaching in the Division of Education at the University of Texas of the Permian Basin. He received his Doctor of Education degree from Montana State University in August, 1993.

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CHAPTER I

INTRODUCTION

Introduction

Science and technology have become an integral part of our society. Our government, schools and industry are increasingly dependent upon individuals who are technologically and scientifically literate. A growing demand for such individuals has created a shortage of college graduates who have a high degree of scientific and technical literacy. The demand will become even more acute in the 1990's (Shapiro, 1987).

A common stumbling block for colleges interested in a technological or scientific area is the mathematics course requirements included in these curricula. Increasing the successful course completion by all students enrolled in college mathematics, including female and minority students, is the general problem motivating this study.

Advances in technology and its widespread uses created the demand for technologically and scientifically literate individuals and may hold the key to alleviating this demand as well. The computer has been used successfully to supplement mathematics courses at the elementary, secondary and college levels. Z. R. Mevarech (1985) reported computer-assisted instruction (CAI) improved the achievement and reduced the anxiety levels of disadvantaged third graders. Burns and Bozeman (1981) compared research showing students' mathematical comprehension is higher in classes where the instruction method is enhanced by the incorporation of CAI into the normal classroom methods of instruction. In their meta analysis of research, Kulik, Bangert and Williams (1983) compared studies which noted secondary students who received computer-based instruction (CBI) outperformed students who did not. They also reported these students develop better attitudes toward the subject, final exam scores are higher, follow-up exam scores are higher, and time needed to cover the material is usually much less than their counterparts in traditionally taught classrooms.

Other researchers have shown that CAI motivates students, cultivates better student attitudes towards mathematics and other subjects, and reduces levels of mathematics anxiety. Dugdale (1981), Reglin and Butler (1989), and Thomas (1979) believe CAI is successful in motivating students to perform at higher levels. Heid (1988) and Thomas (1979) found CAI improved student understanding of the concepts they were learning. Heid (1988) found CAI increased student confidence and Thomas

(1979) found CAI lowered student mathematics anxiety levels. The value of lowering mathematics anxiety levels and improving student levels of confidence is pointed out by Skemp (1987), "...reduce anxiety and build up confidence, and thereby improve the performance" (p. 94). Thus, computer-assisted instruction appears to improve student achievement by reducing anxiety levels and improving student confidence.

The graphing capabilities of micro-computers, and computers in general, allow faster and better visual illustrations of mathematical concepts than the traditional sketching of graphs by hand. In his book, "The Psychology of Learning Mathematics", Skemp (1987) cited examples where visualization conveys mathematical information more efficiently than verbal statements. He believes the graphic capabilities of the computer could be employed to visually illustrate many mathematical concepts to the advantage of both the student and the instructor. This view was also supported by Blackburn (1983). In their study, Eisenberg and Dreyfus (1989) concluded using visual images of mathematical concepts can deepen student understanding and help student progress in mathematics. Ethington and Wolfle (1984) reported that improving spatial visualization skills of females resulted in positive increases in achievement in mathematics. These results lead to the conjecture that using the computer to generate graphical images of functions may help calculus students visualize the mathematical concepts that are the basis of freshman level college calculus. Because the material is presented with a strong visual emphasis, computer generated graphs may also improve the achievement of female and minority calculus students, and calculus students whose preferred mode of learning is primarily visual.

Purpose of Study

The purpose of this study was to determine if supplementing a traditionally taught freshman college calculus course with CAI, that visually illustrated key mathematical concepts as they were covered in the course, would improve student achievement and attitudes towards mathematics and reduce mathematics anxiety levels. Because this study was interested in the improvement of student achievement in a traditional college calculus course, and because many college mathematics professors are wary of weakening the rigor and content of this course by the assimilation of the computer into the classroom, this researcher made the decision to supplement the course and not to alter it or to change the methods of instruction. In addition to the purpose mentioned above, it was the intent of this researcher to investigate three other facets dealing with the affects of CAI on the achievement, attitudes, and anxiety levels of female students, minority students, and students who were designated as primarily visual learners.

This study analyzed raw scores and success rates of students taking freshman level college calculus. It examined effects on attitudes and anxiety by analyzing student confidence in learning mathematics, attitude toward success in mathematics, view of the usefulness of mathematics, and level of mathematics anxiety as measured on the appropriate subscales of the Fennema-Sherman Mathematics Attitude Scales (Fennema & Sherman, 1986).

Need for the Study

Each autumn quarter over 400 students register at Montana State University (MSU) to take freshman level calculus. While the mathematics courses and the methods of instruction used at MSU are continually being revised and improved, many of the students in Math 181 receive grades lower than C (below 2.00 on a four-point scale) or withdraw from the class. For example, during autumn quarter, 1988, 420 students were enrolled in 14 sections of Math 181, freshman level calculus, at Montana State University. Sixty-seven students received a letter grade of A, 82 received a letter grade of B, 92 received a letter grade of C, 39 received a letter grade of D, 67 received a letter grade of F, 39 withdrew from the course with a passing grade, and 34 withdrew with a failing grade. Two hundred forty-one students received grades of C or higher. This means 197, or 43% of the students who enrolled in the course, withdrew or received grades lower than a C. Similar findings were reported by Cipra (1988), "at some institutions as many as 50% of the students enrolling [in] calculus either fail or withdraw from the course" (p.1491).

Positive results in college algebra programs where CAI has been used suggest the need for a study addressing the utilization of CAI in a college calculus course. Payton (1987) found that college students enrolled in algebra classes utilizing CAI scored higher than those who were enrolled in a traditional algebra course. College students enrolled in algebra made significant gains in solving systems of linear equations when they utilized the computer's assistance (Gronberg, 1987). In a study completed by Kiser (1986), CAI enhanced the students' ability to visualize linear and absolute-value inequalities.

A preliminary search conducted by this researcher found one study by Kiser (1986) which dealt directly with the effectiveness of CAI in visualization and mathematics. Eisenberg and Dreyfus (1989) reported the need for more research into the possible connection between mathematics and visualization. The research reported by Heid dealt with a college calculus course in which the method of instruction was altered to accommodate the use of computers (Heid, 1988). In this adapted course, Heid found college students better understood the concepts when the course utilized CAI.

These results are important, but this study investigated the possibility that the course does not need to be altered to fit the computer, that is, the computer is flexible enough to fit the course. No research was found during this preliminary review of literature in which the computer, and CAI, was used to supplement the existing course with graphical representations of calculus concepts. This researcher was interested in the affects such supplementary CAI might have on student achievement and attitude as described previously.

In concept, functions play an important role in calculus. Therefore, to be truly successful, a student must have a deep understanding of functions and their behaviors. In traditionally taught calculus courses functions are often represented using algebraic equations. But functions can also be represented visually through the use of graphs. Ayers, Davis and Lewin (1988), found students receiving CAI scored significantly higher on tests covering concepts dealing with functions. Although many functions are very difficult for an instructor to graph by hand, the computer can graph even difficult functions easily, and much more clearly. This makes the function easier to visualize, and visual symbols are often easier to understand than algebraic representations of the same material (Skemp, 1987). Skemp states, "...visual imagery is that most favorable to the integration of ideas" (p.80).

Questions to be Answered

The increasing availability of computer facilities in high schools and on college campuses, and the claims put forth about the capabilities of CAI, has tempted many mathematics instructors to send students to the "computer lab" as a means of increasing student achievement and supplementing their own instruction. Therefore, more research into the use of supplemental CAI is needed to establish what effects it may have on student achievement and attitude toward mathematics. With this in mind, the questions addressed by this study were: How does CAI affect student achievement when it is used to supplement traditional methods of instruction in a college freshman level engineering calculus class?; How does CAI affect the achievement of students in underrepresented groups when it is used to supplement traditional methods of instruction in a college freshman level engineering calculus class?; How does CAI affect student attitudes when it is used to supplement traditional methods of instruction in a college freshman level engineering calculus class?; and How does CAI affect student mathematics anxiety levels when it is used to supplement traditional methods of instruction in a college freshman level engineering calculus class?

In Chapter III these four research questions are refined and divided into distinct questions dealing with their inherent sub-parts. They are then rewritten in null hypothesis form for analysis purposes. The number of female or minority students in the sample population is also considered in Chapter III.

General Procedures

The students in 12 sections of Math 181, Calculus and Analytic Geometry I, at Montana State University were given a researcher-created multiple-choice diagnostic test designed to determine how prepared they were to take the course. The concepts tested included topics in algebra, geometry, trigonometry and calculus. All included items were from topics judged necessary for adequate calculus student preparation by experienced math professors in the department.

The research design for this study was a matched group design (Drew & Hardman, 1985). The results of the diagnostic test were used to create four matched pairs of sections based upon their mean scores. The eight sections with the closest means were paired. The remaining four sections, from the original 12, were excluded.

One section from each of the four pairs was randomly placed into either the experimental treatment group or the control treatment group. Thus, the experimental treatment group consisted of four sections of Math 181 as did the control treatment group. A t-test of the means of the two groups, as measured on the pretest, was used to determine if this method of selection resulted in equivalent groups (see Chapter IV).

All eight sections used in the experiment were given a preliminary survey containing a page of background data and selected scales of the Fennema-Sherman Mathematics Attitudes Scales (see Appendix C). The selected scales were: the Confidence in Learning Mathematics Scale, the Attitude Toward Success in Mathematics Scale, the Usefulness of Mathematics Scale, and the Mathematics Anxiety Scale (Fennema & Sherman, 1986). The two groups were also given the Perceptual Response Subscale of the Learning Style Profile (LSP) created by a task force for the National Association of Secondary School Principals, in 1986, to differentiate an individual's primary mode of learning (Keefe, Monk, Letteri, Languis, & Dunn, 1986, see Appendix D).

The treatment for the experimental group consisted of five supplementary computer-assisted labs designed by the researcher to illustrate some of the major concepts covered in Math 181, the first quarter calculus course (see Appendix A). These labs were edited for content by professors and graduate teaching assistants with experience in teaching the course. No training on the use of the computer was given to the students or classroom instructors. The students received an instruction sheet. Any additional directions necessary for completion of a specific lab was included with the lab. The labs closely followed the daily lessons presented by the course instructors. The questions were designed to encourage the students to analyze the graphs created by the computer software. Students were required to complete labs outside of class. Labs were scored by the classroom instructors with guidance from the researcher. No training in the use of the software was given to course instructors.

Treatment for the control group consisted of five homework assignments similar to the treatments of the experimental group, but without the graphs of the functions (see Appendix A). Students answered questions similar to those answered by the experimental group, but without benefit of the function graphs generated by the computer. These assignments were also completed outside of the class and graded by the course instructors.

All sections of Math 181, including experimental and control treatment groups, were given two common hour exams and a final exam. All sections took the same exams at the same time. The first exam occurred after two of the treatments and the second exam was administered after the three remaining treatments were completed. After the second common hour exam the eight sections in the study were given the same survey of attitudes given before the treatments began. The difference between the results of this post-treatment survey and the pretreatment survey were used as data in the analysis. The final exam was given approximately two weeks after the second common hour exam.

A student's final course grade was determined by the total number of points accumulated in the course. Each common hour exam was worth 100 points. The final exam was worth 200 points. In addition to the exam scores, 100 points were given by each individual instructor for homework and quizzes. For those sections receiving the treatments of the study, 50 of the 100 total course points determined by each individual instructor were awarded for correct completion of the computer lab worksheets.

Student raw scores and course grades were used to examine differences in achievement and rate of success of experimental and control groups. All collected data were analyzed using analysis of variance. Analysis of variance was also used to determine if any interaction effects occurred between selected background variables, learning style preference, attitudes and the treatments.

Limitations and Delimitations

Limitations

The limitations of this study are as follows:

1. This study was limited to students enrolled in Math 181, Calculus and Analytic Geometry I, at Montana State University during winter quarter, 1991.

2. The number of minority students enrolled in the

above mentioned course may be too small to make meaningful inferences from the statistical analysis.

3. All exams given to the students in this study were created by one professor, the Math 181 course supervisor.

Delimitations

The delimitations of this study are as follows:

1. The treatment of the experimental group consisted of five computer lab activities over a six-week period.

2. The treatment of the control group consisted of five take-home exercise sheets over a six-week period.

3. The topics covered in the treatments closely followed the course syllabus during the time the treatments were given.

4. The computer software used in this study is designed for IBM compatible computers only.

Definition of Terms

For the purpose of this study, the following definitions were used:

1. Computer-assisted instruction (CAI) - employing a computer to assist in the teaching of a course. It may be used for remediation, tutorial, simulation, drill and practice, or other applications.

2. Computer-Based Instruction (CBI) - instruction that utilizes the computer as the primary source of teaching. It may or may not be used with teacher input to assist the

students with the lesson. An example would be a user interactive software package.

3. Computer lab worksheets (labs) - worksheets utilizing computer-assisted instruction in visualization to guide the students through the graphing of functions and the analyzing of those graphs to improve their understanding of the underlying mathematical concepts.

4. Fennema-Sherman Mathematics Attitudes Scales - a collection of nine scales developed by Fennema and Sherman to assess student attitudes toward many different items pertaining to the teaching and learning of mathematics. The five scales chosen to make up the survey given to the students in this study are (a) confidence in learning mathematics; (b) attitude toward success in mathematics; (c) usefulness of mathematics; and (d) mathematics anxiety scale (Fennema & Sherman, 1986).

5. Learning Style Profile - a test created by a task force for the National Association of Secondary School Principals, NASSP, in 1986 to differentiate those whose primary mode of learning is visual, auditory, or kinesthetic (Keefe et al., 1986).

6. Math 181 - Calculus and Analytic Geometry I. The first quarter college calculus course at Montana State University, using traditional methods and textbooks.

7. Raw score - the total number of a possible 500 points a student obtains in Math 181.

8. Satisfactory results - grades of "C" (2.00 on a four-point scale) or higher. Students who are enrolled in programs with courses that rely heavily upon the calculus sequence are advised that they need a grade of "C" (2.00 on a four-point scale) or better to continue on with the curriculum. Thus a satisfactory result is such a grade.

9. Success rate - a successful course completion rate. The decimal fraction of all the students in a group who complete the course with satisfactory results.

10. Underrepresented groups - groups not traditionally representative of those individuals who embark on careers in fields dependent upon technology such as engineering, mathematics, and sciences.

11. Visual learners - individuals whose preferred mode of learning is primarily visual. Such learners might prefer that information is presented visually as well as verbally.

12. Learning style (or modality) - "the sensory channel through which information is perceived and processed most efficiently" (George & Schaer, 1987, p. 1).

CHAPTER II

REVIEW OF LITERATURE

Introduction

In this study, computer-assisted instruction (CAI) was used to supplement traditional college calculus instruction through the use of graphical representations of several key mathematical concepts. Students in mathematics courses may benefit from the use of computer-generated graphics because the visual presentation of course concepts provides an alternative format through which the information could be processed (Bork, 1980). Bialo and Sivin (1990) suggested technology could be used successfully as a supplement to traditional instruction. Another advocate of the use of the microcomputer in the classroom, Caissy (1987) feels:

> The computer is a classroom tool that can enhance and improve instruction and learning. It should be used to complement and supplement the curriculum and should not require a revamping of the curriculum to fit the computer....The computer is intended to assist teachers with instruction and students with learning (p. 12).

The concerns of this study were the affect CAI had on mathematics achievement, attitudes towards mathematics, and level of mathematical anxiety of the sampled student population. It was the intent of this researcher that this study investigate and report on results for all students in the sampled student population including minority and female students, and students who were primarily visual learners. With this in mind, the review of literature pertained to: CAI and mathematics achievement; visualization and mathematics achievement; and CAI and the affective domain.

CAI and mathematics achievement as prescribed in this study dealt with the three subtopics: the affectiveness of CAI, CAI and female students, and CAI and minority students. Visualization and mathematics achievement dealt with the four subtopics: visual learners, visualization and computers; female students and visualization; and minority students and visualization. CAI and the affective domain dealt with the two topics: student attitudes towards mathematics and CAI, and CAI and its affects on mathematics anxiety.

Computer-Assisted Instruction and Mathematics Achievement

Using CAI has many enthusiastic supporters who believe that utilizing computer generated graphics could be a useful tool for mathematics instruction. Bork's (1980) article, "Learning Through Graphics," discusses the use of graphics in learning, especially in mathematics and science, and the critical role the computer plays in the use of graphics in teaching.

There are others who feel computers are of value in the mathematics curriculum: the graphics capabilities of the computer make it a powerful tool in the teaching of mathematics (Piele, 1983); using the microcomputer a student can illustrate mathematical concepts which may have been difficult and time consuming to do by hand (Blackburn, 1983); and the graphic capabilities of the computer could be employed to visually illustrate many mathematical concepts to the advantage of the student and the instructor (Skemp, 1987).

Kiser (1987) conducted research utilizing computer-enhanced instruction (CEI), a variation of computer-assisted instruction, which involved two intact college algebra classes and the teaching of solving linear inequalities. The treatment was conducted over a short, two-week period during the trimester. The control presentation consisted of a traditional expository approach where the overhead and chalkboard were used to graphically illustrate solution procedures without the use of computer support. In the experimental group, the computer presentation was designed as a highly visual treatment to utilize the spatial abilities of the students in the instruction. Both classes had the same objectives and were measured with the same criteria. Results indicated students in the CEI treatment classes performed significantly better and had a more positive attitude than students in traditionally taught classes. Students in the experimental treatment class with high spatial abilities significantly outperformed their counterparts in the control class. Kiser (1987) feels these results indicate CEI can improve the achievement and attitude of many students, "there is a possibility of higher student achievement in elementary, secondary, and college level by matching CEI presentations to students higher spatial abilities" (p. 39). While Kiser's study showed CEI to be effective in a college algebra course; it may be equally effective in a college calculus course.

The Effectiveness of Computer-Assisted Instruction

A review of literature dealing with the effectiveness of CAI in education has shown CAI improves achievement and attitudes of students at the elementary, secondary and college levels. In a study involving 204 disadvantaged third graders, Mevarech (1985) found CAI to facilitate achievement and reduce math anxiety. And in a previous study involving 376 disadvantaged elementary students in third, fourth and fifth grades, Mevarech and Rich (1985) found that CAI had a positive effect on mathematical achievement and attitudes. They also found CAI raised the math self-concepts of these students higher than those students in the control group.

Further evidence of the effectiveness of CAI at the elementary level appears in a study by Carrier, Post and Heck (1985) involving 144 fourth grade students. These researchers found "support for the claim that microcomputers can enhance some aspects of elementary school children's achievement in mathematics" (Carrier et al., 1985, p. 51).

In their meta-analysis of studies in which CAI was utilized, Burns and Bozeman (1981) found that CAI was effective in increasing mathematics achievement at both the elementary and secondary levels. The 40 studies dealing with CAI were included in the meta-analysis because they met the following criteria: CAI was used in conjunction with mathematics instruction; CAI was used as a supplement to the traditional instruction; the study was conducted at elementary or secondary grades; control group performance was compared to the treatment group performance; student achievement was the outcome variable; and the supplementary CAI took the form of drill and practice or tutorial assistance. Three important outcomes of this analysis were: student achievement was significantly increased through the use of supplementary CAI; high achieving and disadvantaged students at both the elementary and secondary levels achieved significantly higher when CAI was used to supplement traditional instruction; and the results found were independent of the design and length of the studies (Burns & Bozeman, 1981).

In a meta-analysis of 59 studies in which computer-based instruction (CBI), a form of computer-assisted instruction which utilizes the computer as a primary source of teaching, was employed at the college level, Kulik, Kulik and Cohen (1980) reported: CBI significantly improved the achievement of college students in a small positive direction; the attitudes of the students toward instruction and the subject were positively affected; and the time needed to learn the material was substantially reduced. Similar to the previously reported meta-analysis, the design of the experiments did not influence the outcome (Kulik et al., 1980).

In a study in which microcomputers were used, Rhoads (1986) obtained results similar to those found by Burns and Bozeman (1981) and Kulik et al. (1980). One hundred fourteen students in five high school algebra one classes were given a total of 51 minutes of instruction using microcomputers over the course of two days. The treatments differed in the amount of guidance given through the use of worksheets, and whether the students worked in same-sex pairs or alone. Although this study dealt with a very short length of time, the results indicated microcomputer instruction significantly promoted the learning of skills and concepts for high school students regardless of the conditions of the treatment.

In a third meta-analysis of CBI research dealing with secondary students, Kulik et al. (1983) reported on 51 studies involving students in grades six through 12. The studies included in this analysis met the following criteria: the study was carried out in a secondary classroom, grades 6-12; results of both experimental and control groups were reported in the study; and no possibly crippling methodology flaws were found in the study. The results obtained indicated secondary students who received computer-based teaching scored higher on final examinations, developed positive attitudes towards the courses they were taking, and learned the material in a shorter length of time. Results also indicated these "effects were greater in studies of shorter duration," (Kulik et al., 1983, p. 23).

At the post-secondary level, research as far back as 1976 encouraged the use of computers to supplement calculus instruction and called for more research in the use of CAI in college mathematics classes. In a study conducted by Lang (1976), the use of the computer as an extension to traditional instruction was found to be effective as a tool in teaching the basic concepts of introductory calculus. During Fall semester of 1972 at the University of Texas at Austin, two classes of introductory calculus were divided into eight discussion sections, four assigned to the experimental group and four to the control group. The experimental group received instruction supplemented by assignments in which students were to use prepared computer programs to investigate underlying mathematical concepts and the control group received supplementary assignments which did not utilize the computer. Students were to enter data into the computer using punch cards and wait for their results. Another important result indicated male students benefitted significantly from the use of the computer in this study. Lang concluded that use of computer extended instruction should be explored more fully as an aid in calculus classes. "Serious thought should be given toward implementing computer extended instruction in introductory calculus in our colleges and universities" (Lang, 1976, p. 279). It should be noted that in 1972, when this research was conducted, using the computer in a college mathematics course could have been exciting and novel to new freshmen students.

In 1977, two studies utilizing CAI, in the form of computer programming, to directly supplement the traditional instruction in college calculus were reported. In an experiment where college students in an introductory calculus course were invited to participate in a programming applications project, Berkey (1977) noted students responded positively to the use of the computer. And in a computer programming application reported by Sanger (1977), freshmen engineering students enrolling in the first year of calculus were allowed to choose the traditional course or the computer supplemented one. Students choosing the computer-assisted course were given one two-hour laboratory session each week instead of one hour of classroom instruction. During this laboratory session the students were taught the basics of computer programming and were assisted with the writing of these programs. The results were positive: "The students as a whole have enjoyed the courses, accepting the computer as one of the tools with which they must be familiar in today's society" (Sanger, 1977, p. 217).

In both of these studies students did the programming themselves and were taught the language as part of the course. However, with the introduction of the microcomputer and the development of more advanced user-friendly applications software, CAI is now affordable to most classrooms and much easier to implement. These advances allow teachers and students to have the power of the larger mainframe computers in smaller less expensive personal microcomputers.

More recent research utilizing microcomputers has shown similar results. When CAI was used in college mathematics courses other than calculus, higher levels of mathematics achievement were obtained by those students (Payton, 1987, Gronberg, 1987, and Ganguli, 1990).

In a study by Gronberg (1987), three sections of freshman business mathematics were taught to solve systems of linear equations using three different methods. The control group was taught in the traditional manner, one treatment used CAI as a supplement to the instruction, and one treatment used CAI as the primary mode of instruction. Based upon course grades, 23 students from each class were matched for the purpose of the study. The achievement level of the students in the treatment group which utilized CAI as a supplement to traditional instruction was significantly higher than the levels of both the other two groups (Gronberg, 1987).

In the study conducted by Payton (1987), four classes of basic mathematics were equally divided into the experimental group and control group. Of the 135 students on the final roster, complete data were obtained for only 87 of them. In addition to a pretest and a post-test, a survey of attitudes towards mathematics and computers was administered to each student before and after the treatment. The treatment for the experimental group consisted of supplementing the traditional lecture with computer-assisted instruction. The control group was taught using just the traditional lecture method. The experimental group was given demonstrations on the use of selected computer software and were then assigned worksheets to be completed using the demonstrated software. The software used in this study centered around function plotters and problem solvers. Results of the two-way analysis of covariance indicated significant gains in achievement for students in the experimental group on the post-test of knowledge of graphs, relations, and functions. No other significant results were found although a positive improvement in attitudes towards mathematics and computers was found for the experimental group (Payton, 1987).

The study conducted by Ganguli (1990) found students in the experimental group scored significantly higher on the comprehensive final than did the control group. Four sections, 118 students, of intermediate college algebra were matched based upon their pretest scores. One student from each pair was randomly assigned to the experimental treatment with the other assigned to the control group. Treatment for the experimental group was given over a five-week period during the semester and consisted of microcomputer demonstrations of four selected course topics. Students in the experimental group watched visual illustrations of the topics while students in the control group were taught using the traditional lecture/chalkboard method. Ganguli interpreted the positive results as an indication "that overall the students in the experimental group performed better than the students in the control group" (p. 158).

Not all studies attribute such results to the use of CAI. In a case study conducted by Wright (1989), where 28 college algebra students were given assignment worksheets and the option of using a computer to complete them, the higher averages of the students who opted to use the computer might be attributed to their higher level of motivation and not necessarily to the computer treatment. Although no change in student attitudes towards mathematics or computers was indicated when the students were surveyed, about half of the students involved believed the computer helped them better understand the material in the course. Because students were given the option of using the computers, Wright concluded "...it is not apparent from this experiment whether or not the use of computers significantly enhanced the teaching of college algebra" (p. 60).

In a college calculus study conducted by Ayers et al. (1988), CAI was used as a supplement to traditional instruction. A total of 30 college students in three sections of an optional first-year mathematics lab were divided into three treatment groups, two computer groups and a group which received a pencil and paper treatment. The study was conducted over a six-week period with all three groups receiving a weekly two-hour treatment session. During the first session all three groups were administered a pretest covering the mathematical concepts necessary for function and composition. During the following five weeks the students: completed assignments dealing with function and composition, were given a two-hour lecture on function and composition during the fourth session, were instructed on the connections between the lab exercises and the lecture, and were given a post-test during the sixth session. Results indicated students in the computer groups scored higher on the post-test than did students in the pencil and paper group:

> The scores on the post-test are consistent with our hypothesis that the computer experiences given to the

> students in the Computer groups were more effective in inducing the reflective abstractions involved in constructing the concepts of function and composition than was the traditional treatment given to the Paper-and-Pencil group (Ayers et al., 1988, p. 256).

In college calculus courses which were redesigned to utilize the computer, Heid (1988) noted, "There was evidence that the students in the experimental classes understood concepts as well as, and in most cases better than, the students in a traditional version of the course" (p. 22). Hickernell and Proskurowski (1985) reported students in the group receiving supplementary CAI achieved significantly higher final exam scores than those in the control group.

In the study conducted by Heid (1988) the sections of applied calculus were taught by the researcher in the study conducted by Heid (1988). These sections met three times each week for 50 minutes during the semester and used special materials developed by the instructor to incorporate CAI. Students in the experimental classes used the microcomputer to carry out most of the algorithms in the course and to find solutions to assigned problems and analyze the computer generated results. Students in a traditionally taught lecture section met twice a week for a 75-minute lecture and once a week for a 50-minute recitation section. Students in the traditionally taught lecture section were not given instruction incorporating CAI. Students in the experimental classes were expected to complete special assignments designed to be completed using microcomputers and attend the weekly class meetings. Fundamental ingredients in the course given to the experimental sections were the construction of computer generated graphs and the analysis of those graphs. While only the last three weeks of the course were used to work on the skills found in a traditionally taught course, the results indicate students in the experimental classes understood the concepts of the course as well as students in the traditionally taught class. Some students in the experimental classes were more confident in the results they obtained and felt the computer took some of the tedious calculation out of the course and allowed them to think more about the concepts and problem solving in the course (Heid, 1988).

Hickernell and Proskurowski (1985) reported on a college calculus course designed to incorporate CAI in the form of menu-driven software which students used to create graphs of mathematical concepts and for numerical applications covered in the course. Students were not taught programming, nor were they expected to have had previous experience with the use of computers. Hickernell and Proskurowski acknowledged:

> Comparing the students who used our computer system to those who took the traditional Calculus course is difficult because of several factors which cannot be easily measured. Examples of these are: the quality of instructors and teaching assistants, the effects of class size, and the academic ability and preparation of the students upon entering the course. Nevertheless, the difference between the final exam scores of these

> two groups of students, median 133 versus 119.5, is greater than a chance event. Therefore, a soft conclusion is that the students improve in a computer enhanced environment, at the expense of some extra work (p. 123-124).

They go on to recommend "Our experience suggests that the computer can be a valuable tool for teaching Calculus if it is used properly" (Hickernell & Proskurowski, 1985, p. 124).

In a study involving 78 college calculus students Palmiter (1991) reported a significantly higher achievement for the students in a calculus course designed around a specific application-package computer algebra system. The traditionally taught control group covered the integral calculus concepts in the normal ten-week period while the experimental group covered the same material in five weeks. Students in the experimental group were not presented with the techniques of integration which made up the largest part of the traditional course, but employed the computer software to perform the computation needed for the integrals found in the homework assignments and on the exams. At the end of the ten-week traditionally taught course and the five-week experimental course, both groups were administered the same traditionally created exams. Students in the experimental course scored significantly higher than the traditionally taught control group. In addition, the students who continued on in subsequent calculus courses performed as well as the students in the control group who continued. While these results are impressive, Palmiter (1991) noted:

> Although the ...[experimental] group significantly outscored the traditional group on both the conceptual and computational exams, several underlying factors may have influenced the positive results. The students in the ...[experimental] group were actively participating and were fully aware of their participation in the study. It is well understood that subjects in an experiment perform better by being a part of an experiment....Likewise the traditional class was being tested for concepts presented over ten weeks instead of only the 5 weeks of conceptual development in the ...[experimental] class. Thus, the traditional class may have scored lower because of the longer time period and the interference of computational work (p. 155).

These cautions are important to note and should be concerns for all educational researchers, especially those concerned with CAI research.

All of these studies and reports of research indicate the effectiveness of supplemental CAI. However, several researchers noted there may have been factors other than CAI which could have produced positive results. Perhaps stricter control for the teacher variable, for the unequal amounts of work given to the two groups, for the different lengths of time spent on the topics in the course, and for the effect knowing one is participating in an experiment may have on the outcome of that experiment should be established in CAI studies. Controlling these and other possibly contaminating variables was an important consideration in the present study.

Computer-Assisted Instruction and Female Students

In reviewing literature related to CAI and the mathematics achievement of female students, this researcher found results which were not restricted to female students alone. Mevarech and Rich (1985) reported higher achievement scores for all disadvantaged third, fourth, and fifth graders in their study, but no significant difference was found between boys and girls due to the treatment. Carrier et al. (1985) noted in their research report, where CAI was utilized as a supplement to traditional mathematics instruction, "The only sex difference was in the retention of division facts, where the girls made greater gains." While this is significant, it does not ensure CAI will benefit female students more than male students.

Accepting that males and females do not necessarily process mathematical information in the same way, Damarin (1988) believes designers of Intelligent Computer-Assisted Instruction (ICAI) should take these differences into account when writing curricula which utilize ICAI. ICAI might be used to correct some of the inequalities between males and females in education, since the computer shows none of the preconceived notions which may dictate teacher prejudice.

In studies involving college students, Reglin (1987, 1988), and Reglin and Butler (1989) reported CAI to be more effective than traditional instruction methods for both male and female students. The study conducted by Reglin (1987) was concerned with student mathematics achievement, locus of control, and academic self-concept. It began with 84 high school aged students enrolled in a vocational training program and ended with 76 of these students. Reglin (1987) described the design of the research as a "nonrandomized pretest-post-test experimental group design" (p. 12). The experimental and control groups finished with 50 male students, 17 white and 33 black, and 26 female students, ten white and 16 black. The difference in treatment of the two groups was that the experimental group received ten minutes of CAI in mathematics during each 60-minute session of the 12 weeks (60 sessions in all), while the control group did not receive CAI. The results of the analysis of covariance (using pretest scores as the covariate) indicated no significant difference in mathematics achievement, locus of control, or academic self-concept between the students in the experimental group and the control group. There was a significant change in academic self-concept and locus of control between male and female students (Reglin, 1988). While these results did not indicate an increase in mathematics achievement specific to female students, Reglin (1988) noted:

> The interesting difference which appeared on the measures of academic self-concept and locus of control between the males and females may also indicate the need for further research into the area of sex difference (p. 65).

The study conducted by Reglin and Butler (1989) consisted of 49 college students, 48 minority, enrolled in a mathematics seminar designed to prepare them for a required education program admissions examination. Students were randomly assigned to the experimental and control groups. Students in each group attended 18 sessions during the six weeks of the seminar. All of the students were administered the same pretest and post-test during the six weeks. The only difference in the treatments was the experimental group received 30 minutes of CAI in mathematics during each 60-minute session, while the control group did not receive any CAI. Results of this study indicated the students in the experimental group made significantly higher gains than did those students in the control group, but no significant differences were shown between the male and female students in either group (Reglin & Butler, 1989).

This present review of literature indicates a definite need for more research into what affect CAI may have on female students enrolled in college calculus. This study addressed that topic.

Computer-Assisted Instruction and Minority Students

The little research and information concerned with CAI and its affect on minority students indicates more research into this aspect of CAI is needed. Bork (1980) suggested the interactive graphics capabilities of the computer may be a useful aide in education and noted, "nonverbal modes are particularly important with students from minority backgrounds."

Reglin (1987) reported on research he conducted with minority college students where CAI was used to enhance instruction in a six-week seminar designed to help them pass the mathematics portion of an examination for entrance into the college's education program. Although minority group membership was not a variable in this study, all but one of the 49 students in the treatment groups were minority students. Results were positive, with the group that received CAI performing significantly better than the group that did not receive CAI (Reglin, 1987). Reglin and Butler (1989) reported on research into enhancing instruction with CAI. Their research also dealt with predominantly minority students. Their results indicated that the students who received CAI scored significantly higher on a mathematics post-test than students who did not receive CAI.

The lack of research dealing with mathematical achievement of minority students is evident. This study attempted to address that topic.

Visualization and Mathematics Achievement

A review of literature on visualization and learning, visualization of mathematical concepts, and visualization and mathematics achievement was included in this chapter because this researcher was interested in how CAI incorporating visualization of mathematical concepts may affect the achievement of college calculus students. While many mathematical concepts have visual interpretations and most educators feel students benefit from visual approaches, few utilize them in the classroom (Eisenberg & Dreyfus, 1989). They noted, "It seems as though building visual concepts images can be exploited to take students further into mathematics, and deeper" (Eisenberg & Dreyfus, 1989, p. 4) and called for more research into the role of visualization in mathematics (Eisenberg & Dreyfus, 1989). And, while visual illustrations are not to be considered mathematical proof, others also feel they supply an insight that is invaluable to the student. As Vinner (1989) stated "visual considerations are always illuminating even if not taken as a mathematical proof. They are indispensable in the calculus course" (p. 155).

Iben (1989) feels one possible explanation for why Japanese students do so well in mathematics may be that throughout their lives they are developing visual-spatial abilities through many paper folding experiences. He suggested more research into enhancing student achievement in mathematics should be conducted.

Harel (1989) reported on a successful program in which high school and college students learned linear algebra in a course which incorporated the use of visualization to intuitively teach some abstract theories. In the teaching experiment involving 56 high school students and 72 college students, students and teachers were very positive about this method of instruction. He went on to state:

> We believe that the idea we proposed in this paper of gradual abstraction of the concepts and their construction processes along with a firm intuitive visual base is applicable to other domains. We believe that similar treatment in teaching these theories would yield similar results. (Harel, 1989, p. 147-148)

And in their overview of research dealing with the enhancement of visualized instruction, Dwyer and Dwyer (1989) suggested:

> At present, educators have no way of knowing whether one type of visual is more effective than another in transmitting certain types of information, nor do they know whether instruction without visuals would be any more effective than the same instruction with visuals. (p. 117)

Visual Learners, Visualization and Computers

This researcher was concerned with the effects on student achievement of supplementing the traditional freshman college calculus course with computer generated illustrations of some of the mathematical topics covered, and as components of that concern, how this approach affected female and minority students, and students whose preferred mode of instruction is primarily a visual one.

Visual Learners. Students' preferred mode of learning, or learning style, is the manner of presentation from which they find the material easiest to comprehend and process. "The three modalities used most often for learning are visual, auditory, and kinesthetic" (George & Schaer, 1987, p. 1). Therefore, visual learners learn best when information is presented in a visual mode.

Because a large quantity of research has been conducted into learning styles and education, this review is restricted to literature dealing primarily with visual learning styles, or spatial visualization, and the interconnection with computers and CAI at the college level.

Canelos, Taylor, Dwyer and Belland (1988) reported on research which found simple visual instruction and visual feedback resulted in significant learning improvement for college students in an experiment designed to compare visual instruction and nonvisual instruction. The study involved 112 college freshmen who were given programmed instruction on parts of the human heart and how it operated. The programmed instruction simulated a computer display and presented material in two types of visual methods. The first type consisted of simple line drawings of the heart, while the second type consisted of more detailed line drawings. Both visual methods supplied the necessary information, but the second method had added detail. A recall test in different forms, two visual and three verbal, was then used to determine the effects of the two types of instruction. Results of the tests indicated that when visual feedback is paired with simple visual instruction the result is a significant improvement in learning (Canelos et al., 1988).

Similar results were found in an experiment by Akanbi and Dwyer (1989). Similar to the study by Canelos et al. (1988), their study involved 67 graduate and 139 undergraduate students and visual instruction methods about the human heart and its parts. Results indicated instruction with visualization was helpful to college students classified as having low prior knowledge of the material while students classified as having high prior knowledge benefitted from the non-visualized instruction. They noted, "the findings of this study emphasize the importance of the interrelatedness of variables associated with learning and the effective use of visualization in the teaching-learning process" (Akanbi & Dwyer, 1989, p. 9).

Dwinell and Higbee (1989) recommended instructors of high-risk college freshmen use a variety of teaching methods, including visual aids. And Hinterthuer (1984) found CAI could be effective for developmental studies students in college when it was matched to their learning styles. He noted, "An initial match of preferred style of learning to preferred mode of instruction may increase motivation and interest to work on basic skills" (Hinterthuer, 1984, p. 103). He found the use of CAI which matched the student learning style increased motivation.

Other researchers also recommended that the method of instruction should take into account the visual mode of learning as well as other learning modes. Bork (1980) noted, "many students, at all levels of education, are not this sophisticated in assimilating verbal information, and would be greatly aided by the use of other channels of communication" (p. 68). Shrum (1985) noted the anxiety, which results when the mode of the presentation and the learning style preferred by the student differ, could be reduced if, "teachers vary the mode of presentation within a lesson and from day to day" (p. 13). Keefe and Monk (1986) stated "students with strong visual response are likely to learn less effectively if instruction is strictly verbal (auditory)" (p. 15). And Schaalma (1989) recommended students be provided with activities that allow them to practice their spatial skills. She went on to state, "[mathematics] teachers must provide learning activities that cater to the learning styles of all students" (p. 34).

And in a study in which the preferred learning mode of the student was taken into account and the instructional method emphasized visualization, Miller (1988) found female minority college calculus students whose preferred mode of learning was primarily visual outperformed corresponding students whose preference was not primarily visual. Her research supports the idea that students who are visual learners perform better when the instruction includes presentation of materials in visual, or graphical, ways.

While the above researchers indicate visual-spatial abilities may affect mathematics achievement, Dick and Balomenos (1984) cautioned that success in programs designed to enhance visual abilities may not necessarily translate into improved achievement in calculus. Their study involved 268 first-semester college calculus students, 124 females and 144 males. Students filled out a background questionnaire and were administered a diagnostic test covering precalculus topics during the first week of the semester. In addition, they were surveyed about their attitudes towards mathematics and were given a test of visualization skills. The unit and final exams were used to determine student achievement for the semester. These researchers stated in their conclusions:

> Differences in attitudes toward mathematics or in cognitive skills such as spatial ability make little contribution to explaining variance in calculus achievement. This implies that special program [sic] designed to improve attitudes or spatial ability, even when successful, should not be expected to have a "transfer" effect to improvement in calculus achievement. (p. 19)

Visualization and Computers. Kiser (1987) found college algebra students who were taught with computer enhanced instruction designed for high visual-spatial ability students did significantly better than did students in the traditionally taught group. He found the microcomputer to be an effective instrument to assess and enhance mathematics instruction, "the microcomputer in the classroom does make a significant difference" (Kiser, 1987, p. 39).

Other educators feel computers and microcomputers should be effective in visually enhancing mathematics instruction through the use of the graphics technology these devices can provide (Elsner, 1983; Greenfield, 1987; Head & Moore, 1989; Laughbaum, 1989).

Laughbaum (1989) was impressed with the abilities of function plotting software and its effect on the way college algebra and calculus are being taught. With a graphing calculator or function plotter, visual images can be used in the classroom to enhance mathematics in the classroom. Seeing a 'picture' of the function helps the student visualize some of its characteristics and behaviors. The function plotter is a new tool to use to solve equations (Laughbaum, 1989). With this new tool students can graph almost any function, determine the domain and range of that function, and visually analyze the consequences of changing the parameters of the function.

Female Students and Visualization

A review of literature dealing with female students and visualization appears to indicate a difference in mathematical ability due to the gender of the student, and controlling for spatial visualization may close the gap in the differences in math achievement between males and females.

Using data from a national survey, Ethington and Wolfle (1984) utilized a "covariance-structures model of mathematics achievement" (p. 367) in an attempt to determine "why men exhibit higher average mathematics achievement scores than women" (p.362). They feel several variables contribute to the difference in mathematics achievement between men and women. In the area of spatial visualization they note, "women tend to have less spatial visualization ability than men, but the effects of this variable on mathematics achievement are greater for women" (p. 361), and conclude, "a unit increase in spatial ability produces greater increases in mathematics achievement for women than it does for men" (p. 375).

In a report of their research, Fennema and Tartre (1985) found females made use of pictures more often than did males when solving word problems. Their study involved 669 sixth grades students who were given tests to determine spatial visualization, verbal skills, and mathematics achievement. These students were retested in the eighth grade. In addition to this data students were asked to solve pretested word and fraction problems in the spring of of their sixth, seventh, and eighth grades. They suggested from their results, "the hypothesis that females are more debilitated than males by low spatial visualization skills should be investigated" (p. 204).

Research in spatial visualization at the college level was conducted by Ferrini-Mundy in 1987. A random sample of 334 first-semester calculus students, 167 male and 167 female, were selected and randomly assigned to seven groups, with equal numbers of each gender in each group. Pretests dealing with the calculus background and spatial visualization of the students were administered at the beginning of the semester. Students were asked to complete six worksheets which accompanied six researcher-designed modules emphasizing spatial visualization during eight weeks of the semester. Two unit tests of calculus achievement were used to assess student achievement in the course. A third unit test was analyzed separately. Results of the multi-variate analysis of covariance were mixed, however the researcher notes, "perhaps the most interesting finding of the study is that practice on spatial tasks enhanced women's ability and tendency to visualize while doing solid-of-revolution problems" (Ferrini-Mundy, 1987, p. 137).

In their report of research dealing with visual-spatial learning differences between males and females, and how such differences may affect the success in math and science, Baker and Belland (1988) suggested visual-spatial learning preference might be a factor in the choice and selection of a career in science and mathematics and might be one reason females are underrepresented in technology related careers. They go on to make the statement and ask the important question:

> It is surely too simplistic to claim that women are so underrepresented in science and technology because they perform less well in visual-spatial thinking, but if visual-spatial thinking is a factor, isn't it appropriate that educators and educational researchers should work to provide experiences for female learners to eliminate it? (p. 17)

In a meta-analysis of 43 doctoral dissertations dealing with visual spatial abilities, Druva-Roush and Wu (1989) found evidence the effects of spatial manipulation become more important as the age of the student increases. Their analysis contradicted other researchers findings on the differences between males and females. They suggested their results indicated the difference in spatial abilities between males and females is not as large as other articles have reported.

While these results appear to indicate a connection between visual abilities and mathematical achievement, especially in the case for female students, a need for more research into visualization and the mathematical achievement of female college students is indicated.

Minority Students and Visualization

It is a widely held belief that Native Americans learn better when the presentation contains a large amount of instruction utilizing spatial visualization techniques.

This review of literature has found little actual research in that area. Kleinfeld and Nelson (1988) reported that research concerning Native Americans and spatial visualization has resulted in inconsistent findings. In their review of educational research studying Native Americans and learning styles they stated, "What is clear is that visual-spatial abilities [of Native American students] are an area of relative cognitive strength" (p. 6), however they go on to note:

> Despite more than twenty years' discussion of the importance of adapting instruction to Native American students' visual learning style, research has not succeeded in demonstrating educational benefits. (p. 16)

While Kleinfeld and Nelson discuss research involving Native Americans and instructional methods involving visualization, none of the studies they reported dealt with mathematics and Native Americans.

In his work cited previously, Bork (1980) stated, "nonverbal modes are particularly important with students from minority backgrounds" (p. 68).

These results appear to indicate a void exists in research into visual presentations for minority students, especially in the area of mathematics education.

<u>Computer-Assisted Instruction and the Effective Domain</u>

<u>Student Attitudes Towards Mathematics and CAI</u>

In his report comparing the development of mathematical abstraction and spatial relations in U. S., Japanese, and Australian students, Iben (1989) noted "mathematics confidence and lack of anxiety are consistently significant predictors [of success in mathematics] for Australian and U.S. caucasian males and Japanese males" (p. 8). Confidence in one's ability to do mathematics is important to a student's success in mathematics, and female students are not as confident about their mathematical abilities as are their male counterparts. These statements are supported by Greenberg (1991) and Meyer (1989).

In a study conducted during the summer of 1990 involving college students enrolled in intermediate algebra, Greenberg found "successful students were more confident than unsuccessful students that they had learned the course material well" (p. 10). And in an article dealing with gender differences and mathematics achievement, which discusses the results of the National Assessment of Educational Progress, Meyer (1989) noted "... both males and females made significant gains from 1982 to 1986 is encouraging, but the gap between males and females remains a concern" (p. 151). She went on to state:

> Attitudes about mathematics and about oneself as a learner of mathematics are important not only because they are outcomes of learning mathematics but also because they potentially influence the learning of new mathematics. (p.154-155)

She pointed out that females continued to be less confident in their abilities to do mathematics than their male counterparts. Their attitudes towards the practical use of mathematics was on par with males, but they did not envision their future careers would be in areas where a good background in mathematics was necessary. This last statement was supported by Schaalma (1989), "Student attitudes may affect females' decisions about continuing in mathematics beyond the minimum requirements in high school" (p. 34).

Many educators have reported that computers motivate students and improve their attitudes toward mathematics. Bork (1980) suggested incorporating graphics and CAI into the traditional classroom could be motivating for the students. In their report, Bialo and Sivin (1990) concluded there is evidence that using microcomputers motivates students and improves their attitudes toward the subject they are studying. Dugdale (1981) and Reglin (1989/90) also reported that using the computer is a good method of motivating students in mathematics courses. Caissy (1987) feels just being allowed to use the computer motivates students "Computers themselves provide a form of motivation for students that other teaching aids cannot match" (Caissy, 1987, p. 14).

Other educators reported students developed positive attitudes toward instruction and subject matter when the computer and CAI are used to supplement traditional instruction. Where computers were used as part of the