SPATIAL SKILLS, CONFIDENCE, GENDER AND GRAPHING CALCULATOR USE IN THE HIGH SCHOOL PRECALCULUS CLASSROOM

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in the Graduate School of The Ohio State University

By

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1996

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ABSTRACT

This study examined relationships between gender, spatial skills, achievement, confidence and attitudes toward graphing calculator use in high school precalculus classrooms.

The subjects for this study were 134 junior and senior precalculus students-69 males and 65 females- from 6 classrooms in 4 Midwestern high schools where graphing calculators were required.

The students were tested for confidence-without-graphing-calculator, confidence-with-graphing-calculator, spatial and visualization skills. The confidence instruments were researcher developed Likert-type scales with algebraic and graphical subscales. The *ETS Card Rotations Test* and *Paper Folding Test* were used to test spatial and visualization skills. Mathematical achievement was defined as the students' grades from the last mathematics class taken. Interviews were conducted with a purposeful sample of 25 students.

T-tests were used to examine differences between confidence-with-calculator and confidence-without-calculator scores, and the algebraic and graphical subscales. ANOVA was used to check for possible gender or teacher differences. Pearson's r was computed to check for relationships between confidence-with-calculator and spatial skills and confidence-with-calculator and visualization. Spearman's ρ was used to examine

relationships between achievement and confidence-with-calculator. Gender and teacher effects were also examined.

Confidence-with-calculator scores were significantly higher than confidence-without-calculator scores ($p<.01$). Significant differences in the confidence-with-calculator scores favored the males ($p<.02$). The algebraic subscale scores were significantly higher than the graphical subscale scores-without-calculator ($p<.01$), but the graphical scores moved ahead of the algebraic scores when a calculator was available. Significant gender differences existed between the subscales-without-a-calculator, but calculators helped to equalize the differences. The correlations between confidence-with-calculator scores and spatial skill were significant ($p<.05$), and confidence-with-calculator and visualization ($p<.01$). This was due mostly to the male scores. Significant correlations ($p<.01$) existed between grades and confidence-with-calculator.

A majority of the students interviewed regarded the graphing calculator in a positive light. Most of the negative comments came from students low in spatial ability. Females made negative comments more than males in a ratio of 2 to 1. Females with low spatial skill exhibited more negative attitudes than males of low spatial skill. Sixteen out of 25 students noticed significant gender differences in attitudes and use of graphing calculators in their classrooms.

These results indicate that graphing calculator use in these high school precalculus classrooms increased confidence levels significantly. Some differences existed according to gender and problem type. Positive linear correlations were found between some of the variables with some gender differences. The majority of students interviewed felt positive about graphing calculator use, but differences according to spatial skill and gender were noted.

Soli Deo Gloria

ACKNOWLEDGMENTS

I wish to thank my adviser, Dr. Sigrid Wagner, for her encouragement, guidance and support during my doctoral studies, and for her patience and advice throughout the dissertation process. She has been a mentor and a friend. I am also indebted to Dr. Doug Owens and Dr. Bob Gold for giving so generously of their time, advice, and encouragement in the midst of busy schedules. Thank you to Dr. Marilyn Suydam, who before her retirement encouraged me to explore the questions connected with using graphing calculators in the classroom. These professors have made an indelible impression which will influence my research, teaching and advising, for years to come.

I also wish to express my gratitude to Dr. Jack Anderson for allowing me the time and providing resources and encouragement throughout these four years. I am grateful to Dr. Paul Whitaker for his encouragement, prayers and support in many tangible ways.

A debt of thanks also goes out to the six classroom teachers who so graciously gave of their time and energies–sharing their students and their ideas–during the research process; Jackie Craigo, Susan Cunningham, Sherry Torrens, and Matt Wilbur. Thanks especially to Bev Sivits and Cathy Zagula, who not only participated in the study, but were faithful friends and supporters throughout my graduate school experience. Without the cooperation and help of these classroom teachers this study could never have been completed.

Finally, to my loving family-Steve, Stephanie, Ami and Aaron-without your love, encouragement, prayers and support, I would not be where I am today. Thank you for your patience, understanding and prayers. Thank you for being willing to give up a little bit of your wife and mother that she might realize her potential.

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CHAPTER I

INTRODUCTION

The Curriculum and Evaluation Standards for School Mathematics (NCTM, 1989) and other important literature in the area of reform in mathematics education (Mathematical Sciences Education Board, 1990; National Research Council, 1989) call for increased participation in mathematics by women. Many things have been done over the past few years to break down barriers that might discourage female involvement in mathematics and mathematically based careers. In spite of advancements, fewer females than males enroll in more advanced mathematics courses in the United States and around the world (Leder, 1990). As of 1992, only about 13% of the nation's practicing engineers and scientists were women (Thomas, 1992).

In a study of mathematics professionals who had obtained Ph.D.s from MIT between 1980 and 1984, the gap between women and men was striking (Landau, 1995). Of 65 out of 80 living graduates, 52 men and 13 women, over 75% of the men are in tenured positions, while just over 50% of the women are tenured. Only 2 of the 13 women hold positions in one of the top 172 Ph.D. granting institutions, while 25 of the 52 men are in that group. The gender gap in mathematics is still a reality.

Historically, studies of spatial skills and gender have shown that boys excel girls on spatial tasks (Ethington, 1990; Fruchter, 1954; Hyde, 1981; Maccoby and Jacklin, 1974). Because successful use of graphing calculators depends on interpretation of highly visual information, will students with poor spatial visualization skills have less confidence in their abilities to use graphing calculators, and thus be at a disadvantage in a classroom where they are used? Will this occur more often with females who may have poorer spatial visualization skills?

The same literature (MSEB, 1989; NCTM, 1989; NRC, 1990) calling for educators to encourage females in mathematics course-taking and mathematical careers, is also encouraging greater use of technology in mathematics education. As a result, graphing calculator technology is rapidly becoming an almost indispensable tool in many advanced mathematics classes. In the spring of 1995, the College Board required graphing calculators for the AP Calculus exams for the first time (Dunham, 1995). What if this requirement is a disadvantage for girls? Are these two contemporary goals of mathematics education–encouragement of female participation and increased use of technology–in conflict with each other?

The present study looked at how gender and spatial skills are related to confidence and attitudes toward graphing calculator use in a high school precalculus classroom. If spatial skill and gender are related to confidence and attitudes as well as graphing calculator use, this could have strong implications for the current trend in mathematics education of encouraging the use of graphing calculators in the classroom, a trend that has the potential to widen the gender gap rather than narrow it.

Problem Statement and Focus Questions

How are gender and spatial skills related to confidence and attitudes toward graphing calculator use in a high school precalculus classroom? Because successful use of graphing calculators depends on interpretation of highly visual information, will students with poor spatial visualization skills have less confidence in their abilities to use graphing calculators and thus be at a disadvantage in a classroom where they are used? Will this occur more often with females who may have poorer spatial visualization skills? If there is a lack of confidence in the use of graphing calculators, will this carry over into a negative attitude toward mathematics, and as a result, lower achievement in mathematics? When we recommend the use of graphing calculators in the classroom are we encouraging a practice that will be to the detriment of students with poor spatial skills, especially females?

Model

Figure 1 is a model of the significant variables in the present study and how they relate to each other. An arrow going from one variable to another indicates that the variable on the receiving end is related in some way to the variable from where the arrow originates. For example, there is literature supporting the fact that attitudes and confidence vary in some way according to gender, so there is an arrow going from gender to attitudes. Attitudes and confidence, however, cannot change gender, so the arrow cannot be pointed in the other direction. Double arrows indicate the relationship is two ways. This model is not illustrating all of the variables at work in a mathematics classroom, only the important variables being considered in this study.

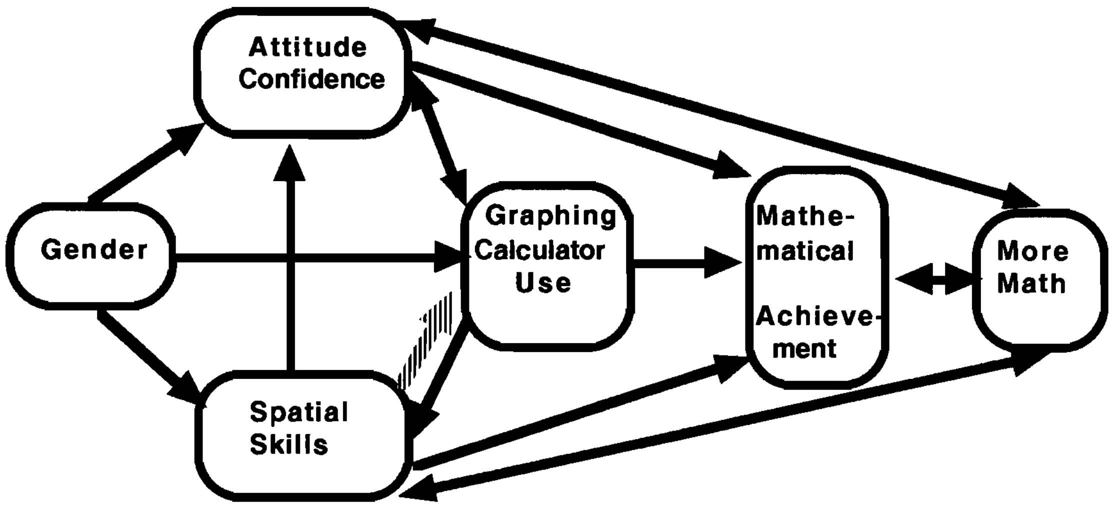


Figure 1: Model of Significant Variables and Their Relationships

Definitions

Terms used in a special way in the present study are defined below:

Confidence: A feeling sure or certain; a firm belief in oneself and one's abilities; something that gives a feeling of security (Barnhart & Barnhart, 1990). Confidence is defined operationally for this study as the score a student earns on a Likert-type quiz asking their level of confidence in answering certain precalculus problems correctly.

CWCalc-score on quiz asking level of confidence when permitted to use a graphing calculator on the quiz.

CW/OCalc-score on quiz asking level of confidence when not permitted to use a graphing calculator on the quiz.

ODDSW/O-score on the odd numbered items 1 through 11 on the quiz asking level of confidence without use of graphing calculator. These items are presented graphically and are often referred to as the graphical subscore.

ODDSW-score on the odd numbered items 1 through 11 on the quiz asking level of confidence with use of graphing calculator. These items are presented graphically and are often referred to as the graphical subscore.

ODDS-refers to both the ODDSW/O and ODDSW subscores.

EVENSW/O-score on the even numbered items 2 through 12 on the quiz asking level of confidence without use of graphing calculator. These items are presented algebraically and are often referred to as the algebraic subscore.

EVENSW-score on the even numbered items 2 through 12 on the quiz asking level of confidence with use of graphing calculator. These items are presented algebraically and are often referred to as the algebraic subscore.

EVENS-refers to both the EVENSW/O and EVENSW subscores.

Spatial skills: Skills involving understanding and interpretation of visual representations. These skills can be subdivided into the categories of spatial visualization and spatial orientation. Spatial skill is defined operationally for the present study as the scores a student receives on the Spatial Orientation and Visualization Tests from the Educational Testing Service *Kit of Factor - Referenced Cognitive Tests.*

Spatial orientation (S S): to be able to "detect arrangements of elements within a pattern and the ability to maintain accurate perceptions in the face of changing orientations" (Owens, 1990, p. 48). SS is the score a student receives on the ETS *Card Rotations Test* (S-1) and could range from 0 to 160.

Spatial visualization(VZ): the ability of a person to mentally rotate or rearrange a visual representation. VZ is the total earned by each student on the ETS Paper Folding Test (VZ-2) and could range from a low of 0 to a high of 20.

Mathematical achievement (GRADE): is defined operationally for this study as the grade the student received for their last mathematics class before precalculus as reported by the guidance office.

Need for the Study

The Curriculum and Evaluation Standards for School Mathematics published by the National Council of Teachers of Mathematics (NCTM) in 1989 state "scientific calculators with graphing capabilities will be available to all students at all times" (p. 124). Many other reputable sources (Dick, 1992; Dunham & Dick, 1994; Lauten, Graham, & Ferrini-Mundy, 1994; Wilson & Krapfl, 1994) call for the increased use of technology in the mathematics classroom because of the information age of today. In Reshaping School Mathematics (Mathematical Sciences Education Board, 1990), a book emphasizing reform in mathematics education, it states that technology has "the greatest potential for revolutionary impact" on mathematics education (p. 22), and strongly advocates calculator use in the mathematics classroom. The same source indicates that computer graphics, more than any other aspect of technology will "totally transform the way mathematics is used" (p. 19). The graphing calculator is an excellent example of this facet of technology.

Scariano and Calzada (1994) noted that a review of the literature "demonstrates that dialogue on this issue [graphing calculator use] spans the entire spectrum from avid enthusiasm to staunch opposition. For better or worse, graphing calculator technology has forever changed the delivery of mathematics education" (p. 60). What will this mean for those students, if any, for whom the graphing calculator is not an advantage?

Everybody Counts (1989), a report to the nation on the future of mathematics education by the National Research Council, stated that "the practitioner of mathematics in the computer age is more likely to solve equations by computer-generated graphs and calculations than by manual algebraic manipulations" (p. 5). Graphing calculators are assuming this role more and more. What impact will this have on the education of students whose strength is algebraic manipulation and whose weakness is visualization?

Dick (1992) credited the graphing calculator with unleashing "the power of . . . visual representations to full advantage in our mathematical instruction" (p. 3). Other authors (Lauten et al., 1994) claimed that graphing calculator use would help students understand relationships between graphical and symbolic representations (p. 227). What does this mean for the student with low spatial skills? Will use of the graphing calculator have more of a negative impact on their attitudes, confidence, and achievement?

Earlier research on computers in education often found that females were more likely than males to have negative attitudes toward computer technology (Collis, 1987; Lockheed, 1985; Wilder, Mackee, & Cooper, 1985).

More than one study (Lockheed, 1985; Wilder et al., 1985) indicated that in our culture the computer is viewed as more of a "male machine". How do students of today perceive the graphing calculator?

Wilder (1985) reported that "the differences in self-reported comfort and skill [in computer use] appear to be resistant, at least in females, to the effects of experience" (p. 227). This also could be significant in the study of graphing calculators in the classroom.

A recent study ("Gender Balance," 1995) placed Internet use by male and female users in a ratio of 2 to 1. This was lauded as an improvement over an earlier survey citing the ratio as 9 to 1. The current ratio of male to female use, however, still indicates significant differences in the amount of technology use according to gender. What implications do these findings have for graphing calculator use in the classroom? Will the same trends be evident?

On the other hand, studies of non-graphing calculator use have shown a positive impact on female performance and attitudes (Bitter & Hatfield, 1992; Hembree & Dessart, 1986). Willoughby, in Mathematics Education for a Changing World (1990), noted that "as calculators have become steadily more sophisticated, it has become more difficult to define or describe the difference between a calculator and a computer" (p. 66). If females perceive the graphing calculator as being more like a computer, because of the graphics and programming capabilities, will the use of graphing calculators in the mathematics classroom promote lower confidence in their mathematical abilities? Will it encourage negative attitudes toward mathematics overall?

At a time when mathematics education reform is calling for increased participation by females and minorities, is the use of graphing calculators in the classroom inadvertently turning the tide in the wrong direction? In noting that the College Board required graphing calculator use for the Advanced Placement Calculus Exams in the spring of 1995, Dunham (1995) questioned whether the requirement of graphing calculators would adversely affect the achievement of young women on the exams. There has not been enough research in this area to understand fully the impact this might have on females, or students who might be handicapped by this requirement.

Recently, researchers have cited the need for further research into whether graphing calculator use might actually impede understanding, and what might account for the difference between success and failure in the implementation of graphing calculators in the classroom (Dunham & Dick, 1994; Wilson & Krapfl, 1994). The present study looked at whether a student's spatial ability was an important factor in the answers to these questions.

Theoretical Rationale

Research seems to indicate that there is some link between mathematics achievement and gender. Fennema and Leder (1990), two of the leading specialists in the area of mathematics and gender relationships, state:

> We have collectively worked in the area [gender and mathematics education] for over 25 years and each of us is growing more and more aware of the complexity of the problem. . . . It appears to us that, while most of the important variables have been identified, and while the problem is somewhat diminished, gender differences in mathematics still exist and still inhibit females from taking their rightful place in society (p. 196).

The present study examined the relationship between spatial skills and graphing calculator use and the gender problem.

Gender and Attitudes

The link between gender and attitudes toward mathematics and confidence in mathematical abilities has been documented many times in the literature (Eccles, 1983; Fennema & Sherman, 1977, 1978; Leder, 1990; Reyes,1984). In a Fennema and Sherman study (1977) in every comparison except one, "males scored higher in mathematics confidence and these

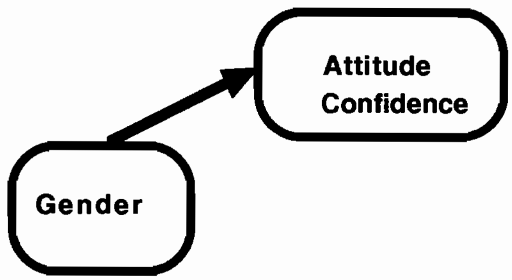


Figure 2: Gender and Attitudes

differences were significant at three out of four high schools." Tocci (1991) noted that this relationship also was evident in studies in Thailand, and that gender differences in attitudes toward mathematics were significant. More than one study indicated that "females had a less positive self-concept of their mathematics abilities than did males" (Boswell, 1985; Eccles, 1983; Meyer & Koehler, 1990).

Gender and Spatial Skills

Gender studies by Fennema and Tartre (1985), Tartre (1990), and Fruchter (1954), indicate a definite link between gender and spatial skill. Hyde

(1981) in her meta-analysis of ten studies of gender differences in visual spatial ability concluded that these differences in spatial ability were larger than the

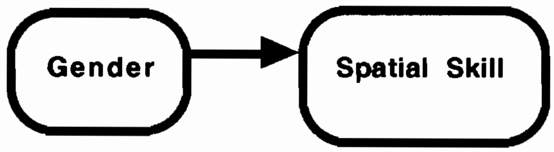


Figure 3: Gender and Spatial Skill

differences in verbal ability. Hyde also noted that although these differences were statistically reliable and replicable, they were small. These differences favored males in each case.

Attitudes and Graphing Calculator Use

The relationship between attitudes and graphing calculator use is in the initial stages of study. Ruthven (1990) and McClendon (1992) indicated that graphing calculator use affected attitudes positively. In Dunham's (1991) study,

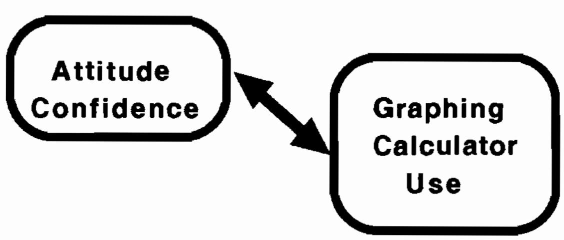


Figure 4: Attitudes and Calculator Use

both sexes made significant gains in confidence after graphing calculator use in a precalculus classroom. Wilson and Krapfl (1994), on the other hand, found that use of the graphing calculator was confusing for some students, even after instruction. Giamati (1991) reported that students with poorly or partially formed conceptual links between equations and graphs were cognitively distracted by also having to learn how to use graphing technology. Munger and Loyd (1989) reported that students with more positive attitudes toward graphing calculators performed better mathematically than students with more negative attitudes. It is this researcher's belief that the relationship between attitudes and graphing calculator use goes both ways. If a student has an attitude of confidence and exploration, the student will be more likely to use the graphing calculator for experimentation and problem solving, and increasing graphing calculator use may promote confidence in one's ability to use it correctly.

Spatial Skills and Graphing Calculator Use

The studies on this aspect of graphing calculator use have only looked at the effect of graphing calculator use on spatial skills, and not conversely. Vasquez in a 1991 study, indicated that students using the graphing calculator exhibited significant gains in visualization skills, with no significant gender

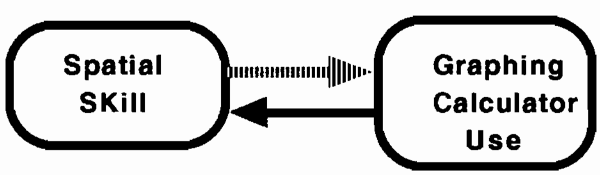


Figure 5: Spatial Skill and Calculator Use

differences. Shoaf-Grubbs (1993) and Dunham (1991) both reported gains in visualization after graphing calculator use. Scariano and Calzada (1994) also indicated that "graphing calculators enhance visualization" (p. 61). The present study investigated if there was a relationship between a student's initial spatial skills and their confidence in the use of graphing calculators. This arrow is lightly shaded because there has not been research up to this point to indicate a relationship in this direction.

Mathematical Achievement

There has been evidence in the literature that attitude, spatial skills, and graphing calculator use, affect mathematical achievement. According to the Fennema and Sherman studies (1977, 1978) confidence was more strongly correlated with mathematical achievement than any other affective variable studied. Clewell, Anderson, and Thorpe (1992) in Breaking the Barriers: Helping Female and Minority Students Succeed in Mathematics and Science, cited attitude as one of the principal barriers to success in mathematics and science.

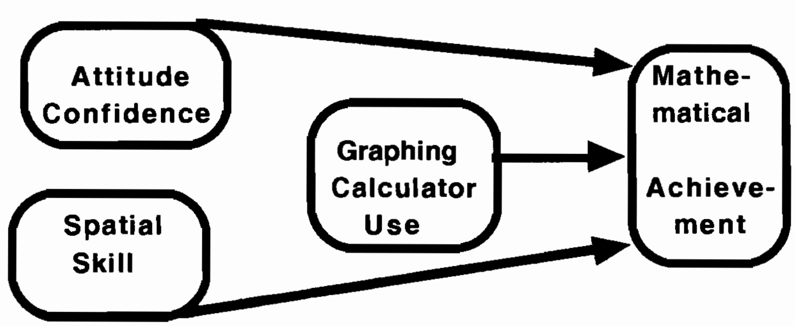


Figure 6: Achievement

Begle (1979) noted that "there is a small but significant correlation between measures of spatial visualization and mathematics achievement" (p. 92). In a study by Fennema and Tartre (1985) the scores on tests of spatial visualization and achievement correlated in a range of +.3 to +.6 (p. 184). Fennema and Sherman (1977) also found that spatial visualization was importantly related to mathematics achievement. Better spatial visualization skills correlated with higher mathematical achievement.

Studies by Ruthven (1990), Quesada and Maxwell (1994), and Harvey (1993) cited significant differences in achievement in favor of the groups who were using graphing calculators. Estes (1990) showed significant gains on conceptual achievement, but no significant difference in procedural achievement. On the other hand, Becker (1992), Giamati (1991), Rich (1991), and Army (1992), found no difference in overall achievement for the graphing calculator groups.

Hypotheses

Findings from the literature have led to the following research hypotheses:

H_1. There will be a significant difference in the mean scores of the confidence-quizzes-with-graphing-calculators and the confidence-quizzes-without-graphing-calculators. Specifically, the scores of confidence-quizzes-with-graphing-calculators will be higher.

H_2. There will be significant differences in confidence-with-graphing-calculators according to gender. Specifically, males will express greater confidence than females.

H_3. There will be significant differences in the mean subscores of the confidence quizzes, relative to problem presentation. Specifically, students will express greater confidence in items presented graphically than those presented algebraically.

H_4. There will be significant differences in mean subscores of confidence quizzes according to gender. Specifically, females will exhibit greater confidence on algebraic items, while males will express greater confidence on graphical items .

H_5. There will be a positive correlation between scores of confidence-with-graphing-calculator use and spatial skills, and this will vary by gender. Specifically, females will have a higher correlation.

H_6. There will be a positive correlation between scores of confidence-with-graphing-calculator use and visualization skills, and the correlation will vary by gender. Specifically, females will have a higher correlation.

H_7. The correlation between graphical items and spatial scores will be higher than the correlation between algebraic items and spatial scores.

H_8. The correlation between graphical items and visualization scores will be higher than the correlation between algebraic items and visualization scores.

Hg. There will be a positive correlation between the confidence-with-graphing-calculator use and the grades the students received in the last mathematics class taken.

These hypotheses were proposed for the quantitative portion of the present study.

The qualitative portion focused on differences in attitudes toward graphing calculator use in the classroom. Were there differences in the attitudes toward graphing calculator use in the classroom between males and females? Did students with higher visualization or spatial skills exhibit different attitudes or perceptions than those with lower skills? Were there differences in the male and female perceptions of how useful graphing calculators were in the classroom and what negatives might result? It was hoped that the interviews would provide rich insights into the impact of graphing calculator use in the classroom from the students' point of view, and thus provide a depth to the study not otherwise possible.

Significance

All of the findings of the present study have implications for the selection of future mathematics courses and career choices of students. Two of the five goals from the Curriculum and Evaluation Standards for School Mathematics (1989) —valuing mathematics and becoming confident in the ability to do mathematics (p. 5)— focus on student attitudes. Research has shown that attitudes and confidence have a strong influence on continued participation in mathematics course taking and career choices (Cockcroft, 1982; Ethington and Wolfe, 1988; Fennema & Sherman, 1977; Meyer & Koehler, 1990). Kloosterman (1988) cited several studies in stating that "students who are more confident of their ability to learn mathematics are more likely to take mathematics when it becomes optional" (p. 345). Hart (1989) notes that "traditionally women have not entered careers requiring mathematical knowledge as often as men" (p. 242). Some educators would like to think that this is in the past, and that mathematics education is more equitable now. A current article by Landau (1995) explored what happened to women mathematicians ten to fifteen years after obtaining their Ph.D. from MIT during the time period of 1980 to 1984, when there was strong emphasis on affirmative action. Landau's statistics show that "the gap between where the men are and where the women are is striking" (p. 6-7). So gender inequity in mathematics education and careers involving mathematics is a thing of the present, not just the past.

If spatial skill and gender are related to confidence in and attitudes toward graphing calculator use, this could have strong implications for the current trend in mathematics education of encouraging the use of graphing calculators in the classroom. Research up to this point has not looked at the relationship between a student's spatial skill and their confidence in and attitudes toward graphing calculator use in the classroom. In examining this issue, the present study hoped to alert teachers to possible problems for students with low spatial ability in the classroom where graphing calculators are used, and to investigate whether this would be especially true for females. Graphing calculator use could widen the gap between males and females in the mathematics classroom rather than reducing the differences. In a time when we are trying to encourage more female involvement in mathematics, teachers need to be aware of any factors that might hinder that process, and be educated as to ways to cope with those problems.

CHAPTER II

REVIEW OF THE LITERATURE

This literature review focuses on three main areas of research in mathematics education. First, the relationships between gender, spatial skills, and mathematics performance will be examined. The second body of literature will look at confidence and attitudes toward mathematics and how they relate to achievement, also considering gender. Last, research on technology, with any relationships to confidence, spatial skills, or mathematics achievement, will be explored. These areas form the important pieces of a puzzle investigating how gender and spatial skills are related to confidence and attitudes toward graphing calculator use in mathematics education.

Spatial Skills and Gender

Spatial skills are an important factor in the study of graphing calculator use, since this technology requires students to process information that is presented visually. Research on spatial skills can be traced back as early as the 1880's, with Galton's work on imagery (Tartre, 1990). Fruchter (1954) noted that on the average boys performed better than girls on spatial tasks, so research in this area is not a new phenomenon. Maccoby and Jacklin (1974) are often cited for their findings that gender differences in spatial ability were well established. According to Fennema and Leder (1990), "spatial ability is one of the factors most consistently linked to gender differences in mathematics achievement" (p. 188).

Fennema and Sherman have extensively studied relationships involving gender and mathematics education. In a widely cited study (1977), Fennema and Sherman examined spatial skills, mathematics achievement, and affective factors. This 1977 study involved 589 female and 644 male students from grades 9–12. The findings were consistent with earlier work in confirming the importance of spatial visualization in mathematics learning and in explaining some differences in mathematics performance according to gender. The results indicated that the correlations between mathematics achievement and spatial visualization were approximately as high as the correlations between mathematics achievement and verbal skills. Although males tended to score higher on spatial tasks, it was noted that these differences were only significant at two out of four schools. Fennema and Sherman indicated that smaller differences in spatial skills according to gender, compared to earlier studies, could be accounted for by better control for mathematics background in their study.

Hyde (1981), in a meta-analysis of eleven studies of gender difference in visual-spatial ability, revealed that nine out of eleven studies showed a spatial skill difference in favor of males. Hyde's analysis also indicated that gender differences in spatial ability were larger than in verbal ability, and the differences were statistically reliable and replicable, but small.

In the final report to the National Science Foundation on a research study examining relationships between spatial skills and confidence to mathematics achievement, Fennema (1983) stated that students with high spatial skills tended to use them more than students with low spatial skills. Of special relevance to the current study, was the fact that Fennema also cited differences in the ways boys and girls used their spatial skills. Girls who were low in spatial skills used them less than any other group in the study. Given this information, what effect will requiring the use of a graphing calculator, a highly visual instrument, have on students with low spatial skills? Will use of a graphing calculator be even more of a negative factor for females, especially those with low spatial skills?

A study by Fennema and Tartre (1985) on "The Use of Spatial Visualization in Mathematics by Girls and Boys" yielded some interesting results. This 1985 study gave some indication that students with low spatial visualization skills and high verbal skills were less able to use pictorial representations than students with high spatial skills and low verbal skills. Girls with low spatial skills, although they understood relevant features of the problems, were less able to translate this information into pictures that would enable them to solve the problems. Fennema and Tartre stated that "low spatial visualization skills may be even more debilitating to girls' mathematical problem solving than boys'" (p. 184). The study by Fennema and Tartre also yielded correlations in the range of +.3 to +.6 in scores of spatial visualization and mathematics achievement.

In a review of literature on sex differences in mathematical ability, Aiken (1986) found that males tended to surpass females in both mathematical reasoning and spatial ability. Other interesting results indicated that at younger ages, girls demonstrated equal or superior spatial ability but this declined until by twelfth grade, or earlier, girls exhibited less spatial skill than boys. Another finding, perhaps even more significant to the current study, was the fact that girls were more likely to misuse spatial information. This seems to indicate that even if the graphing calculator helps produce the visual representations, females might be more likely to interpret that visual information incorrectly.

In a meta-analysis of studies that took place between 1974 and mid-1987 on sex differences in mathematical tasks, Friedman (1989) found that average sex differences were small, but that the advantage was on the male side. Friedman also noted that sex differences in mathematical performance were decreasing over the years, which was consistent with other findings in the literature. The reports on spatial skills were mixed, with some studies indicating spatial skills may play a role in the differences between sexes in mathematical achievement. It was observed that spatial skill was often found to be a significant predictor of success for girls, but not for boys. Could this mean that low spatial skills in girls are more of a detriment to graphing calculator use in the classroom than with boys?

Ethington (1990) in an analysis of data from the Second International Mathematics Study, examined results from 8 of the 24 countries involved. In the Ethington study, students were tested at the end of the 1981-1982 academic school year using internationally developed mathematics achievement tests. The content areas were fractions, ratio/proportion/percent, algebra, geometry, and measurement. The largest gender effects were found in the geometry items, and this favored males. It is important to recognize that geometry is often regarded as a highly visual subject.

A 1985 study by Tartre reported in *Mathematics and Gender* (1990), compared the spatial orientation skills and mathematics ability of high school students. Tartre found that the high spatial orientation female group scored as well as any other group on mathematics achievement, and had the highest mean for the number of correct problems overall. The low spatial orientation females had more trouble than any other group in doing mathematics problems and scored lower than any of the other groups on mathematics achievement. It was interesting to note that in Tartre's study high-spatial and low-spatial males either performed equally well, or the low-spatial males scored higher. These findings seemed to indicate that spatial skill level is more related to mathematics achievement for females than for males. Does this mean that females with low spatial skills will exhibit lower confidence and poorer attitudes toward graphing calculator use than males with low spatial ability? Will graphing calculator use more adversely affect low spatial ability girls than low spatial ability boys in the classroom?

This has been a sampling of the abundant literature available on gender, spatial skills and mathematics. Let us now turn our attention to the literature relating gender, confidence and attitudes, and mathematical performance.

Gender, Confidence and Attitudes

There is a wealth of literature available concerning the relationships of these factors in regard to mathematics education. This review will consider a few of the major studies and their findings.

As Tocci and Englehard (1991) noted, "educators have consistently reported that affective factors have strong relationships with course and career selections" (p. 280). Confidence in mathematics is often reflected in continued participation in mathematics courses and career choices in quantitative fields (Meyer and Koehler, 1990). It has also been shown that a significant positive correlation exists between attitudes and achievement in mathematics, with positive attitudes being accompanied by greater achievement (Begle, 1979).

Two of the major studies in this area of the literature were conducted by Fennema and Sherman in 1977 and 1978. According to these studies, both middle school and high school females exhibited lower levels of confidence in their ability to learn mathematics than males at the same grade level. At the lower grade levels, this difference was not reflected in differences in mathematics achievement. This changed gradually, until by the twelfth grade, attitudes related more highly to achievement for girls than boys on six of eight affective scales. Confidence was more strongly correlated ($r = .40$) with mathematics achievement than any other affective variable being studied. Gender difference in favor of males in mathematical achievement was accompanied by gender differences in confidence, also in favor of males (Meyer and Koehler, 1990). Dowling (1978) found an even stronger relationship between confidence in mathematical ability and mathematics achievement than Fennema and Sherman. The Fennema and Sherman studies also revealed that students with higher levels of confidence planned to take more courses in mathematics than students with lower confidence levels. This is important to note in the light of the effort to encourage greater female participation in mathematics. If graphing calculators promote lower confidence in females with low spatial skills, this could result in decreased participation in mathematics courses by females.

Eccles (1983) found that females had a less positive self-concept of their mathematical abilities than males. Reyes (1984) identified confidence as one of the most important affective variables. It was also shown that students who were confident in their ability to learn mathematics were more likely to take mathematics in school when it becomes optional. This was consistent with the Fennema and Sherman results.

In a longitudinal study, Meyer (1986) found that when prior achievement was included as a control variable, affective variables had more of a predictive ability for females than males as far as predicting achievement and participation in mathematics. The sample in Meyer's study consisted of 84 females and 67 males with data collected during their sixth, eighth, and twelfth grade years of school. For males, in only five of the fifteen analyses was an affective variable predictive beyond prior achievement. For females, affective variables were predictive in twelve of the fifteen analyses. In both the male and female cases, the variable that most frequently predicted achievement and participation in mathematics was confidence (Meyer and Koehler, 1990).

Tocci and Englehard (1991) reported findings using nationally representative samples of thirteen year-old students in the United States (n=3,846) and Thailand (n=3,528). The data were collected as a part of the Second International Mathematics Study. "Achievement and gender were significant predictors of attitudes toward mathematics. Gender differences in attitudes toward mathematics were significant" (p. 280).

The studies cited seem to indicate that there is a gender difference in attitudes toward mathematics and confidence in ability to do mathematics, with males most often being favored. It has also been shown that confidence is related to achievement and future participation in mathematics courses and careers. If mathematics educators wish to encourage increased female participation in the field, the effect of using graphing calculators with females, especially those of low spatial ability, needs to be investigated further.

Technology

The growth of technology in the past few years has been phenomenal. The changes have occurred faster than research can keep up with them, and the magnitude of the impact on mathematics education is still not completely known.

> "Of the many forces at work that are changing the way mathematics is learned, the impact of technology is both the most urgent and most controversial. In less than two decades society has moved from primitive electronic calculators to desk-top workstations that are as powerful as the largest computers of only a few years ago" (Mathematical Sciences Education Board, 1990, p. 17).

Since the time this statement was written, technology has made even greater leaps in the refinement of the hand held graphing calculator. This discussion of the literature involving graphing calculators would not be complete without a summary view of research on the forerunners of the graphing calculator-calculators and computers.

Calculators. Since the introduction of calculators into mathematics education there has been a reluctance on the part of many parents and even teachers to accept them as an integral part of the mathematics education. Conferences were held and many articles written debating the place of calculators in mathematics education. Because of the importance of this development, the Calculator Information Center, directed by Dr. Marilyn Suydam of The Ohio State University, was funded by the National Institute of Education and the National Science Foundation. The purpose of this center was to collect and disseminate information about the use of calculators in education. There was more written about calculators and their use in the mathematics classroom than had been written on any topic before that time. Educators realized that good or bad, technology was here to stay and had the potential to completely change the way mathematics was taught. Only a few of the findings relevant to the present study will be mentioned here.

Munger and Loyd (1989) conducted a study of sixty high school students at a summer enrichment program at the University of Virginia. Students with more positive attitudes toward calculators were found to perform better mathematically than students with more negative attitudes. This 1989 study found no significant sex-related differences.

Bitter (1989) and Bitter and Hatfield (1992) reported that girls scored as well or better than boys after using calculators in mathematics class for a year. The boys who used calculators performed better than boys who had not used calculators. The girls in the study experienced greater improvement with calculator use than boys.

One of the major meta-analyses of calculator use involved 79 studies spanning over twenty years. Hembree and Dessart (1986) found significant positive effects for attitude toward mathematics, self-concept in mathematics, and calculator use. Calculators were found to increase confidence in the ability to do mathematics for both males and females, and improved performance in many areas across all grade levels.

Research in the area of calculator use, indicates positive gains in both attitude and performance, with females gaining as much or more than males.

Computers. Let us now review research on computers, as it relates to mathematics education and the present study. Since the graphing calculator is considered by some educators to be a mini-computer, the research in this area could also be applicable to a study involving graphing calculators.

Lockheed (1985) in "Women, girls, and computers: A first look at the evidence", notes that "several studies have found that boys and men are more positively disposed towards computers than are girls and women" (p. 118). Data were given to support the conclusion that "our culture is defining computers as preeminently male machines" (p. 116). Males were reported to take more computer courses than females, in a ratio from 5:1 to 2:1, use school computer laboratories more, and use home computers more.

Wilder, Mackee, and Cooper (1985), in a study involving incoming college freshmen, found males felt more comfortable interacting with computers and rated themselves more highly competent in computer use than females. This was true even when the females had essentially the same background and skills. In other data from more than 1,600 students in grades kindergarten through twelve, the researchers found a slight tendency for children to view the computer as a more masculine than feminine object. Other findings included boys liking computers more than girls at all grades levels, and both boys and girls liked computers less the older they got. It was noted that in this 1985 study, the differences in attitudes toward computers between the sexes was statistically significant but small.

Collis (1987) conducted a study of 1,818 students in grades eight and twelve in a British Columbia school district. Collis reported that females were more likely than males to associate negative attitudes toward mathematics with negative attitudes toward computers. Also noteworthy in terms of the study, is that a negative correlation was found for eighth grade girls between mathematics class computer use and self-confidence in mathematics. Could the same results be found for girls and graphing calculator use in the mathematics classroom?

Research seems to indicate that whether the graphing calculator is perceived as being more like a calculator or a computer, will have an important bearing on the effect the graphing calculator will have on students' attitudes, especially females.

Graphing Calculators. Graphing calculator technology is a relatively new arrival on the scene of mathematics education. The number of studies concerning graphing calculator use in the classroom is increasing, but there are still gaps in the literature for this type of technology. To date, this researcher has not found any studies comparing a student's spatial skills to confidence level or mathematical performance while using a graphing calculator. This is a review of some of the literature available that could be relevant to the current study.

Estes (1990) surveyed students in an applied calculus course and found that graphing calculator and computer technology were perceived as being helpful, but only if the student understood how to use the technology. Students also preferred graphing calculators to computers.

Ruthven (1990) directed a graphing calculator project in England with upper secondary students. The study involved classrooms where a graphing calculator was standard equipment, and classrooms of students with similar backgrounds, but without regular access to graphing calculators. The experimental group outperformed the control group by well over a standard deviation. Females outperformed males in the project group, but males outperformed females in the control group, on overall items. Women calculator users scored higher than men on converting graphs to their algebraic form. Men were better than women on graph interpretation problems, with and without graphing calculators. Although Ruthven did not test for attitudes, he noted that the use of graphing calculators seemed to give females more confidence and decrease anxiety.

In a study conducted at The Ohio State University, Dunham (1991) looked at confidence and achievement in 200 students enrolled in precalculus. After ten weeks of instruction using graphing calculators, both sexes showed significant gains on the post test. Males showed superior performance on pretest visual items, but no performance difference emerged on the post test. Both sexes improved in confidence levels. On the confidence pretest there were no gender differences, but males exhibited more confidence on visual post test items than females. Another interesting finding of Dunham's study was that low-confidence females relied on graphing calculators more and algebra less, than any other group. High-confidence females used algebraic approaches most often and were the least likely to use a graphing-only solution. Low-confidence males used calculators more than high-confidence males, but not as much as low-confidence females. Many students reported feeling "algebraic guilt"-a feeling that they relied too much on calculator solutions.

Vasquez (1991) studied 57 students in two eighth grade prealgebra classes. The findings showed no significant differences between treatment or gender groups in mathematics achievement. Students who used graphing calculators exhibited significant gains in spatial visualization skills and in attitudes towards calculators. There were no significant gender differences in these areas and no significant differences in attitudes toward mathematics.

In a study of 126 students in a five-and-a-half week unit in precalculus, Giamati (1991) found that the group **not** using graphing calculators was superior at sketching functions, understanding translations, stretches and shrinks, and describing parameter variations. Giamati noted that some students were cognitively distracted by having to learn the new graphing technology, especially those with poorly formed conceptual links between graphs and equations.

Rich (1991) found that use of graphing calculators in precalculus did not improve overall performance, but that graphing concepts were impacted positively. Rich's study also gave evidence of a negative effect on paper-and-pencil procedures for finding slope and verifying trigonometric identities.

Shoaf-Grubbs (1992) found that college women in a graphing calculator section made greater gains in spatial visualization skills than women in a non-technology section.

Army's (1992) study of a college course in trigonometry, did not show achievement gains, but indicated a positive effect on student attitudes toward mathematics usefulness and the usefulness of graphing calculators.

Scariano and Calzada (1994), in a look at graphing calculators in basic skills mathematics, noted that "graphing calculators enhance visualization and invite self-discovery" (p. 61). Basic skills students gained confidence in using mathematical reasoning and problem-solving skills. Students were able to make connections to new situations.

Implications

Past studies have shown a link between gender and attitudes toward mathematics and confidence in mathematical abilities (Eccles, 1983; Fennema & Sherman, 1977, 1978; Reyes, 1984). The present study looked to see if there were significant differences in the confidence level of males and females in the use of graphing calculators. If females are less confident, teachers need to be aware of this and take extra care to help females become comfortable with the graphing technology, in order for them to be successful.

The literature also reflects differences in the spatial abilities of males and females (Fennema & Tartre, 1985; Hyde, 1981; Tartre, 1990), and that sometimes these differences are related to differences in mathematics achievement (Fennema & Tartre, 1985; Fennema & Sherman, 1977). Other research has examined how the use of graphing calculators could improve a student's achievement (Harvey, 1993; Quesada & Maxwell, 1994; Ruthven, 1990) or spatial skills (Dunham, 1991; Shoaf-Grubbs, 1993; Vasquez, 1991). The current study wanted to determine if a student's spatial skill was related to their confidence in using a graphing calculator in the classroom, and whether there was a difference according to gender. If a relationship does exist, this could be an important factor in successful implementation of the graphing calculator into the mathematics classroom. If teachers are aware that students with low spatial abilities may have lower confidence in using graphing calculators, and are given some intervention strategies, this could lead to increased confidence in graphing calculator use and more success in the mathematics classroom, especially for females.

Dunham (1991) looked at the relationship between confidence and performance in terms of algebraic and visual contexts. The present study looked at the relationship between spatial skills and confidence to see if there were differences according to algebraic or graphical presentation of problems, or differences according to gender.

Some studies have examined whether confidence levels improved with using graphing calculators over time. The present study looked for significant differences in confidence levels with and without graphing calculator use at one point in time, and if these differences were affected by gender and problem type.

All of the evidence is not in on the effect of graphing calculators on mathematics education. There are still many questions to be answered. One author has stated, "graphical calculators promise to unleash the power of visual representations to full advantage in our mathematics instruction" (Dick, 1992, p. 3). What impact will this have on students who are not visual learners, and are in fact, weak in spatial ability? The present study hoped to look at this issue in graphing calculator research.

CHAPTER III

METHODS AND PROCEDURES

This research study took place from December 1995 through April 1996, and had both quantitative and qualitative components. The quantitative portion of the study included analyzing relationships between the students' confidence on a quiz of precalculus items with and without the availability of a graphing calculator, the students' spatial and visualization abilities, and prior achievement in mathematics. The qualitative portion of this study included interviews to investigate the students' attitudes toward graphing calculators and the use of graphing calculators in high school precalculus classrooms.

Site

The study took place in four high schools in the central Ohio area: East Knox High School, Fredericktown High School, Mount Vernon High School, and Utica High School. Mount Vernon High School with approximately 1100 students is the largest of the four schools and is located in Mount Vernon, Ohio, a small community of about 15,000. East Knox, Fredericktown, and Utica each enroll between 400 and 450 students and are situated in small communities surrounding Mount Vernon. These are predominantly white, middle class, rural communities.

There were six high school precalculus classes involved in the study, with each class taught by a different teacher. The teachers were all experienced at teaching precalculus using graphing calculators, and included five female teachers and one male. Three of the classes were at Mount Vernon High School, while each of the smaller schools had one class involved in the study.

The smaller schools each had classroom sets of TI-81 graphing calculators which the precalculus students are permitted to sign out for the year. Many of the students in these classes purchase their own calculators. Mount Vernon High School has classroom sets of graphing calculators that can be used in the lower levels of mathematics, but the precalculus students at this school were expected to supply their own graphing calculators. Mount Vernon High School has been involved in graphing calculator technology since the earliest days of graphing calculator studies by Waits and Demana at The Ohio State University. The smaller schools have also used graphing calculator technology for some time.

Subjects

The participants in this study were 134 out of the 146 high school students from these four high schools enrolled in precalculus classes where the use of graphing calculators is required. The twelve students not participating were absent on the days of the testing. Table 1 illustrates a breakdown of some of the significant characteristics of the participants in the study.

Table 1

Number and Percentage of Students

According to Background Factors

N=134

	School 1	School 2	School 3	School 4			
	T1	T2	T3	T4	T5	T6	Total
Males	10 45%	9 56%	7 41%	12 48%	14 61%	17 55%	69 51.5%
Females	12 55%	7 44%	10 59%	13 52%	9 39%	14 45%	65 48.5%
Seniors	6 27%	16 100%	10 59%	25 100%	21 91%	1 3%	78 58.2%
Juniors	16 73%	0 0%	7 41%	0 0%	1 4.5%	29 94%	54 40.3%
Sophomores	0 0%	0 0%	0 0%	0 0%	1 4.5%	1 3%	2 1.5%
Total	22 16.4%	16 11.9%	17 12.7%	25 18.7%	23 17.2%	31 23.1%	134 100%

Table 2

Number and Percentage of Students

According to Graphing Calculator Data

	Teacher							
	T1 N=22	T2 N=16	T3 N=17	T4 N=25	T5 N=23	T6 N=31	**Total** N=134	
Years of Use								
Less than 1 year	21	1	14	0	1	2	**39**	**29.1%**
1 year or a little more	0	0	0	10	4	7	**21**	**15.7%**
Approximately 2 years	1	3	2	12	11	12	**41**	**30.6%**
3 years or more	0	12	1	3	7	10	**33**	**24.6%**
Ownership of Calculator								
Belongs to the student	2	9	4	23	18	28	**84**	**62.7%**
School owned	20	6	13	1	4	2	**46**	**34.3%**
Share or borrow	0	1	0	1	1	1	**4**	**3.0%**
Type of Calculator								
TI-81	22	13	15	8	8	9	**75***	**56.0%**
TI-82	0	0	1	1	2	6	**10**	**7.4%**
TI-85	0	2	1	12	11	11	**37**	**27.6%**
Other	0	1	0	4	2	5	**12**	**9.0%**
Graphing Calculator Use								
In math class	4	0	1	0	2	1	**8**	**6.0%**
In class and on homework	7	5	8	11	10	12	**53**	**39.6%**
Fairly often	8	7	7	12	6	17	**57**	**42.5%**
All of the time	3	4	1	2	5	1	**16**	**11.9%**

* Note: This higher amount is partly due to the calculators loaned out by the schools, which are all TI-81's.

Table 2 contains information gathered from the demographic questions at the end of the confidence quiz.

For the qualitative portion of the study, a purposeful sample of 25 students was selected from the original 134 students, and interviewed in detail about their attitudes and perceptions regarding graphing calculator use in the classroom. The researcher tried as much as possible for the interviewed group to reflect some of the characteristics of the entire sample, but this was not a random selection process. The researcher wanted to closely examine differences in attitudes and feelings of students of high spatial ability and low

Table 3

Comparison of Significant Characteristics of

Total Sample Studied and Interview Sample

	Total Sample N=134		Interviewed Sample N=25 (18.7%)	
Gender				
Male	69	51.5%	13	52%
Female	65	48.5%	12	48%
	Mean	S.D.	Mean	S.D.
Confidence without Calculator	42.9	7.34	40.8	7.54
Confidence with Calculator	49.4	6.54	46.3	7.31
Spatial Skill	111.3	28.06	102.8	36.12
Visualization	12.5	3.84	11.2	5.35

spatial ability, so there was a higher ratio of high and low spatial scores than in the total sample. Table 3 illustrates the some of the significant characteristics of the total group studied as compared to the interviewed sample. A more complete table comparing the characteristics of the total sample to the interviewed sample appears in Table 17 in Chapter V.

Instrumentation

The testing of confidence levels and spatial and visualization skills took place the first week of December 1995. The Educational Testing Service's *Kit of Factor-Referenced Cognitive Tests* (Ekstrom, French, Harman, and Dermen, 1976) was used to test the spatial abilities of the students. This is a highly reputable set of research-based tests providing investigators with a means of studying and comparing certain cognitive skills. The *Card Rotations* (S-1) *Test* for spatial orientation and the *Paper Folding* (VZ-2) *Test* for visualization were given to all 134 students present on the testing days.

Card rotations test. The *Card Rotations Test* (S-1) is a test of the student's ability to see differences in figures. It is a two-part timed test with 10 items and 3 minutes per section. The Educational Testing Service indicates that the test is suitable for subjects in grades 8-16. Each test item presents a drawing of a card cut into an irregular shape. To the right of this card are eight other drawings of the same card, sometimes turned over to the opposite side and sometimes merely rotated. The student is to indicate, in each of the eight cases, whether or not the card has been turned over (Ekstrom et al., 1976). There are a total of 160 cards to categorize during the six minute time period. A student's score is the number of items answered correctly minus the number of items marked incorrectly.

The *Card Rotations Test* (S-1) was originally developed in 1963 and revised in 1976. The reliability for the test is given as .86 for males and .89 for females. This was computed as the result of a suburban study involving 11th and 12th graders which included 300 males and 325 females . The test manual states that "spatial orientation requires only mental rotation of the configuration" and short term visual memory skills (Ekstrom et al., p. 149, 1976).

Paper folding test. "Visualization requires both rotation and performing serial operations" as well as short term memory (Ekstrom et al., p. 173, 1976). The *Paper Folding Test* (VZ-2) from the ETS Kit was used to evaluate this aspect of spatial ability. This test also consisted of two parts, each three minutes in length. In this test the students are to imagine folding and unfolding pieces of paper. In each item there are figures drawn to the left of a vertical line representing a square piece of paper being folded. The last of these figures has circles drawn representing places the paper has been punched. The student is to imagine that each hole is punched through all thicknesses of the paper at that point. To the right of the vertical line are five figures illustrating where the holes might appear when the paper is completely unfolded. The student is to decide which one of the five figures is the correct representation and draw an X through it. The student's score on this test is the number marked correctly minus one-fourth of the number marked incorrectly. The highest possible score is 20. This test is said to be suitable for grades 9-16.

This test is the original instrument that was developed in 1976. The ETS Kit gives the reliability as .75 for males and .77 for females, computed from the same suburban study of over 600 11th and 12th graders as the *Card Rotations Test* (Ekstrom et al., 1976).

Confidence instrument. The instrument for the confidence portion of the study was created by the researcher in the fall of 1994 (see Appendix A). This test was modeled after confidence instruments used by Dowling (1978) and Dunham (1991) for earlier studies. The confidence quiz was a multiple-choice test of 12 precalculus items. The student was not to answer the questions, but only to indicate on the Likert-type scale at the side their confidence that they could get the item correct on a scale of 1 to 5. One indicated a low confidence level and five indicated a high confidence level. For each test item, the student chose two responses—one to estimate their confidence without the use of a graphing calculator and the other with a graphing calculator. A student's confidence score was the total points obtained by summing their responses to the confidence portion of the quiz. Each student received two confidence scores, one indicating their confidence level without the aid of a graphing calculator and the other indicating their level of confidence if they were permitted to use a graphing calculator. Each of the scores could be a minimum of 12 and maximum of 60.

The confidence quizzes were also purposely designed so that the odd problems were all accompanied by graphs, while the even problems were not accompanied by graphs and were more algebraic in nature. This design created what will be referred to as the graphical subscale and the algebraic subscale. Each of these subscale scores for each student could be a minimum of 6 and a maximum of 30. A copy of the confidence instrument is included in

Appendix A. Six demographic questions concerning graphing calculator use were included at the end of the instrument.

To validate the confidence instrument, the researcher enlisted the aid of a panel of experts including colleagues and professors in the doctoral program at The Ohio State University, and two high school precalculus teachers. The quiz was pilot-tested in the fall of 1994, revised and then retested in the fall of 1995. Using Cronbach's alpha, the reliability of the revised instrument in 1995 testing was computed to be .78 for the quiz without the availability of graphing calculators, and .80 on the quiz with the availability of graphing calculators.

Interview protocol. The interview protocol was developed and pilot-tested winter quarter 1995. The researcher enlisted the aid of the same panel of experts as well as the addition of a person very familiar with interview techniques, to validate the instrument. Practice interviews were conducted by the researcher that same quarter to check the appropriateness of the questions for this particular study and the time required for each interview. A copy of the interview protocol is included in Appendix B and a composite of most of the student responses is included in Appendix C.

Procedures for Collecting Data

In early November the students were given forms thoroughly explaining the study and requesting permission from parents for their child's participation in the study. The individual teachers were responsible for distributing and collecting the permission forms. The first week of December 1995, the students in the six precalculus classes were given the *Card Rotations Test* (S-1), the *Paper Folding Test* (VZ-2), and the confidence quiz. Demographic information was also collected during this time. The researcher conducted all of the testing sessions in order to insure uniformity of method and conditions as much as possible.

During the last part of December 1995 and January 1996, the researcher scored the spatial and visualization tests and confidence quiz for each student. During this same time period the students' grades from their last mathematics class were collected from the guidance offices.

The students selected for the qualitative portion of the study were approached personally about participating in the interview process. During the pilot study in the spring of 1995, the researcher found that approaching students directly to ask their participation in the interview process was much more effective than having them fill out a card stating whether they were willing to participate or not. When using the latter method, no females would agree to be interviewed while almost all of the males expressed an interest in participating. When the females were approached personally, they were willing to be interviewed. All students in the current sample who were asked, agreed to be interviewed. Students were given the choice of being interviewed at school during a study hall or lunch, or coming to the researcher's office after school. Each student who was interviewed at school received $5 as a token of appreciation, while the students who came to the researcher's office received $10 for their extra effort.

The face-to-face interviews with 25 of the students were semi-structured. An interview schedule was followed, but the researcher felt free to probe further in some areas or revise some questions when it seemed appropriate. The interview protocol is included in Appendix B. The interviews were approximately 15 to 20 minutes in length and were conducted at a time convenient to the student. Each interview was tape-recorded with the student's permission so that excessive time would not be required to take notes during the actual interview and so that the researcher could focus on the student's responses. The transcripts were then typed in their entirety and a composite of the interviews is included in Appendix C.

The interviews were used to obtain a more in-depth understanding of the students' attitudes toward graphing calculators and their use in the high school precalculus classroom. The results of the interviews will be discussed in Chapter V. The researcher feels that these interviews which yield insight into the students' feelings about using graphing calculators add a depth to the study that would not have been possible without this phase of the research process.

Methods of Analysis of Data

A repeated measures *t*-test was used to examine the means of confidence-with-graphing-calculator and confidence-without-graphing-calculator, to see if there was a significant difference. An analysis of variance was used to see if differences in these means were affected by gender or teacher.

An independent sample *t*-test was used on the total confidence-with-graphing-calculators to check for significant differences according to gender. An analysis of variance was used to see if the teacher affected the scores, and if there was any interaction effect between gender and teacher.

A repeated measures *t*-test was used with graphical and algebraic subscale scores to see if there were significant differences. An analysis of variance was used to see if these results were affected by gender. A repeated measures *t*-test was also used to check significant differences between the graphical and algebraic subscales. ANOVA was used to investigate any possible gender effect.

T-tests for independent samples were used to check for significant differences in spatial skill scores for males and females, as well as visualization scores for males and females.

Pearson's product-moment correlation was computed for confidence-with-graphing-calculator and spatial skills for the whole group, and then individually for males and females. This same statistical procedure was used to compute correlations between confidence-with-graphing-calculator and visualization, both for the whole sample and according to gender.

Spearman's rank correlation was used to compute correlations between confidence-with-graphing-calculator and the students' grades from the last mathematics class they had taken. This procedure was applied to the total sample and then for males and females as individual groups. This same process was used to check correlations involving the graphical and algebraic subscales with the grade from the last mathematics class.

Analysis of variance was used to check any significant effects of the answers to the demographic data collected from questions number 13 through 18 at the end of the confidence quizzes. The results of all of these statistical procedures will be discussed in detail in Chapter 4.

Limitations

One of the limitations of this study is that the sample was not randomly selected. There were not enough high school precalculus classrooms in the geographical area that required graphing calculator use to enable the researcher to use random sampling and still have a sample with a significant number of participants.

Another possible limitation could be the lack of a control group. The high schools used in the study did not have precalculus sections that did not require the use of graphing calculators, and choosing classes from other high schools to fulfill this role would have introduced more confounding variables.

Caution must be used in extending the results of this study to other populations due to several factors. The classrooms used in this study were from predominantly white, middle-class, rural areas of the Midwest. The majority of the students in this study (more than 55%) had used graphing calculators for two years or more. The results might have been different with a more novice group.

The relatively short length of the confidence instrument could also be considered by some to be a limitation of this study. A longer instrument might have been more reliable. The researcher was trying to be sensitive to the amount of time being used by the testing process, and to keep that time as minimal as possible.

There were also limitations due to the interview process. Because the scoring of the initial testing took such a long time and other conflicts such as school vacations, as well as mid-year exams and proficiency testing, approximately two months of time elapsed between the initial testing and when the interviews were started. The interviews were conducted from February 1996 until the first week of April 1996. This could mean that the attitudes and confidence levels of the students might have changed between the time of the initial testing and the interviews. The ideal situation would have been to be able to interview immediately after the testing.

It is also a possibility that the "Hawthorne Effect" (Gay, 1987) influenced some of the student responses during the interview process. This also could be considered a limitation. The student responses could have been affected by the fact that they knew that they were participating in a research study about the possible connection between spatial skills and confidence in graphing calculator use. The researcher encouraged the students to respond honestly with any negative or positive comments, by telling them that both negative and positive comments would be helpful in the study. In a couple of the instances, interviewer fatigue led to the inadvertent omission of a couple of questions. It might be considered a strength of the study that the researcher conducted all of the interviews, which led to a greater consistency in the interview process.

CHAPTER IV

PRESENTATION AND ANALYSIS OF QUANTITATIVE DATA

This chapter contains the results of the statistical analysis of the scores for confidence-with-calculator, confidence-without-calculator, spatial skills, and visualization. The effects of problem type, gender, and teacher on the data are also examined for significant differences. Correlations are computed for the different types of confidence, visualization, and spatial skills.

Some Demographic Data

The last page of the confidence instrument contained five questions about the student's graphing calculator use and one question regarding their classification in school. These questions were presented in a multiple choice format.

Q13: How long have you used a graphing calculator?
Q14: How often do you use your graphing calculator?
Q15: How do you feel about using your graphing calculator?
Q16: What kind of graphing calculator do you use?
Q17: What is your classification in school?
Q18: Whose graphing calculator do you use?

For a complete transcript of the questions and possible responses see the confidence instrument in Appendix A. The results of this information, as well as a summary of student grades is included in Appendix D.

Over one-half of the students in the sample had used a graphing calculator for 2 years or more. More than 50% of the sample classified their calculator use as either "fairly often" or "all of the time". Only 3 out of the 134 said that they only use the calculator because it is required. Fifty-five percent of the sample are using TI-81's, and that is because the schools which lend out calculators lend out TI-81's. There were no freshman in the sample, 3 sophomores, 54 juniors, and 77 seniors. Almost all of the students either own their own calculator or use the school's, only 4 students stated that they shared their calculators with someone else.

Table 4

ANOVA Results for the Effects of Demographic Questions #13-18 on Confidence with Calculator Scores

	df	F	P(F)
Q#13	3	6.256	0.0006**
Q#14	3	3.958	0.0101*
Q#15	3	4.022	0.0093**
Q#16	3	0.017	0.9971
Q#17	2	0.624	0.5379
Q#18	3	0.274	0.8441

*Significant at 98% level; ** Significant at 98% level.

An analysis of variance was used to determine the relationship between any of these answers and the students' scores for confidence-with-graphing-calculator. Table 4 displays the results for when the questions are added sequentially one at a time. These data seem to indicate that in the order presented, there is a significant relationship ($p<.02$) between questions 13, 14 and 15 and the confidence-with-graphing-calculator scores. Question 15 was significant ($p<.05$) in every arrangement of the questions tested. This is not surprising as it is asking the student how they feel about using a graphing calculator and that is directly related to confidence.

Summary Statistics for Confidence Scores

A summary of the means and standard deviations for the confidence scores is included in Table 5. This table is organized by gender and problem type (algebraic and graphical), for the confidence-without-calculator and confidence-with-calculator scores.

The mean of the total confidence scores increased 6.44 points when the students knew that they would be permitted to use a graphing calculator on the quiz. The males demonstrated a slightly greater gain (+6.70), but the females confidence mean also gained more than 6 points (+6.15).

When confidence scores were examined by problem type, mean gains were also evident when students considered using a graphing calculator. It is in these gains that we realize that the bulk of the overall gain in the total confidence scores lies with the increased confidence on the graphical items. The increase in mean confidence scores on the algebraic items was +1.92

Table 5

Confidence Means and Standard Deviations by Problem Type and Gender

	Total Sample N=134		Males N=69		Females N=65	
Confidence Without Calculator	Mean	S.D.	Mean	S.D.	Mean	S.D.
Total Score	42.94	7.343	44.04	7.517	41.79	7.023
Problem Type						
Algebraic	22.75	3.877	22.80	3.995	22.69	3.779
Graphical	20.20	4.370	21.25	4.275	19.09	4.223
Confidence With Calculator						
Total Score	49.38	6.541	50.74	6.566	47.94	6.245
Problem Type						
Algebraic	24.67	3.817	25.26	3.620	24.05	3.947
Graphical	25.05	3.700	26.00	3.400	24.05	3.764
Gains in Confidence Means From Using Calculator						
Total Score	+6.44		+6.70		+6.15	
Problem Type						
Algebraic	+1.92		+2.46		+1.36	
Graphical	+4.85		+4.75		+4.96	

Note: Total score possible range is from 12 to 60; Algebraic and Graphical scores possible range are from 6 to 30.

compared to a +4.85 gain in confidence on the graphical subscore. This pattern was consistent in both male and female scores, with the males exhibiting slightly greater gains on the algebraic items and females slightly greater gains on graphical items. In every case, the male confidence means were greater than the females, with the least difference (+.11) occurring on the algebraic subscale of the confidence-without-calculator, and the greatest difference (+2.16) appearing in the means for the graphical items without calculator use. These data seem to indicate that there is a greater difference in confidence on graphical items according to gender, than on algebraic items, with the advantage pointing toward the males.

It is interesting to note that on the confidence-score-without-calculator use, the females were more confident on the algebraic items than on the graphical problems with a mean difference of +3.60. This difference in confidence level by subscore was eliminated for the females when graphing calculators were permitted. The male confidence-mean-without-calculator was greater on the algebraic items (+1.55) and this reversed with the mean of the confidence-with-calculator graphical subscore being +.74 greater than the algebraic subscore. This seems to indicate that although the availability of a graphing calculator increases the overall confidence of a student, it has a greater effect on the graphical items than algebraic problems.

In examining the standard deviation, in every case the standard deviation decreased when graphing calculators were permitted, except in the case of the female algebraic items, where there was a slight increase. These decreases were also greater in the graphical items than in the algebraic items for the total sample and according to gender. This seems to indicate that graphing calculator use can perhaps help minimize variability in confidence levels of students, especially on graphical items. The maximum score in each of the instances did not change, indicating that the decrease in standard deviations was a result of increases in the lower confidence scores.

Examining the Link Between Confidence and Graphing Calculators

It was hypothesized in Chapter I that there would be significant differences in the mean scores of the confidence-quizzes-with-graphing-calculators and the confidence-quizzes-without-graphing-calculators, thus indicating a link between the students' attitudes and graphing calculator use.

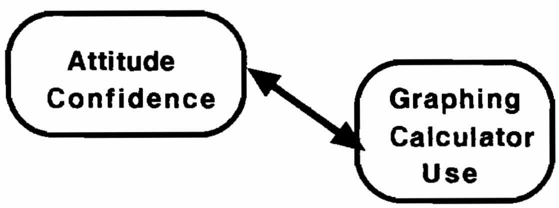


Figure 7: Attitudes and Calculator Use

It was also proposed that there would be significant differences in the mean subscores of the confidence quizzes relative to problem type. Specifically, students would express greater confidence in items presented graphically than those presented algebraically. Table 6 illustrates the data significant to this portion of the model.

Table 6

A Repeated Measures *t*-Test Results Comparing
Confidence with Calculator and Confidence without Calculator

Confidence Without Calculator	Mean	S.D.
Total Score	42.94	7.343
Algebraic Subscore	22.75	3.877
Graphical Subscore	20.20	4.370
Confidence With Calculator		
Total Score	49.38	6.541
Algebraic Subscore	24.67	3.817
Graphical Subscore	25.05	3.700

	t	p
Total Score	10.64	0.00*
Algebraic Subscore	5.15	0.00*
Graphical Subscore	15.30	0.00*

*Significant at 99% level; df=133.

A repeated measures *t*-test was used to test the following null hypotheses.

H_{01a}: There will be no significant difference in the students' scores on confidence-without--graphing-calculator and confidence-with-graphing-calculator.

H_{01b}: There will be no significant difference in the algebraic item subscores for confidence-without-graphing-calculator and confidence-with-graphing-calculator.

H_{01c}: There will be no significant difference in the graphical item subscores for confidence-without-graphing-calculator and confidence-with-graphing-calculator.

Table 6 is a summary of these data. In each case the *t* value represented a significant difference ($p<.01$). All of the null hypotheses H_{01a}, H_{01b} and H_{01c} were rejected. This indicates that the increased scores probably did not occur by chance, but were the result of increased confidence because a graphing calculator would be available. These data seem to support the fact that there is a link between a student's attitude and graphing calculators, as was proposed in the model.

Examining Possible Gender or Teacher Effects on Differences Between Confidence Scores

An ANOVA was used to see if these observed differences were affected by gender or teacher. The null hypothesis for this part of the analysis follows Table 7.

Table 7

ANOVA Results Examining Gender and Teacher Effects on Differences Between Confidence with Calculator and Confidence without Calculator Scores

	Confidence Without Calculator		Confidence With Calculator	
	Mean	S.D.	Mean	S.D.
Male	44.04	7.517	50.74	6.566
Females	41.79	7.023	47.94	6.245
Teacher 1	40.09	6.654	46.77	6.362
Teacher 2	42.75	5.927	52.00	4.382
Teacher 3	41.12	6.594	46.06	6.514
Teacher 4	46.16	6.944	50.96	5.303
Teacher 5	41.13	8.683	49.39	7.165
Teacher 6	44.84	7.119	50.42	7.131

	df	**F value**	**P(F)**
gender	1	0.196	0.66
teacher	5	1.295	0.27
gender/teacher	5	0.236	0.95

H_{0gt}: The observed difference in confidence-without-graphing-calculator scores and confidence-with-graphing-calculator scores is not affected significantly by gender, teacher, or interaction between gender and teacher.

These results appeared in Table 7. There does not seem to be any significant gender or teacher effect on the data; therefore, the null hypothesis H_{0gt} is not rejected.

Differences in Confidence Scores According to Gender

It was proposed in Chapter I that there would be significant differences in the confidence-with-graphing-calculator scores according to gender. Specifically, males would express greater confidence than females. Relative to subscores, it was proposed that females would express greater confidence on algebraic items, while males would express greater confidence on graphical items. Relative to these questions, the following null hypotheses were proposed;

H_{02}: There will be no significant difference between males and females on confidence-without-graphing-calculator and confidence-with-graphing-calculator.

H_{04a}: There will be no significant difference between males and females on subscores of algebraic items for confidence-without-graphing-calculator and confidence-with-graphing-calculator.

H_{04b}: There will be no significant difference between males and females on subscores of graphical items for confidence-without-graphing-calculator and confidence-with-graphing-calculator.

The null hypothesis H_{02} is rejected ($p<.02$) with males exhibiting significantly greater confidence than females on the total confidence-with-graphing-calculator score. There were no significant differences between the males and females on subscores of algebraic items for confidence-without-calculator and confidence-with-graphing-calculator. There were significant differences ($p<.01$) between the males and females on subscores of graphical items for confidence-without-calculator and confidence-with-calculator. This confirmed the original hypothesis in Chapter 1 that the males would express greater confidence on graphical items, but contradicts the hypothesis that the females would exhibit greater confidence on the algebraic items. It is interesting to note that the gap between males and females was a lot smaller on the algebraic items than the graphical items. These results appear in Table 8.

These results seem to indicate that there is a link between confidence with graphing calculator use and gender as was proposed by this part of the model in Chapter I.

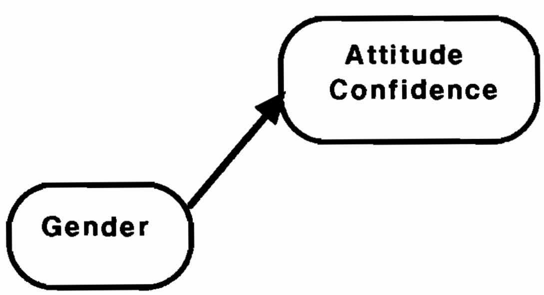


Figure 8: Gender and Attitudes

Table 8

Independent-Sample *t*-Test Results for Differences in Confidence Quiz Scores According to Gender

	Males		Females	
	Means	S.D.	Means	S.D.
Confidence Without Calculator				
Total Score	44.04	7.517	41.79	7.023
Algebraic Subscore	22.80	3.995	22.69	3.779
Graphical Subscore	21.25	4.275	19.09	4.223
Confidence With Calculator				
Total Score	50.74	6.566	47.94	6.245
Algebraic Subscore	25.26	3.620	24.05	3.947
Graphical Subscore	26.00	3.400	24.05	3.764

	t	p
Confidence Without Calculator		
Total Score	1.80	0.074
Algebraic Subscore	0.16	0.88
Graphical Subscore	2.93	0.004**
Confidence With Calculator		
Total Score	2.53	0.013*
Algebraic Subscore	1.85	0.066
Graphical Subscore	3.15	0.002**

*Significant at 98% level; ** Significant at 99% level.

Differences in Confidence Scores According to Problem Type

Hypothesis 3 in Chapter I stated that there would be significant differences in the mean subscores of the confidence quizzes, relative to problem type. Specifically, students would express greater confidence in items presented graphically than those presented algebraically.

Table 9

One-Sample *t*-Test Results for Differences in Confidence Quiz Subscores

	Confidence Without Calculator		Confidence With Calculator	
	Mean	S.D.	Mean	S.D.
Algebraic	22.75	3.877	24.67	3.817
Graphical	20.20	4.370	25.05	3.700
	t	**p**		
Difference in Algebraic & Graphical Subscores without Calculator	7.78	0.00*		
Difference in Algebraic & Graphical Subscores with Calculator	-1.09	0.28		

*Significant at 99% level.

Table 9 examines one-sample *t*-test results regarding the null hypotheses that follow.

H_{03a}: There will not be significant differences in mean subscores relative to problem type on confidence-without-graphing-calculator scores.

H_{03b}: There will not be significant differences in mean subscores relative to problem type on confidence-with-graphing-calculator scores.

These results indicate that on the confidence-quizzes-without-graphing-calculator use there is a significant difference in the subscores ($p<.01$) so the null hypothesis H_{03a} would be rejected in this case. When confidence is measured considering a graphing calculator can be used, there is not a significant difference in subscore means so H_{03b} would not be rejected.

An ANOVA calculating the effect of gender and teacher, as well as any interaction of the effects of gender and teacher, on the differences between algebraic and graphical subscores yielded some interesting statistics appearing in Table 10. The null hypotheses used to investigate these questions are;

H_{04a}: There will be no significant gender effect on the differences in algebraic and graphical subscores for confidence-without-graphing-calculator.

H_{04b}: There will be no significant gender effect on the differences in algebraic and graphical subscores for confidence-with-graphing-calculator.

H_{0Ta}: There will be no significant teacher effect on the differences in algebraic and graphical subscores for confidence-without-graphing-calculator.

H_{0Tb}: There will be no significant teacher effect on the differences in algebraic and graphical subscores for confidence-with-graphing-calculator.

H_{0Ia}: There will be no significant effect from the interaction between gender and teacher on the differences in algebraic and graphical subscores for confidence-without-graphing-calculator.

H_{0Ib}: There will be no significant effect from the interaction between gender and teacher on the differences in algebraic and graphical subscores for confidence-with-graphing calculator.

Table 10

ANOVA Results for Gender and Teacher Effects on the Differences in Algebraic and Graphical Subscores

		Confidence Without Calculator		Confidence With Calculator	
	df	F	p	F	p
Gender	1	7.52	0.007*	0.63	0.431
Teacher	5	3.67	0.004*	7.89	0.000*
Gender/ Teacher	5	0.78	0.567	0.94	0.461

*Significant at 99% level.

These results seem to indicate that the teacher had a significant effect on the differences between the algebraic and graphical subscores both with and without graphing calculator use, thus rejecting null hypotheses H_{0Ta} and H_{0Tb} ($p<.01$). Gender only had a significant effect on the differences in subscores when a graphing calculator was not permitted, so null hypothesis H_{04a} is rejected ($p<.01$) while H_{04b} is not rejected. This seems to imply that the graphing calculator helped equalize males and females in this respect. There did not appear to be any interaction effect in either case, thus H_{0Ia} and H_{0Ib} were not rejected.

Spatial and Visualization Scores

Earlier research seemed to indicate a link between gender and spatial skills as indicated by the model in Figure 9. *T*-tests for independent samples were used to check for significant differences in spatial skill scores for males and females.

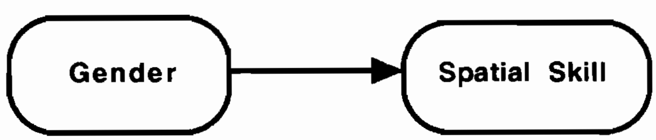


Figure 9: Gender and Spatial Skill

These null hypotheses state

H_{0S}: There will be no significant difference in the spatial skill scores according to gender.

H_{0V}: There will be no significant difference in the visualization scores according to gender.

These data are recorded in Table 11. These results seem to indicate that the differences in male and female spatial and visualization skills are significant, thus rejecting the null hypotheses, with $p < .01$ for spatial skills and $p < .02$ for visualization. This corresponds with findings in other studies citing differences in male and female spatial abilities.

Table 11

Results of *t*-Tests for Independent Samples on

Spatial Skill and Visualization Scores by Gender

	Mean	S.D.	*t*	P
Spatial Skill			3.98	0.0001**
Male	120.2	25.4		
Female	101.8	27.8		
Visualization			2.46	0.015*
Male	13.26	4.06		
Female	11.07	3.42		

*Significant at 98% level; ** Significant at 99% level.

Pearson's Product-Moment Correlations

Correlations between confidence scores and spatial skills. We will now turn our focus to the part of the model in Chapter I dealing with the relationship between spatial skill and graphing calculator use.

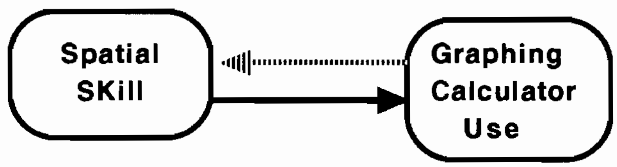


Figure 10: Spatial Skill and Calculator Use

Another important consideration of this study was the positive correlation that might exist between a student's spatial skill or visualization skill and their confidence in using a graphing calculator. A positive linear correlation between confidence and spatial skills or visualization would indicate that students with high spatial or visualization ability would also have higher confidence scores, and those with lower spatial abilities would have lower confidence scores. the stronger the correlation, the more often this would be true. Gender-related differences in the strengths of the correlations, as well as differences according to problem type, algebraic or graphical, were expected.

Pearson's product-moment correlation coefficient was computed for confidence-with-graphing-calculator and spatial skills for the whole group, and then individually for the males and females. This same statistical procedure was followed in computing correlations for confidence-with-graphing-calculator and visualization. The following null hypotheses were used in this phase of the analysis.

H_{05a}: There will be no significant correlation between the students' confidence-with-graphing-calculator scores and their spatial skill scores.

H_{05b}: There will be no significant correlation between the males' confidence-with-graphing-calculator scores and their spatial skill scores.

H_{05c}: There will be no significant correlation between the females' confidence-with-graphing-calculator scores and their spatial skill scores.

H_{06a}: There will be no significant correlation between the students' confidence-with-graphing-calculator scores and their visualization scores

H_{06b}: There will be no significant correlation between the males' confidence-with-graphing-calculator scores and their visualization scores.

H_{06c}: There will be no significant correlation between the females' confidence-with-graphing-calculator scores and their visualization scores.

The statistical significance of a correlation coefficient is determined by the numerical value of the coefficient and the size of the sample on which it was calculated. These two factors combine in a special kind of *t*-test for correlations. Equation 1 is used to compute the *t*-statistic found in Table 12.

$$t = r\sqrt{\frac{N-2}{1-r^2}} \qquad (1)$$

where *r* is the correlation coefficient for the sample and N is the number of cases in the sample (Garvin, 1981). This *t*-statistic is then used to determine the p-value or probability. These results appear in Table 12.

Table 12

Pearson's Product-Moment Correlation with Confidence with Calculator, Spatial Skills and Visualization for Total Sample and by Gender

	t	df	p-value	*r*
Confidence with Calculator/Spatial Skill				
Total Sample	2.25	132	0.026*	0.19
Males	1.74	67	0.087	0.21
Females	0.44	63	0.66	0.06
Confidence with Calculator/ Visualization				
Total Sample	2.77	132	0.007**	0.23
Males	2.31	67	0.024*	0.27
Females	0.82	63	0.418	0.10

*Significant at 95% level; ** Significant at 99% level.

The data indicate that there is a significant correlation (r=0.19, $p<.05$) between the students' confidence-with-graphing-calculator scores and their spatial skill scores. Significant correlations were also evident between the students' confidence-with-graphing-calculator scores and visualization scores for the total sample (r=0.23, $p<.01$) as well as for the males (r=0.27, $p<.05$). this led to the rejection of these null hypotheses. It is interesting to note that the bulk of the correlation between confidence-with-calculator and spatial skill, as well as with visualization, seems due in a large part to the male scores in each case.

These results indicate no significant correlations between the males' scores on confidence-with-graphing-calculator and their spatial skill scores, and the females' scores on confidence-with-graphing-calculator and spatial skills or visualization. These findings contradict hypotheses 5 and 6 as found in Chapter 1 which stated that females would have the higher correlation in both spatial skills and visualization with their confidence scores.

Table 13

Pearson's Product-Moment Correlation for Confidence with Calculator, Spatial Skills and Visualization as Computed by Teacher

		t	df	p-value	r
Confidence with Calculator/Spatial Skill					
Teacher	1	0.58	20	0.56	-0.13
	2	1.06	14	0.31	0.27
	3	1.82	15	0.09*	0.43
	4	0.83	23	0.41	0.17
	5	0.45	21	0.66	0.10
	6	1.13	29	0.27	0.21
Confidence with Calculator/ Visualization					
Teacher	1	0.39	20	0.70	0.09
	2	0.16	14	0.87	-0.04
	3	1.74	15	0.10*	0.41
	4	0.40	23	0.69	0.08
	5	1.55	21	0.14	0.32
	6	1.10	29	0.28	0.20

* Significant at 90% level.

Correlations computed by teacher. When individual correlations were computed for each teacher, it did not appear that the teacher had a significant effect ($p<.05$) on the correlation between confidence-with-graphing-calculator and spatial skill or visualization. These results appear in Table 13.

Table 14 is a matrix of Fisher's transformed *z*-statistics for the total group, males, and females, for correlations between confidence scores and spatial skills and confidence scores and visualization. Fisher's *z*-transformation is a way to convert the correlation coefficients (r) so that they will be normally distributed. A statistician, R.A. Fisher, discovered that the quantity

$$Z = \frac{1}{2} \ln \frac{1+r}{1-r} \qquad (2)$$

is approximately normally distributed, with r being the correlation coefficient (Townsend and Wheatley, 1978). Equation 2 was used to convert the correlation coefficients to Fisher Transformed z's.

In examining these data it is evident that for this sample, visualization was more closely correlated with the confidence scores than spatial skills, and the highest correlations occur with the graphical items. Some exceptions to this were the female coefficients for confidence-without-graphing-calculator algebraic scores and visualization, and the male without calculator algebraic scores and spatial skills. It was interesting to note the negative correlations with the female spatial skills and confidence-without-graphing-calculator. These were minimal in size but interesting. Could it be that the females are more likely to visualize in their own minds without the graphing calculator, or possibly resort to some method other than visualization?

Table 14

Fisher Transformed Z-Statistics for Correlations between Confidence Scores and Spatial Skills and Confidence Scores and Visualization

	Total Sample		Males		Females	
	SS	VZ	SS	VZ	SS	VZ
Confidence w/out Calculator	0.121	0.255	0.182	0.288	-0.030	0.141
Algebraic	0.121	0.203	0.245	0.224	0.010	0.192
Graphical	0.090	0.245	0.090	0.310	-0.060	0.070
Confidence with Calculator	0.192	0.234	0.213	0.277	0.060	0.100
Algebraic	0.172	0.131	0.172	0.182	0.080	0.020
Graphical	0.182	0.299	0.172	0.354	0.040	0.161

Rank Order Correlations

Spearman's rank correlation coefficient (ρ) was computed to investigate possible correlations between the confidence-with-graphing-calculator available and the students' grades in the last mathematics class, for the total sample, males, and females. Hypothesis 9 in Chapter I stated that there would be a positive correlation between the confidence scores and grades. The null hypotheses used for this portion of the study state;

H_{09a}: There will be no significant correlation between the students' confidence-with-calculator score and their grade in the last mathematics class.

H_{09b}: There will be no significant correlation between the males' confidence-with-calculator score and their grade in the last mathematics class.

H_{09c}: There will be no significant correlation between the females' confidence-with-calculator score and their grade in the last mathematics class.

Table 15 displays the results of these computations.

Table 15

Spearman's Rank Correlation Coefficients for Confidence with Calculator and Students' Grades

	Normal-*z*	p-value	ρ
Total Sample	2.634	0.008*	0.23*
Males	3.038	0.002*	0.37*
Females	0.192	0.848	0.02

*Significant at 99% level.

There was a significant positive correlation between confidence-with-graphing-calculator score and grades for the total group ($p<.01$). The significance for the total group appeared to be due in a large part to the male scores. The correlation for the males was also significant ($p<.01$). The null hypotheses stating that there would not be significant correlations between the confidence scores and grades for the total group and for the males were rejected on the basis of these significant correlations. The correlation between confidence-with-graphing-calculator scores and grade was not significant for the females, therefore that null hypothesis was not rejected.

Table 16

Spearman's ρ Computed by Teacher for Correlation Between Confidence with Calculator and Grade

	Normal-z	p-value	ρ
Total Sample	2.634	0.008**	0.23**
Teacher 1	0.290	0.772	0.06
Teacher 2	0.467	0.641	0.12
Teacher 3	0.449	0.653	0.12
Teacher 4	0.287	0.022*	0.47*
Teacher 5	0.182	0.856	0.04
Teacher 6	2.037	0.042*	0.37*

*Significant at 95% level; **Significant at 99% level.

Spearman's ρ was also computed by teacher. These results are summarized in Table 16. Teacher's 4 ($p<.01$) and 6 ($p<.05$) had significant correlations, but the other correlations were far from significant. Because of these data, it was determined that the significance of the overall correlation was not affected by teacher.

Summary of Quantitative Data Analysis

The following is a summary of the hypotheses examined and tested in this study. The conclusions given are a result of the *t*-tests, ANOVA's, and correlations computed which were already presented in detail in this chapter. Significant findings have been given in bold type.

H_1. There will be a significant difference in the mean scores of the confidence-quizzes-with-graphing-calculators and the confidence-quizzes-without-graphing-calculators . Specifically, the scores of confidence-quizzes-with-graphing-calculators will be higher.

Conclusion. The total confidence-scores-with-graphing-calculator were significantly higher, as well as the confidence scores for the algebraic and graphical subscores (p<.01).

H_2. There will be significant differences in confidence-with-graphing-calculators according to gender. Specifically, males will express higher confidence than females .

Conclusion. There were significant differences in confidence-with-graphing-calculator scores favoring the males for the total scores(p<.02) and for the graphical subscores (p<.01).

H_3. There will be significant differences in the mean subscores of the confidence quizzes, relative to problem presentation. Specifically, students will express higher confidence in items presented graphically than those presented algebraically.

Conclusion. There were significant differences in the mean subscores of the confidence quizzes when a graphing calculator was not available ($p<.01$), but these differences favored the algebraic items. When a graphing calculator was permitted, the graphical scores moved ahead of the algebraic scores, but the difference between graphical and algebraic was not statistically significant.

H_4. There will be significant differences in mean subscores of confidence quizzes according to gender. Specifically, females will exhibit higher confidence on algebraic items, while males will express higher confidence on graphical items.

Conclusion. Gender had a significant effect on the differences in subscores when a graphing calculator was not permitted ($p<.01$) and the males did express higher confidence on graphical items. The females were not higher in confidence on algebraic items. This seemed to imply that the availability of graphing calculators helped equalize the differences between males and females.

H_5. There will be a positive correlation between scores of confidence-with-graphing-calculator use and spatial skills, and this will be affected by gender. Specifically, females will have a higher correlation.

Conclusion. The correlations between confidence-with-graphing-calculator scores for the total group and their spatial skill scores was significant ($p<.05$), but the correlations by gender were not significant. The correlation for the males was much higher (r=0.21, p=.087) than for the females (r=0.06, p=.66).

H_6. There will be a positive correlation between scores of confidence-with-graphing-calculator use and visualization skills , and this will be affected by gender. Specifically, females will have a higher correlation.

Conclusion. **The correlations between visualization and confidence-with-graphing-calculator score for the total sample ($p<.01$)and separately for the males ($p<.05$) were significant, but the same correlation for the females was not significant.** The males had the higher correlation.

It is interesting to note that in regard to both H_5 and H_6, the significant correlations for the whole group were due in the most part to the male scores. Also, the correlations for visualization were stronger and more significant in each case than the corresponding spatial skill correlations.

H_7. The correlation between graphical items and spatial scores will be higher than the correlation between algebraic items and spatial scores.

Conclusion. **The correlation between graphical items with graphing calculator scores and spatial scores was higher than the correlation between algebraic items with graphing calculator scores and spatial scores for the total sample.** This was not true for confidence-without-graphing-calculator scores and spatial scores.

H_8. The correlation between graphical items and visualization scores will be higher than the correlation between algebraic items and visualization scores.

Conclusion. **The correlations between graphical items and visualization were higher than the correlations between algebraic items with graphing calculator and visualization in every case except for the females without graphing calculator.**

These data might also indicate that visualization is a more important skill for graphing calculator success than spatial skill.

H9. There will be a positive correlation between the confidence-with-graphing-calculator use and the grades the students received in the last mathematics class taken.

Conclusion. There were significant positive correlations between the confidence-with-graphing-calculator scores and the students' grades in the last mathematics class for the total sample (ρ=0.23, p<.01) and for the males (ρ=0.37, p<.01). The significance of the correlation for the total sample was due in a large part to the male scores.

Other findings discussed in this chapter included;

—the differences in confidence-without-calculator scores and confidence-with-calculator scores were not affected significantly by gender, teacher, or interaction between gender and teacher;

—the teacher had an effect on the differences in algebraic and graphical subscores both with calculator and without calculator available;

—gender, teacher interaction had no effect on the difference between the algebraic and graphical subscores;

—significant differences were found in both the spatial skills of males and females and the visualization skills. This result supports findings of earlier studies;

—teacher did not have a significant effect on the correlation between confidence-with-graphing-calculator score and spatial skill, or confidence-with-graphing-calculator score and visualization;

—in 4 out of 6 cases, the correlation between grade in the last mathematics class and confidence-with-graphing-calculator score was not significant when computed for each teacher. Therefore it is concluded that the significance of the correlation between grade and confidence-with-calculator score for the total sample was not significantly affected by teacher.

Conclusion

The results of this study seem to confirm that the availability of a graphing calculator in these high school precalculus classrooms significantly increased the students' confidence level on a quiz of precalculus items, especially the graphical items. The male confidence level in every case was greater than the female confidence level, with and without graphing calculators available. The availability of a graphing calculator equalized the confidence of the females on graphical and algebraic items, when without the calculator the females had expressed greater confidence on the algebraic items than the graphical items. There appeared to be no significant gender effect on the positive changes in total confidence levels.

There were significant differences according to gender favoring the males on the graphical item subscores both with and without graphing calculator. When a graphing calculator was not available, the difference in graphical and algebraic subscores was significant, while use of a graphing calculator minimized but did not completely erase the difference. There were significant gender and teacher effects on the differences in the scores on the algebraic and graphical items.

There were significant differences in the spatial skill and visualization scores according to gender favoring the males. Positive, significant correlations existed between the confidence-with-graphing-calculator scores and spatial skills, as well as confidence-with-graphing-calculator and visualization scores, and in both cases these were due in a major part to the male scores. Correlations between graphical items and visualization were higher in every case than the correlations between graphing items and spatial skills, especially for males. This suggests that visualization is much more important for graphing calculator use than spatial skill.

Rank correlations between confidence-with-graphing-calculator and grade in the last mathematics class were positive and significant ($p<.01$) for the total sample and for males. This was not significant for females, so the correlation for the total group was due in a large part to the male scores.

The demographic questions having the most significant effect on confidence-with-graphing-calculator scores were the number of years of calculator use and how often it was used.

The results of this study suggest that there are some real advantages to using graphing calculators in the high school precalculus classroom, but those advantages can be affected by gender and visualization and spatial skills. More research needs to be done in these areas.

CHAPTER V

ANALYSIS OF INTERVIEWS

The qualitative portion of this study focused on differences in attitudes and perceptions toward graphing calculator use in the classroom. Were there differences in the attitudes of the males and females? Did students with higher spatial and visual abilities exhibit different attitudes or perceptions than students with lower spatial and visual skills? Did males and females have different perceptions of the negatives associated with using graphing calculators in the classroom? It was hoped that the face-to-face individual interviews would provide insight into differences observed in the quantitative data. What is the impact of using a graphing calculator in a high school precalculus classroom from the students' point of view?

Participants

A purposeful sample of 25 students was chosen out of the original 134 students participating for the qualitative portion of the study. Every student approached about participating in the process agreed to be interviewed. The gender balance for the interview sample was reflective of the original group. The χ^2 statistic was calculated for the confidence quiz scores, spatial skill scores, and visualization scores. Chi-square was also computed for gender, teacher, school, and grade. These statistics appear in Table 17.

Table 17

Comparative Statistics for Interviewed Sample and Total Sample

		Total Sample N=134		Interviewed Sample N=25 (18.7%)	
Gender					
Male		69	51.5%	13	52%
Female		65	48.5%	12	48%

$\chi^2 = .003$, df=1; ns

Teacher	1	22	16.4%	7	28%
	2	16	11.9%	3	12%
	3	17	12.7%	7	28%
	4	25	18.7%	1	4%
	5	23	17.2%	3	12%
	6	31	23.1%	4	16%

$\chi^2 = 10.49$, df=5; $p<.10$

School	1	22	16.4%	7	28%
	2	16	11.9%	3	12%
	3	17	12.7%	7	28%
	4	79	59.0%	8	32%

$\chi^2 = 9.75$, df=3; $p<.025$

Grade	A	56	41.8%	11	44%
	B	50	37.3%	11	44%
	C	23	17.2%	3	12%
	D	5	3.7%	0	0%

$\chi^2 = .723$, df=3; ns

Scores	Mean	S.D.	Mean	S.D.	χ^2	p
CW/OCalc	42.9	7.34	40.8	7.54	2.69	ns
CWCalc	49.4	6.54	46.3	7.31	9.21	p<.025
Spatial Skill	111.3	28.06	102.8	36.12	4.30	ns
Visualization	12.5	3.84	11.2	5.35	14.82	p<.005

The characteristics of the interviewed sample were similar in distribution to the original group in 4 out of 8 selected categories. The areas of teacher, school, confidence-with-calculator and visualization were not significantly similar in distribution to the original sample. The purpose of the interviews was to look for patterns or differences in high and low confidence students and high and low visualization students, so those distributions did not have as many middle of the road scores.

An interview protocol was followed for the semi-structured, face-to-face interviews, but the researcher felt free to probe further in some areas, or revise some questions when necessary. The interview protocol is in Appendix B and a composite of the interviews appear in Appendix C. The interviews were approximately 15 to 20 minutes in length and were conducted at a time convenient for the student. Each interview was tape-recorded so that excessive time would not be spent on note-taking, to guarantee accurate recall of the information, and so that the researcher could focus on the student responses and thereby probe further when necessary.

Background Information

The initial interview questions were meant to give the researcher some insight into the students' preferences and future plans and to help put the student at ease. The answers to these questions were not particularly important to this study, but were of interest to the researcher. It was interesting to note that only 2 out of 12 females chose mathematics as their favorite subject while 5 out of the 13 males chose mathematics. This did seem to indicate a possible relationship between gender and mathematics, which is supported in the literature. There seemed to be no particular pattern of visual or spatial skill related to the responses. A table of the responses is included in Table 18.

Table 18

Favorite Subjects of Interviewed Sample

Subject	Total Group	Male	Females
Science	8	3	5
Mathematics	7	5	2
Foreign Language	3	2	1
History	3	1	2
English	2	1	1
Art or Music	2	1	1

The responses to the question about future plans were extremely varied. Many students did not know what they wanted to be doing 10 years from now and gave drastically different answers. One student stated that she wanted to be either a botanist or a movie producer, while another stated that he wanted to be an actor or do something with computer graphics. Eleven out of the 25 did at least mention a field having to do with science or mathematics. These responses also did not appear to reflect any pattern in relationship to spatial or visual skill, or gender.

Table 19 indicates the breakdown according to calculator type of the interviewed sample. It is interesting to note that 5 of the students who use TI-81's could not identify it as a TI-81 but only knew that it was a Texas Instrument calculator and it was blue. It was of interest that all 4 of the TI-85's were owned by males. Particularly because the TI-85 was the most advanced of the Texas Instrument graphing calculators available at the time and had the most technological capabilities.

Table 19

Calculator Use for Interviewed Sample

Type of Calculator	Total Group	Males	Females
TI-81	16	7	9
TI-82	3	1	2
TI-85	4	4	0
Other	2	1	1
Calculator Ownership			
Student	14	8	6
School	11	5	6
Years Used			
1 or less	10	5	5
2	12	6	6
3	1	1	0
4	2	1	1

The only obvious relationship between spatial or visual ability and number of years of graphing calculator use was that both students who have used a graphing calculator for 4 years, one male and one female, have high spatial and visual skills. Research has shown that graphing calculator use can improve spatial skills, but we have no way of knowing if this is the case or if the students had high spatial abilities before they started using a graphing calculator and therefore were keenly interested in using the graphing calculator. Most of the students stated that they use their graphing calculator just for their mathematics class and homework, or for science and mathematics. One male with low spatial skill mentioned that he occasionally used his calculator in psychology class.

Gender, Attitudes, Spatial Skills, and Graphing Calculator Use

The model proposed for this study in Chapter I suggests there is a link between students' attitudes and feelings and their graphing calculator use. One of the purposes of the interviews was to investigate this connection further, as

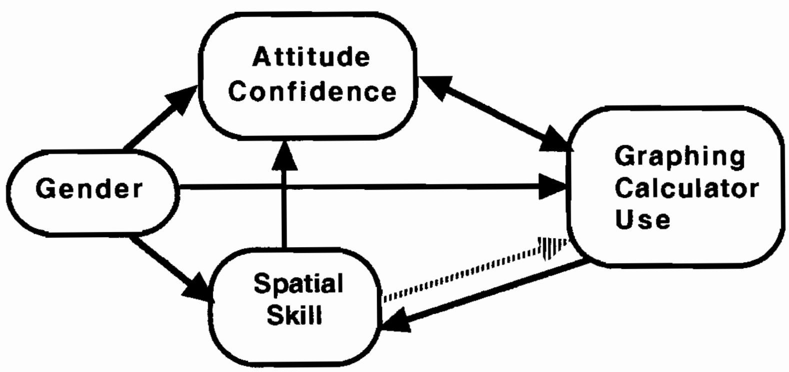


Figure 11 : Model of Relationships Between Gender, Attitudes, Spatial Skill and Graphing Calculator Use

well as any relationships that might be evident relating to gender and spatial skill.

<u>**Gender and attitudes.**</u> Let us first examine data dealing with the connection between gender and attitude or confidence. When the students

were asked how they felt about using a graphing calculator 10 of the 25 students made some sort of negative comment. This does not mean that all of their comments were negative, as some students would say something negative and something positive. Of the 10 students who made negative comments, 7 were females and 3 were males. When asked if this had affected their attitude toward mathematics, 4 females and 3 males indicated some negative attitude toward mathematics. A sample of a couple of the negative responses is included below.

F12 "I'm so terrible in math."
M42 "It was a pain to work out all the details."

In the first 10 questions of the interview, females made more negative responses referring to mathematics in a ratio of 21 to 16. These data seem to support the hypothesis that there will be differences in attitudes or confidence toward graphing calculator use according to gender.

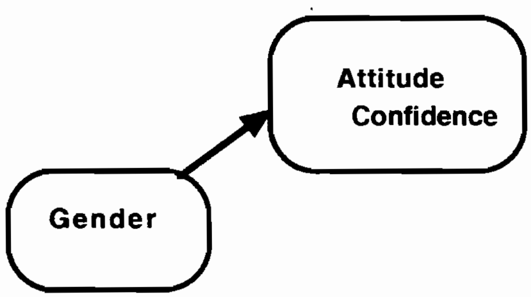


Figure 12: Gender and Attitudes

There was further evidence of this relationship in the responses to the question of taking mathematics when they entered college. Six out of 12 females responded either "I'll probably have to" or no, as compared to only 1 out of 13 males.

There was some evidence that possibly the technological aspect of the graphing calculator was a factor in the difference in attitudes between males and females. The comment below is made by a female of low spatial skill.

> F49: "I don't know very many of the functions. I just know what I need to know to get through class."

Six of the 12 females referred in some way to being uncomfortable with the technology compared to only 1 male. Males also made many comments indicating that they felt that the females were not as comfortable with the technology. These interviews further supported the quantitative findings in Chapter IV when the difference according to gender in the confidence-with-graphing-calculator scores significantly ($p<.02$) favored the males.

Gender and spatial skill. Now let us examine the interview responses for any indications of a link between gender and spatial skill.

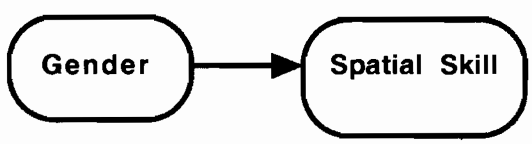


Figure 13: Gender and Spatial Skill

Seven of the 12 females interviewed were below the mean in both spatial skill and visualization scores. This compared to 6 of the 13 males in the sample. In analyzing the data for this portion of the model, the researcher looked for responses containing visual words or references to graphing. A few of the sample responses are included below.

F14 "Oh I use it more to *see*."
F51 "You can *see* the *graph*, and its got a big screen."
F127 "It allows you to *visualize* your problem situations."

M2 "I can *see* everything that I have done and that way I can *see* all of my work."
M27 "I can *picture* all of the things that we are doing."

For the most part the number of responses containing visual references were fairly evenly divided between the males and the females. Some interesting differences occurred in questions 7 and 8. When asked how the graphing calculator helped them, females used visual words or referred to graphing 8 times compared to 5 for the males. The 6 females who chose graphing as the feature used the most, chose only graphing. The 4 males who mentioned graphing in their response also mentioned other features such as programming or equation solver. There seemed to be some evidence of a link between gender and spatial skill, but it was not overwhelming.

The quantitative results indicated significant differences in the visualization ($p<.02$) and spatial skills ($p<.01$) of males and females favoring the males. The females used spatial words or references to spatial features slightly more often than the males in the interviews. Some of the females seem to be using the graphing calculator as a tool to help them in an area where they are weak.

Spatial skills and graphing calculator use. The researcher also analyzed the data for evidence of possible links between spatial ability and graphing calculator use. The quantitative results yielded significant correlations between confidence-with-graphing-calculator and visualization (r=.23, $p<.01$) and spatial skills (r=.19, $p<.05$). The interview data was examined for further possible insights in this area.

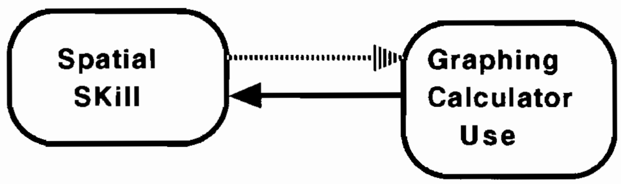


Figure 14: Spatial Skill and Calculator Use

Several students directly referred to the visual features of the graphing calculator. The two statements below were made by males of low spatial and visual skills and low confidence.

M2: "I like it because I can *see* everything that I've already done and stuff, and it helps me out on most of my work."
M44: "I like it a lot. It helps me to *see* things. I'm not very good at drawing lines sometimes and it helps me to *see* it."

These statements would seem to indicate that graphing calculators are viewed as a positive tool by some students with low spatial ability. A female with high spatial skill also mentioned that she liked it because "it's visual."

It is significant to note that except for one, *all* of the negative comments concerning feelings about graphing calculator use in the classroom came from students with low spatial and visualization skills. This seemed to strengthen the theory that there is a link between spatial skill and graphing calculator use. Some of negative comments referred directly or indirectly to technology as being a problem.

F14: "You have to make sure you know how to use it. I have a terrible, terrible time getting my calculator to do the right things."
F52: "I feel pretty unsure about a lot of things."
F102: "I don't always know how to use it."
M9: "I didn't understand all of the buttons."

The responses to this question seem to indicate that students with low visual and spatial abilities may have more difficulty with their graphing calculator, especially females. It also gives some evidence that the fact that the graphing calculator is "technology" with "buttons" is a negative factor to some students.

Two of the most negative comments came from students with low scores in spatial skills, visualization, and confidence. Note that this represents one male and one female.

F52: "It seems more confusing sometimes. . . I would like to be able to use it better, like you use computers."
M5: "With it math is a lot tougher."

It is interesting to note that the reference to computers [technology] was made by the female. The literature has shown that females tend to be more shy of technology than males. The males who were high in spatial ability were much more profuse in their answers as to the positives of graphing calculator use.

When asked if they liked mathematics class better when graphing calculators are permitted, 80% responded in the affirmative. Three of the 4 who answered the question negatively scored low in both spatial and visual skills, and one of them stated that they "like them [math classes] better when we are *not* using graphing calculators." Of the 4 negative responses to the question, 3 were from females. Of 7 males with low spatial and visual skills, 6 expressed positive attitudes toward graphing calculator use. Of 7 females in the same category, 3 expressed negative attitudes of some sort in response to this question. This seemed to indicate that females with low spatial ability are more affected negatively in their attitudes than the males with low spatial and visual skills. Also relevant to this is the fact that the only student who said that she would definitely *not* use graphing calculators in her classroom if she were a teacher was F52 who was low in both spatial skill and visualization.

Some statements made by females of low spatial visual ability and low confidence are included below.

> F52: "You know, if you have no clue, you can try something on the calculator because it has so many different options."
>
> F12: "Yes I do. Because when I was out of trig, I didn't have it [graphing calculator] anymore-this was before I bought my own, and I was back to using my normal calculator and I forgot totally how to use it. It was awful. I think it is much easier to use graphing calculators."
>
> F14: "I use it more to *see* what my equations look like because I'm more of a *visual* learner, so if I don't *see* it, I don't learn it."

These responses seemed to indicate that if students of low spatial ability are taught how to use a graphing calculator it can be a real asset to their confidence and attitude toward mathematics. Many of the low spatial skill students mentioned feeling like they could at least attempt a problem if they had a graphing calculator.

When asked about the drawbacks to using a graphing calculator, it is interesting to note that 5 out of the 6 students citing technological features as being drawbacks were students with low spatial and visual skill. The students of higher spatial and visualization ability referred in some way to "algebraic guilt" as being the major drawback. This seemed to indicate a strong link between low spatial skill and fear of technology.

The data from these interviews give evidence that there is a link between spatial skill and graphing calculator use, and that it is also influenced by gender and attitude.

Gender and graphing calculator use. The proposed model also suggests a relationship between gender and graphing calculator use. Out of the 25 students in the sample, 16 thought there was definitely a difference in the ways males and females in their class used graphing calculators. It was very interesting to note that of the 9 students who did *not* notice a difference, 6 were females. There was a mixture of spatial abilities in this group.

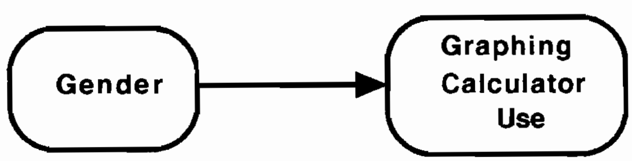


Figure 15: Gender and Graphing Calculator Use

The respondents who perceived differences in male and female use of graphing calculators were almost unanimous in the reasons for their answers. It was mentioned repeatedly that the males liked to experiment more, program more, and play around with them more, indicating that the males were more comfortable with using the calculator. These responses came from males and females of all spatial and visual abilities. The fact that males are more “into” computers was also cited as a reason in at least a couple of instances.

F14: “The guys are more like into computers and stuff. . .and the girls are like well this helps us do our math. . .while the guys are having fun with it.”

F127: “Well, the girls probably use it for the problems presented to them, but the guys like to go the extra mile and do the programming more and explore the graphing calculator more.”

M2: “In my class it is usually the girls who have questions. . .or like. . need another explanation on how to use a certain function.”

M29: “I write programs just so that I don’t have to enter an equation every time, and like my sister, she doesn’t really like to use the calculator. She’ll use it if she has to, but it is the kind of thing where she could do it on paper and like it just as much or more.”

M64: “I’d say that most of the guys really like it, but most of the girls I would say are maybe a little bit afraid of it, but of lot of them [girls] don’t like to use them.”

This last response was especially interesting as at this point in the interview the researcher had not asked about possible differences in attitudes by gender. Most of the students seem to imply that it was a fear of technology or lack of interest that seemed to influence the differences between male and female attitudes toward and use of graphing calculators in the classroom.

In response to Question 7b on how they use their graphing calculator, the female responses were mainly about regular computation, graphing, and using it to obtain values for the trigonometric functions. One female did mention using it for matrix computation. Three of the males talked about the programming capabilities and experimenting and another male talked about using lists. The male responses seemed to indicate that they were more comfortable with exploring and branching out in the use of the technology which was consistent with responses to other questions.

There was an abundance of evidence in the interview data that there is a link between gender and graphing calculator use, with males using it more often and in many different ways. The males were especially adamant in explaining differences between males and females in this respect.

Attitudes and graphing calculator use. Another major portion of this study is concerned with the relationship between a student's attitude or confidence and graphing calculator use. The quantitative results indicated significant differences ($p<.01$) in the students' confidence levels on a precalculus quiz when a graphing calculator was available. By far the majority of the students that were interviewed had positive comments when asked about their feelings about using a graphing calculator.

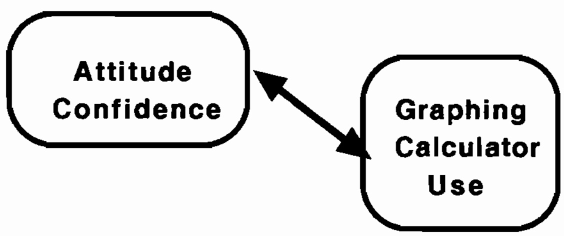


Figure 16: Attitudes and Calculator Use

Many students stated that they "liked" using the calculator or said "it is helpful." When asked if using a graphing calculator had affected their attitude toward mathematics 14 of the students related positive changes in their attitude toward mathematics due to graphing calculator use. This represented a mix of male and female and low and high spatial abilities. Several students stated that it "made things easier" or "it gives me more confidence". The statements below were made by students of low spatial and visual skills.

F12: "It made everything a whole lot easier, because I'm so terrible in math."
F14: "I like it better because it's not so distracting and you're not so worried about having the right answer."
F102: "Everything doesn't seem like it is so impossible."

Students of high spatial skills also expressed some positive changes in attitudes due to graphing calculator use.

M27: "Yeah, it takes out some of the negative things."
M29: "It's a visual perception of math instead of just numbers on paper. It helps to visualize what the numbers are doing in an equation."
M42: "Before I was allowed to use graphing calculators I didn't like it because it was a pain to work out all the details, but now if I get the concepts, all of the work is done."

Question 10 dealt with the participants' perceptions of how other students in their class felt about using graphing calculators. Eighteen out of the 25 felt that the majority of the class, if not everyone, liked using them.

F37: "I think that everyone likes to use them. . . it helps them out."
M27 "I think that pretty much all of us like them. Because if she says we're not going to be using graphing calculators today, there is kind of a sigh, because we like to use them. And that's good because like we'll play around on the calculator with different equations to try and find out what they do, and we probably even pick up something while we are playing."

Ten out of the 25 students interviewed had noticed some negative feelings in their classrooms, and of these 10, 7 were males. Seven out of these

10 were also of low spatial ability. Here are some of the student comments about the negative feelings that they felt existed in their classrooms about graphing calculator use.

F52: "I feel like the minority because I don't understand sometimes."
F97: "Some of them just use it because they have to."
M2: "They get really frustrated when they don't know what is going on-what function or whatever to push-to keep up with the class."
M29: "There is a few people that I would say. . .they really don't understand how to use it, it doesn't become a useful tool. It becomes more of a pain in the rear than anything."
M42: "People don't really like using them at all."
M44: "Some people are afraid generally of computers and don't know how they work sometimes so they mess up."

Many of the negative perceptions were related to the technology aspect of the calculator-not knowing which buttons to push when. It was intriguing to the researcher that many of the males on this question were much more careful and thorough in their responses than the females.

When questioned about parent attitudes, quite a few of the students either felt that their parents did not care one way or another about it, or had never really seen them use it. Some of the negative comments had to do with the cost or how confusing it was to use. One female stated that her father could not even get it to add. On the other hand, the father of M44 "liked it so well he went out and bought one for himself." One mother had stated that she wished that "she would have had one of these when she was in school."

One attitude that seemed to appear over and over could be classified in many ways to what Dunham (1991) referred to as a form of "algebraic guilt". Students feeling like they are too dependent on the calculator, and thus not really learning what they are supposed to be learning, or even forgetting the basic skills. Ten students named this as the leading drawback of using graphing calculators, in one form or another, and it was evenly divided between males and females and high and low spatial abilities. Some of the responses which give evidence to the "algebraic guilt" are given below.

F17: "Yeah. . .like you lose your multiplication skills."
F97: "Maybe just because it doesn't make you think as much. You just type it into the calculator and expect for it to give you the answer."
F122: "Yes, sometimes you don't really learn anything. You just put it into your graphing calculator and let it do the work."
M2: "You might become too dependent on it and like if I wouldn't be able to buy one of my own in the future and I might be stuck and not understand how to do something on my own."
M29: "I'm comfortable with it. I like it...I mean...a lot of things that I couldn't do algebraically on paper I can do on there. It's almost a lazy type of thing."

Some of the negatives were related to how to set the range, remembering to change the mode, and other technological details. Six students cited these types of negatives, and of these 6, 4 were females and 2 were males, and all were of low spatial ability.

F49: "Not knowing all of the functions that it has and how to use them. . in the beginning it was difficult learning how to use it."
F52: "If you don't really understand how to use it, it's easier to know how to figure it out on your own."
F102: "When you try to graph something and it doesn't show up on your screen and you have to fool around and try to get the range. It is very frustrating."

A majority of the responses indicated that graphing calculators have more of a positive impact on the students' confidence and attitudes than negative.

F96: "It makes me more comfortable, and it gives me the extra added incentive, just to be able to say. . .'Hey. . .I can do this!"

M29: "It's like a security blanket. It makes me feel better about my work, and not that I can't do it without it, but I like to use it."

These statements seemed to indicate that using graphing calculators in the classroom, if students are properly trained in their use, can go a long way in helping reduce math anxiety. On the other hand, if students are not taught how to use them properly it could increase anxiety.

Graphing calculator use and mathematics achievement.

Another piece to the model of variables at work in a mathematics classroom which are being considered for this study is the relationship between graphing calculator use and mathematics achievement. The quantitative portion of the study examined the relationship between the students' grades in their last mathematics class taken and their confidence with graphing calculator score. Significant correlations were found for the total group (ρ=.23, p<.01) and for the males (ρ=0.37, p<.01). The correlation for the females was not significant. In the analysis of the interviews, the researcher was especially looking for insights into the students perceptions of how graphing calculator use affected their mathematics achievement, and if there were differences in these perceptions according to gender.

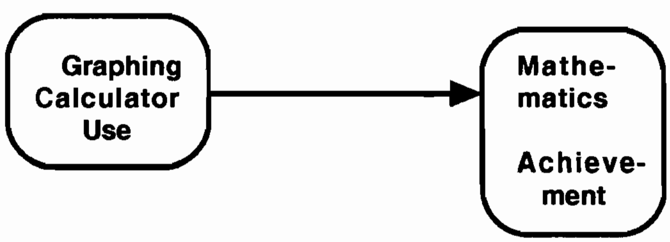


Figure 17: Graphing Calculator Use and Mathematics Achievement

When asked if they felt the use of graphing calculators in their classroom had made a difference in the grade they were going to receive in mathematics, only 8 out of 25 students felt that there would be no difference in their grade, and of these, 6 out of the 8 were males. The majority of the students, especially females, felt that using a graphing calculator had positively affected their grade. Some students felt that their grade was *a lot* better because they were able to use a graphing calculator, and some felt that it just raised their grade a small amount.

> F14: "If I can't use my calculator then I get really nervous because I don't think the answer is right, so I have to go back and check it."
> F17: "Yeah. . .it raises it. If I had to do math without my calculator I would be lost."

A vast majority of the students interviewed (21 out of 25) stated that they felt they approached math problems differently when they were allow to use a graphing calculator. Of the 4 students who did *not* feel this way, 3 were females and all were of low spatial visual ability. Many of the students who responded affirmatively could not think of any specific examples to back up their answer, it was just how they felt. Several students mentioned the advantage of being able to guess, or use trial and error.

The quantitative data indicated a link between achievement and confidence-with-calculator. The interviews show that the majority of these students feel that graphing calculator use improved their grade in mathematics.

Summary

Following are some of the important findings from the qualitative portion of this study.

—The majority of the students interviewed regarded the graphing calculator in a positive light. Some of the students described the positive aspects in visual terms, especially students with low spatial ability.

—Almost all of the negative comments about graphing calculator use came from students with low spatial and visual skills.

—Females made negative comments more than males in a ratio of 2 to 1.

—"Algebraic guilt" was the biggest drawback mentioned, followed closely by technology features.

—The females were much more uncomfortable with the technological aspects of the graphing calculator (6 out of 12) than the males (1 out of 13).

—Highly spatial visual males were more profuse in their answers concerning graphing calculator use than any other category.

—3 out of 4 students who felt that graphing calculators did *not* change the way they approached mathematics problems were females.

—Females and low spatial skill students were less likely to want to change to a different type of graphing calculator than they were currently using.

—A majority of the students liked math better when graphing calculators were used–3 out of 4 who did not were low spatial visual, 3 out of 4 who did not were female.

—Females with low spatial skill exhibited more negative attitudes than males of low spatial skill.

—16 out of 25 students noticed significant gender differences in attitudes and use of graphing calculators in the classroom.

—7 out of 10 students choosing graphing (visual) as the feature used the most often were low in spatial skill and visualization.

These findings support and strengthen conclusions drawn from the quantitative data.

When asked what advice they would give to a teacher who is just starting to teach a class using graphing calculators, the answers reflected some of the concerns that had been expressed in other areas of the interviews. One of the big things mentioned was that the teacher should take plenty of time to make sure that the students are familiar with the calculator. This was from males and females, high and low spatial ability alike.

F14: "Well, don't assume that your students know anything about the calculators, because they probably don't. And it's pretty confusing . . .at least it was for me anyway and you have to go really slow. Take it one step at a time so that they can get it."

M5: "Well, I'd ask for them to be sure and take the time for all the students to know where all of the buttons are and how to do things. Sometimes they go too fast and they think that you know how to do things that you don't and then when it comes time to do homework you don't know which buttons to push."

M27: "I'd tell them to take their time with it and be sure and explain all of the functions very carefully. Never take for granted that they know how to use it."

M29: "Just the more you use it, and the more familiar that the students become with it, then I think it helps them. . .Graphing calculators aren't for everybody, some people just don't like it. They are not used to using computers, just like my parents. They're not computer people."

Some of the most commonly given suggestions were to go slow, use visual aids such as the overhead calculator and a large poster at the front of the room of the calculator keys, and never assume that they understand. This comment by a low spatial ability, low confidence female was really a promotion for starting the use of graphing calculators early in the student's education.

F52: "I would start out right away with it. I wouldn't. . .I don't know. . . I wish they had started us out a long time ago, kind of like they do with foreign languages. . .I wish they had started us on a complicated computer or a complicated calculator before, so we could *really* learn it."

What a message to mathematics teachers from the heart of a student who struggles with spatial skills and confidence in the mathematics classroom. If only more mathematics teachers could really hear what these students are saying and respond accordingly. What kind of a difference would that make in the confidence and abilities of our mathematics students today? Are graphing calculators a key to helping increase student confidence and decrease anxiety, especially students of low spatial and visual abilities? These responses seem to indicate that if a teacher is very patient and careful in helping students understand the mechanics of operating a graphing calculator, and in explaining how they are helpful, it can be one of the keys to more success in the mathematics classroom.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

The results of this study indicate that graphing calculator use in these high school precalculus classrooms increased confidence levels significantly. Gender differences occurred in some scores, and there were differences according to whether the items were algebraically or graphically presented. There were significant differences in the spatial skills and visualization scores of the males and females in the study. Positive linear correlations were found between some of the variables, and part of these were affected by gender. The majority of the students interviewed felt positive about their overall experiences with graphing calculators in the classroom, however some differences according to spatial skill and gender were noted. This chapter summarizes the differences and examines the implications of the findings for mathematics instruction, assessment, and teacher education programs. Recommendations for curricular and instructional changes are given. The chapter concludes with suggestions for future research on mathematical confidence, spatial and visualization skills, with attention given to gender.

Discussion of the Results

Chapter IV reported results from the quantitative portion of the study. In Chapter V, qualitative findings were discussed in depth. In this section, both the quantitative and qualitative results will be combined to answer the questions from Chapter I which guided this study.

1) *How are gender and spatial skills related to confidence and attitudes toward graphing calculator use in a high school precalculus classroom?*

Male confidence score means were greater than female confidence score means for total confidence-with-graphing-calculator and on the algebraic and graphical subscores. There were significant gender differences favoring the males on confidence-with-graphing-calculator scores and the graphical subscore with graphing calculator. Significant positive linear correlations existed between confidence-with-graphing-calculator and spatial skill [+0.19] and confidence-with-graphing-calculator and visualization [+0.23]. The amount and significance of the correlations were due in a large part to the males. The correlations between graphical items and visualization were higher than correlations between graphical items and spatial skills, seeming to indicate that visualization is more closely related to graphing calculator use than spatial skill.

A majority of the students in the interviewed sample felt positive overall about graphing calculator use in the high school precalculus classroom. There were some differences according to spatial visualization skill and gender. Females made more negative comments overall about graphing calculator use by a ratio of more than 2 to 1. Almost all of the negative comments came from students with low spatial and visual abilities. Approximately half of the interviewed sample noticed negative feelings and attitudes in classmates about graphing calculator use, and of these 70% were males and 70% were low in spatial and visual skills. Males seemed to be much more aware of differences in attitudes according to gender. Males seemed to experiment, program and play around more with their graphing calculators, according to male and female observations. Seven out of 10 students choosing graphing as the feature used most often were students with low spatial and visual abilities. More females than males, in a ratio of 2 to 1, expressed negative feelings in regards to the technological aspects of the graphing calculator.

2) *Because successful use of graphing calculators depends on interpretation of highly visual information, will students with poor spatial visual skills have less confidence in their abilities in using graphing calculators and thus be at a disadvantage in a classroom where they are used? Will this occur more often with females who may have poor spatial visualization skills?*

A significant positive linear correlation [+0.19] existed between confidence-with-graphing-calculator and spatial skill for the total group of 134 students. A significant positive linear correlation [+0.23] also existed between confidence-with-graphing-calculator and visualization for the total group. The correlation for males between confidence-with-calculator and visualization was also positive and significant [+0.27] at the 95% level. In both correlation coefficients for the total group, the correlation was due in a large part to the male scores. This seems to indicate that visualization is a significant factor in confidence-with-graphing-calculator use, especially for males. Correlations between graphical items and visualization were higher than correlations between graphical items and spatial skills. Rank correlations between confidence-with-graphing-calculator and grade were positive and significant ($p<.01$) for the total group [+0.23] and for males [+0.37]. This seems to indicate that visualization is more closely related to confidence levels and thus also to grades or classroom success, for males than for females.

It is also important to note that there were significant differences in confidence-with-graphing-calculator scores favoring males, as well as significant differences in spatial and visualization scores favoring males. This does seem to give some support to the idea that females may have a disadvantage in a classroom where graphing calculators are used.

Interviews did reveal a lack of confidence in the ability to use graphing calculators from many students with low spatial visual skills. This did occur more often with females than males. Students with low spatial and visualization skills made negative comments more often than students with high spatial and visual skills. The one student who said that she would definitely NOT use graphing calculators in her classroom if she were a mathematics teacher was a female of low spatial visual ability.

3) *If there is a lack of confidence in the use of graphing calculators, will this carry over into a negative attitude toward mathematics, and as a result lower achievement in mathematics?*

There is a significant and positive linear correlation between a student's grade in their last mathematics class and their confidence-with-graphing-calculator score, especially for males. This does not however indicate a cause, only a relationship.

Fourteen out of 25 students interviewed expressed positive changes in their attitudes toward mathematics due to graphing calculator use. This represented a mix of gender, high and low spatial visual abilities, as well as high and low confidence levels. Students with low confidence scores made more negative comments overall than students with higher confidence scores. Of the 8 students who did not feel that graphing calculator use had affected their grade positively, 6 were low confidence students. This data does seem to indicate that a lack of confidence in graphing calculator use can carry over into a negative attitude toward mathematics.

4) When we recommend the use of graphing calculators in the classroom, are we encouraging a practice that will be to the detriment of students with poor spatial skills, especially females?

This could be true for some students with poor spatial skills, but not all. Student responses to interviews seem to indicate that graphing calculator use in the classroom can still be a positive factor for some students with poor spatial skills, however other students seem to be more negatively affected. Responses to interview questions seem to suggest that females with low spatial visual skills are more often negatively affected than males. This is not true for all females with low spatial abilities.

Quantitative data seemed to suggest that spatial and visualization skill are not as closely correlated with confidence-with-graphing-calculator use for females as for males. This could imply that females have learned to do other things to compensate for this spatial deficit. It is significant to note that more students made positive comments overall about graphing calculator use in the classroom, and that many of the negative comments had to do with the technological aspects of the graphing calculator, not the visual aspects.

Implications and Recommendations

What implications do the findings of this study have for the teaching and learning of mathematics? It is clear that the availability of graphing calculators on a quiz increased the students' confidence levels significantly. This was true even though none of the problems on the quiz could be directly worked out using graphing calculators. Even the graphical items were carefully stated in literal terms so that students could not just punch equations into their calculator and obtain a result. Overall confidence means increased over 6 points out of 60 possible, for the total group. What is possibly even more significant is the fact that with the availability of the graphing calculator, female confidence on graphical items was equal to their confidence on algebraic items, as opposed to higher confidence levels on algebraic items without graphing calculator available. Since past research has revealed a significant link between confidence and mathematical achievement, this seems to indicate that graphing calculator use can have a positive effect in the high school precalculus classroom.

Teachers need to be aware that there is a possible positive correlation between visualization and confidence-with-graphing-calculator use, and take measures accordingly. Research will only have an impact on the practice of teaching if it leads to the production of appropriate methods which can be adapted to the everyday classroom (Howson & Wilson, 1986). Changes need to be made that will make graphing technology more palatable for students, especially females of low spatial ability. Technology is definitely here to stay, and the answer is not to discontinue its use in the classroom. Teaching students to use technology in problem solving is vital in preparing them for the 21st century. What then is the answer?

The first step is acknowledgment of the problem. Many people feel that gender inequities in mathematics education are insignificant or nonexistent. Major professional organizations such as NCTM and MAA will need to educate their membership through articles in professional journals, magazines, and newsletters. Workshops and talk sessions at conferences, and even on-line discussion groups could be useful in disseminating the information. These organizations need to develop policy which will address this important issue. If the NCTM, MAA, and other such organizations do not acknowledge the problem and promote solutions, it will be next to impossible to facilitate change at a global level.

Implications for the classroom teacher. Policy, however, is not all that needs to change. What is really crucial is change in individual mathematics classrooms. What are some specific strategies the individual classroom teacher can employ to break down the barriers that exist in successful implementation of graphing calculator technology with students of low spatial ability?

When first introducing the graphing calculator, the teacher should proceed slowly, explaining each step with great care. Never assume that the students understand how to use a certain feature of the calculator. These bits of advice were offered almost unanimously by students interviewed for this study.

During this time, the teacher should be especially alert for signs of poor spatial ability or lack of confidence, possibly hesitancy in using the graphing calculator. It is especially important to recognize these signs in females, for whom this might be more of a problem than males (Fennema & Tartre, 1985).

Sometimes all that will be required will be a little one-on-one attention and instruction, in order to help the student become more comfortable with the technology. Another possibility would be to team the student who is unsure with a student who has used the technology for some time, is knowledgeable in its use, and is willing to help. Use of encouragement and positive reinforcement during this time will be very valuable in relieving a student's fears and will help the student build confidence in the ability to use the graphing calculator.

An alternative approach for introduction of the graphing calculator into the classroom is to allow the students to work in groups exploring and experimenting with the properties of graphs. This may not be worthwhile unless guidance, feedback, and eventually a synthesis of important results is built into the process (Zimmerman, 1991). This method would be compatible with Wheatley and Cobb's (1990) theory that students give meaning and structure to spatial patterns based on their experiences, conceptual structures, and ongoing social interactions. It is the classroom teacher's responsibility to provide the atmosphere and activities conducive to this type of interaction.

It is very important for a teacher to realize that "vision is not visualization; to see is not necessarily to understand" (Zimmerman & Cunningham, 1991, p. 4). Because a student sees the graphical representation, it does not necessarily indicate they comprehend what it means. According to Zimmerman and Cunningham in *Visualization in teaching and learning mathematics* (1991), visualization is superior to vision because it implies understanding. The graphical image on the calculator screen needs to be specifically linked with the algebraic and numerical representations students are already familiar with. This is especially important with females for whom the algebraic methods are usually a strength. The teacher should not assume that a student can make these links on their own. Perhaps the most important issue in the use of visualization in mathematics education is how visual and symbolic learning complement each other (Cunningham, 1991). The mathematics educator needs to be aware of this and carefully integrate the two representations in the classroom.

Although there are many benefits to visualizing mathematical concepts, many students and even teachers prefer to use algorithmic techniques over visual thinking (Eisenberg & Dreyfus, 1991; Mundy, 1987; Vinner, 1989). This is especially true for females. For teachers, this method of teaching based on visualization and technology requires relearning many pedagogical skills. It is not enough in this technological age to understand mathematics. "We must also understand how to communicate our mathematics visually" (Cunningham, 1991, p. 74).

To be effective in this arena, teachers must devote time to explicit discussion of how to interpret figures and diagrams (Zimmerman, 1991). If the teacher is careful and thorough in preparation, students might "develop insight and understanding of functions through the study of their graphs, but the intuition and knowledge required does not come automatically. It must be learned" (p. 128).

This is vitally important, as graphical images are links between mathematical models and the real world they represent. Students must learn to recognize that a diagram or graph may contain the information needed for the solution of a problem. It is not enough to know *how* to graph. Students need to know how to understand and interpret the graphs they see. According to Cunningham (1991) "adding visualization to mathematics education promotes intuition and understanding" (p. 70). Hopefully, students will not only learn mathematics, they will learn new ways to think about and do mathematics. Teachers will know that they have helped students achieve a higher cognitive level, when in response to a given question they reply, " Let's look at the graph first."

Cunningham (1991) has offered specific guidelines for teachers wishing to incorporate more visualization into their classrooms. First, determine exactly what the critical mathematical details are and highlight them, while removing any conflicting information. Next, present the material in a logical and connected sequence. Make connections with prior experiences and knowledge so that students will develop stronger conceptual understanding during the process (Shoaf-Grubbs, 1994). Offer students options without overwhelming or confusing them, and give them appropriate opportunities to explore. Through all of this, consider carefully how students learn visually (Cunningham, 1991, p. 4).

To facilitate successful implementation of the graphing calculator into the classroom, the mathematics educator should be sure that students understand that algebra and geometry are alternative languages for expressing mathematical ideas (Zimmerman, 1991). Zimmerman suggests that students need to know the rules and conventions associated with graphing and be taught how to obtain specific information from graphs and diagrams. Many students can see the graph, or even reproduce it manually, but cannot analyze it in relationship to certain problems or important characteristics. This can be accomplished through guided practice and group exploration.

Even with careful implementation of the suggestions already given, some students with poor spatial abilities may still not be able to understand and interpret graphing calculator information. We know that spatial understandings are necessary in order to interpret, understand and appreciate the geometric world in which we live (NCTM, 1989), and that "spatial thinking is essential to scientific thought" (Clements & Battista, 1992). What is the next step in trying to overcome the barrier of poor spatial skills in helping students obtain spatial understandings?

Spatial training. The literature on spatial skills contains a ray of hope for teachers searching for ways to help students with low spatial abilities. Studies have indicated that spatial ability can be improved through training (Battista, Wheatley, & Talsma, 1982; Ben-Chaim, Lappan, & Houang, 1988; Bishop, 1980; Shoaf-Grubbs, 1994; Vasquez, 1990).

Connor, Serbin, & Schackman (1977) conducted a study with 133 children in grades 1, 3, and 5. The participants were divided into three groups according to treatment. One group received spatial training using overlays. A second group received training using flat figures, and a third group received no spatial training. On a spatial test on which male superiority has been documented as early as age seven, females in the overlay group scored significantly higher than the flat figure group. The control group of females performed the worst. The mean scores of the males in the three groups did not differ significantly. What is especially important in consideration of the question at hand is that in the control group, without spatial training, the males scored higher than the females. This difference was reduced somewhat in the flat figures group, but males still performed better than females. Males and females in the flat figure group did somewhat better than students in the control group. In the overlay group the females scored higher than the males. These results seemed to indicate that female spatial skills were more affected by training than males. The researchers felt that the types of experiences boys had in manipulating their environment may have developed their spatial ability closer to its full potential before the experimental situation.

In a study examining the influence of a one hour unobtrusive training session on sex differences in spatial test scores, McGee (1978) found that both males and females in an undergraduate psychology course improved after practice. Males scored significantly higher than females in both pre- and posttests. In this study, there was only one hour of the treatment, and three weeks between the tests.

Luchins, Rogers, and Voytuk (1983) found that specially designed computer graphics modules increased the spatial skills of high school girls to a level significantly beyond that of boys.

A study by Lord (1985) looked at the spatial skills of 84 college undergraduates in a biology course. For fourteen weeks the experimental group had 30 minutes of spatial activities once a week. These exercises required the students to mentally bisect three-dimensional geometric figures and to visualize the shape of the two-dimensional figure formed by the bisection. The students then drew this figure on a piece of paper. On the posttest, results indicated that the spatial skills did improve in the experimental group.

Ben-Chaim, Lappan, and Houang (1988) found sex differences before and after instruction. Boys and girls responded similarly and positively to the instructional program with significant gains in spatial skills.

Especially relevant to the this study are studies by Vasquez (1991) and Shoaf-Grubbs (1994). Vasquez studied 57 students in two 8th grade prealgebra classes. Students in the graphing calculator group exhibited significant gains in spatial visualization skills and in attitudes toward graphing calculators. There were no important gender differences. Shoaf-Grubbs in a study of college women also found that students in the graphing calculator section made significant gains in spatial skills.

What does this mean for the classroom teacher? Research seems to indicate that the spatial skills of many students, especially females, can be improved with the use of a few simple training exercises. With careful planning, a teacher can unobtrusively incorporate some of these exercises into classroom activities a couple of times a week or more. This would be a good beginning of the period activity while the teacher takes care of daily housekeeping chores. Sample activities can be found in many mathematics books and journal articles (Izard, 1990; Lappan, Phillips, & Winter, 1984; Moses, 1990; Owens, 1990). These activities could take a minimum amount of time and yet initiate changes in students' spatial abilities that will positively affect them for years to come, not only in terms of graphing calculator use, but in many other ways as well.

"If present trends are any indication, it seems that mathematics education will evolve in a direction which will make visualization even more important in the future than it is now" (Zimmerman & Cunningham, 1991). What can be more exciting than preparing students to face the future with confidence and equipped with the skills needed to succeed?

Implications for assessment. With the integration of more visualization into mathematics education, serious considerations must be given to assessment. The traditional types of assessment used in mathematics education are not always appropriate in this new domain. As one author so fittingly has said,

> One of the more difficult problems in adding visualization techniques to mathematics education is that we do not yet know how to evaluate this kind of learning. Visualization offers intuition, understanding, and concept formation, which other disciplines evaluate by term papers and essay tests, hardly the kind of examination mathematics students are familiar with (Cunningham, 1991, p. 74).

Educators must use care in the type of assessments chosen. Using the methods mentioned by Cunningham- term papers and essay tests -could be beneficial to females who have been shown to excel in verbal tasks. At the same time, this type of assessment could be detrimental to males. On the other hand, assessment tools requiring the interpretation of highly visual information could be harmful to females and benefit males. A good instrument will incorporate a balance of question types, so that females and males have equal opportunity to succeed.

Current literature contains many examples and suggestions of alternative assessment techniques. Teachers should carefully consider a variety of methods, and choose the ones that are most appropriate and fair for the particular situation. Assessment tools in classes where graphing calculators are used should contain both graphing calculator and non-graphing calculator items, as well as visual and symbolic items.

Implications for teacher education programs. It is vitally important that teacher education programs understand the significance of spatial skills and their relationship to gender issues and technology, as well as mathematics achievement. Preservice teachers of mathematics need to be made aware of the important variables at work in the classroom. The first step in teacher education is to alert the students to possible problems in these areas.

In education of preservice teachers K-12, the crucial importance of motor activities, wise use of manipulatives, and other spatial activities in the building of spatial skills needs to be stressed. Students should be taught about the possible connection of spatial ability to mathematics achievement. Preservice teachers should leave teacher education programs with a repertoire of classroom activities to use in this important area of mathematics education.

Not only should students in these programs be made aware of the problems and possible aids, the activities and methods should be modeled in education classrooms. As one old proverb states, "Nothing is in the mind which is not first in the senses" (Davis, 1989, p. 152). If these preservice teachers are to comprehend the usefulness and significance of this type of activity, they need to experience it themselves.

Studies have shown a correlation between students' participation in spatial activities and their measured spatial ability. Motor activity and full body movement are also important in developing spatial skills (Musick, 1978; Newcombe, 1983). Boys often more naturally gravitate to this type of activity. If elementary preservice teachers are made aware of this, they could encourage and promote more female participation in these types of activities.

There has been evidence that performance on spatial tasks increases with grade level, and some feel that the 7th grade could be an optimal time for spatial visualization training (Ben-Chaim, Lappan, & Houang, 1988). However, this type of training has been shown to be effective at many different age levels and should be encouraged at all grades. Teacher education programs should stress this fact, and promote use of spatial training in the classroom at all levels.

Mitchelmore (1980) found that British students were ahead of students in the United States in spatial ability by about three years. He attributed this partly to the greater use of manipulatives at the elementary level and more diagrams at the higher levels. Bishop (1980) found that students taught in schools where manipulatives were used a lot, performed better on spatial skill tests than students from schools where manipulatives were lacking.

Teacher education programs need to emphasize even more, that use of manipulatives in grades K-12 could be important in building students' spatial abilities, and thus are important in promoting mathematics achievement. Again, it is important that this not only be stated, but modeled. Preservice teachers need to be taught how to use manipulatives correctly, for many of them will not have experienced the use of manipulatives in their own K-12 education. It is important to instill in potential teachers, that the use of manipulatives is not sufficient alone. Similar to teaching the use of the graphing calculator, students must be guided to reflect on the use of manipulatives and to relate the manipulative models to symbolic and numerical representations (Raphael & Wahlstrom, 1989). These connections must be clearly and logically made.

The most promising agenda for change, must include this type of reform in teacher education, if it is to be successful.

Conclusion and Suggestions for Further Research

This study has investigated the impact of graphing calculator use on a student's confidence. Links between spatial skill and visualization with a student's confidence in using graphing calculators was also examined. Correlations between confidence level and grade in the last mathematics class, as well as possible gender differences in all of these areas were studied. Interviews were conducted to obtain more in-depth understanding of the students' attitudes and feelings about graphing calculator use in the classroom. Possible areas of further research could include;

—a more in-depth look at how students in a mathematics class lower than the precalculus level might compare on the same questions that were proposed in this study. These students were in their third or fourth year of advanced mathematics, so some students with lower spatial visual skills and lower confidence may have already self-selected out of the mathematics program before precalculus so the results with a lower level class may be different.

—Comparison of classes where a teacher uses spatial exercises at the beginning of the class period over a period of time and a class where these exercises are not used, for possible differences in confidence, spatial and visual skills, and achievement.

—A longitudinal study following a class of students for three or four years of graphing calculator use monitoring changes in confidence levels, spatial skills, and achievement at various stages, especially taking note of any gender differences.

—In depth observations in classrooms with teachers using different methods to introduce graphing calculators into the classroom looking for possible insight into which methods are most effective in reducing algebraic guilt, fear of technology, and lack of confidence. Does the gender of the teacher have any effect?

—A study where students' confidence and spatial visual skills are tested at the beginning of a term, along with interviews of those same students to determine attitudes and feelings toward graphing calculator use. Then conduct intervention strategies, possibly ones mentioned in this chapter, with the students testing low in any of these areas followed by post tests after a period of time to see if there are any significant changes in confidence, spatial visual ability or attitudes.

Consideration of the literature concerning spatial skills and gender, seems to point to a possible inequity involving females, in requiring the use of graphing calculator technology in the mathematics classroom. Yet, in an era when we are trying to promote greater female participation in the field of mathematics, the answer is *NOT* to throw the graphing calculator out the window. Technology is an important part of our everyday lives that is here to stay. If we are to educate females in such a way that they are ready to take their rightful place in the competitive, professional world, we must adapt measures that will help overcome the problem that low spatial ability can pose. This study has attempted to address this issue, and suggest possible solutions. Change is not easy. It takes commitment and effort on the part of everyone, but I firmly believe the effort will be worthwhile.

APPENDIX A

Confidence Quiz

Name:_______________________

Confidence Survey

Directions: This is a math test in which NO PROBLEMS ARE TO BE SOLVED. Suppose that you were asked the following multiple choice questions. Indicate in the first column on the right how CONFIDENT you are that you could give the correct answer if you were NOT permitted to use a graphing calculator on the test. In the second column indicate how CONFIDENT you are that you could give the correct answer if you WERE PERMITTED to use a graphing calculator.

Do not spend much time thinking about the problem- about 5-10 seconds per problem should be plenty. DO NOT SOLVE THE PROBLEMS.

EXAMPLE: Look at the problem below for a few seconds. DO NOT SOLVE THE PROBLEM.

1. What is the range of the function $f(x)= x^2 + 2$?

   A. $y \leq 2$
   B. $y \geq 0$
   C. $y < 2$
   D. $y \geq 2$
   E. $y > 2$

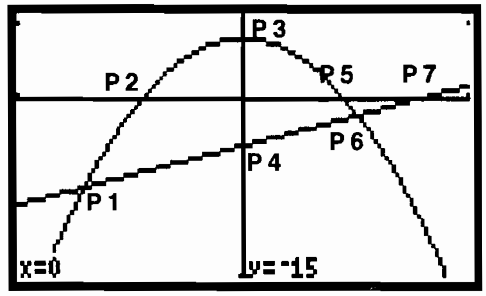
WITHOUT Calculator		WITH Calculator
1.	no confidence at all	1.
2.	very little confidence	2.
3.	some confidence	3.
4.	much confidence	4.
5.	complete confidence	5.

If you are completely confident that you could solve the problem correctly without and with a graphing calculator, circle a 5 in both columns. If you have some confidence that you could solve it without a calculator and much confidence that you could solve it correctly with a calculator, circle a 3 in the left column and a 4 in the right column. If you feel fairly confident that you could solve the problem correctly without a calculator, but not confident at all about solving it with a graphing calculator, circle a 4 in the left column and a 1 or 2 in the right column.

1. The equation of the two graphs in the picture at the right are

$$y = x - 3$$
$$y = 5 - x^2.$$

What is the solution of the system of equations?



A. P3, P4 and P5
B. P1 and P6
C. P2 and P7
D. P3 and P5
E. P4 and P6

WITHOUT Calculator		WITH Calculator
1.	no confidence at all	1.
2.	very little confidence	2.
3.	some confidence	3.
4.	much confidence	4.
5.	complete confidence	5.

2. Let $f(x) = \dfrac{1}{x+5}$. Compute $f(\dfrac{1}{p})$.

A. $\dfrac{1}{p} + \dfrac{1}{5}$

B. $\dfrac{p}{1+5p}$

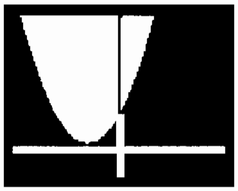
C. $\dfrac{1+5p}{p}$

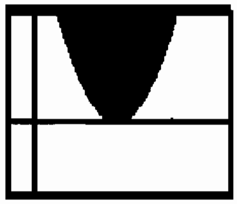
D. $\dfrac{1}{5+p}$

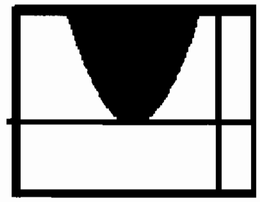
E. $\dfrac{p}{p+5}$

WITHOUT Calculator		WITH Calculator
1.	no confidence at all	1.
2.	very little confidence	2.
3.	some confidence	3.
4.	much confidence	4.
5.	complete confidence	5.

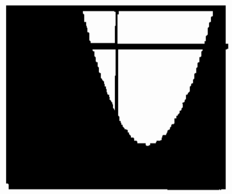
3. Which of the following graphs best represents the solution to $y \leq (x-a)^2$ for $a>0$?

A. 

B. 

C. 

D. 

E. 

WITHOUT Calculator		WITH Calculator
1.	no confidence at all	1.
2.	very little confidence	2.
3.	some confidence	3.
4.	much confidence	4.
5.	complete confidence	5.

4. The functions f and g are defined by $f(x)= x+4$ and $g(x)= \dfrac{x-6}{5}$.
Find the composite function $f[g(x)]$.

A. $\dfrac{x-2}{5}$

B. $\dfrac{x+14}{5}$

C. $\dfrac{x^2-2x-24}{5}$

D. $\dfrac{6x+14}{5}$

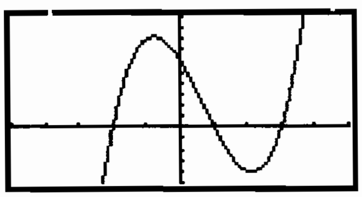
E. $\dfrac{(x+4)(x-6)}{5}$

WITHOUT Calculator		WITH Calculator
1.	no confidence at all	1.
2.	very little confidence	2.
3.	some confidence	3.
4.	much confidence	4.
5.	complete confidence	5.

5. Given the graph below, which of the following - (x-1), (x+1), (x-2), (x+2), (x-3), (x+3), (x -6), (x+6)- could be factors of $x^3 - 2x^2 - 5x + 6 = 0$? [Each mark represents 1 unit]

A. (x+6), (x-1), (x+2)
B. (x-2), (x+1), (x+3)
C. (x+2), (x-1), (x-3)
D. (x-6), (x+3), (x-1)
E. (x-2), (x-1), (x-3)

WITHOUT Calculator		WITH Calculator
1.	no confidence at all	1.
2.	very little confidence	2.
3.	some confidence	3.
4.	much confidence	4.
5.	complete confidence	5.

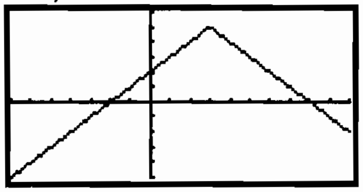


6. If $f(x) = 2x^2 - x + 1$, what is $f(x+h)$?

A. $2x^2 + 2h^2 - x + h + 1$
B. $2x^2 - x + 1 + h$
C. $2x^2 + 4xh + 2h^2 - x - h + 1$
D. $2x^2 + 2h^2 - x - h + 1$
E. $2x^2 + h - x + h + 1$

WITHOUT Calculator		WITH Calculator
1.	no confidence at all	1.
2.	very little confidence	2.
3.	some confidence	3.
4.	much confidence	4.
5.	complete confidence	5.

7. The figure below shows a complete graph of $y=g(x)$. If each mark equals one unit, find the solution to the equation $g(x)= -2$.



A. -2 B. -4 C. 8

D. 0 E. -7

WITHOUT Calculator		WITH Calculator
1.	no confidence at all	1.
2.	very little confidence	2.
3.	some confidence	3.
4.	much confidence	4.
5.	complete confidence	5.

8. Which of the following terms best describes the graph of the following equation $4x^2 - 16y^2 = 64$?

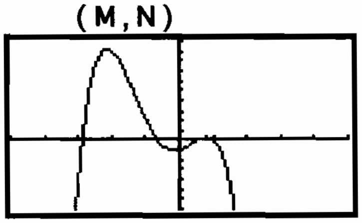
A. Hyperbola
B. Circle
C. Ellipse
D. Parabola
E. Square

WITHOUT Calculator		WITH Calculator
1.	no confidence at all	1.
2.	very little confidence	2.
3.	some confidence	3.
4.	much confidence	4.
5.	complete confidence	5.

9. What kind of slope does the line tangent to the curve at the point (M,N) have in the graph of $y=f(x)$ below?

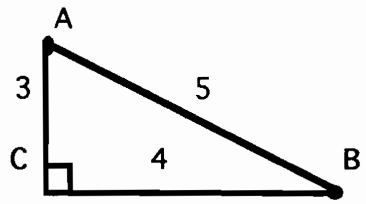
A. Undefined slope
B. Negative slope
C. Positive slope
D. Zero slope
E. None of the above

(M,N)



WITHOUT Calculator		WITH Calculator
1.	no confidence at all	1.
2.	very little confidence	2.
3.	some confidence	3.
4.	much confidence	4.
5.	complete confidence	5.

10. In the figure below what is the sine of angle A?



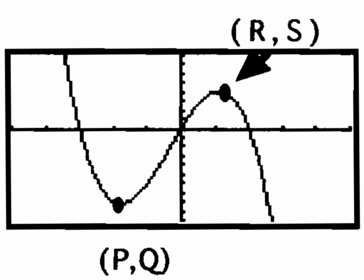
A. 4/3 B. 3/4 C. 3/5

D. 4/5 E. 5/4

WITHOUT Calculator		WITH Calculator
1.	no confidence at all	1.
2.	very little confidence	2.
3.	some confidence	3.
4.	much confidence	4.
5.	complete confidence	5.

11. The complete graph of y=q(x) is given below. For what values of x is q decreasing?

A. x<Q and x>S
B. P < x < R
C. x < P and x > R
D. Q < x < S
E. All real values of x



WITHOUT Calculator		WITH Calculator
1.	no confidence at all	1.
2.	very little confidence	2.
3.	some confidence	3.
4.	much confidence	4.
5.	complete confidence	5.

12. Find (3 + 7i)(2 - 4i).

A. 34 + 2i
B. 6 - 28i
C. 34 - 2i
D. 6 + 28i
E. -22 + 2i

WITHOUT Calculator		WITH Calculator
1.	no confidence at all	1.
2.	very little confidence	2.
3.	some confidence	3.
4.	much confidence	4.
5.	complete confidence	5.

Please circle the best answer for each of the following questions. Please do not leave any questions blank.

13. How long have you used a graphing calculator?

    A. Less than a year
    B. About 1 year or a little more
    C. About 2 years
    D. 3 years or more

14. How often do you use your graphing calculator?

    A. Only in mathematics class
    B. I use it in math class and when I do my homework
    C. I use it fairly often
    D. I use it all of the time

15. How do you feel about using your graphing calculator?

    A. I use it only because it is required
    B. I like to use it because it helps make things easier
    C. I like using it and enjoy showing others how to use it
    D. I love using it and enjoy exploring and learning new ways to use it

16. What kind of graphing calculator do you use?

    A. TI-81 (Blue)
    B. TI-82 (Gray)
    C. TI-85 (Black)
    D. Another type of graphing calculator ________________(type)

17. What is your classification in school?

    A. Freshman
    B. Sophomore
    C. Junior
    D. Senior

18. Whose graphing calculator do you use?

    A. I borrow a friends
    B. I use one the school provides
    C. My sibling(s) and I share a graphing calculator
    D. I use my own graphing calculator

APPENDIX B

Interview Protocol

Interview Protocol
Using Graphing Calculators in the Classroom

1. What is your favorite subject in school?....Why?

2. Do you know what you would like to be doing in 10 years?

3. What type of graphing calculator do you use?
Do you have your own calculator or do you borrow one?

4. Have you used a graphing calculator before this year?
When did you start using one?
In what classes have you used it?

5. How do you feel about using the graphing calculator?
Has it affected your attitude toward mathematics?
Now, math homework and math classes, do you like them better when you are allowed to use graphing calculators?
Are you permitted to use them on tests or not?

6. If you were planning on being a math teacher, would you plan on using graphing calculators in the classroom?

7. How does the graphing calculator help you? How do you use it?
How often do you use it?

8. What features of the graphing calculator do you use the most, overall, in all of your classes? The normal adding, subtracting, multiplying and dividing, or the graphing, or the formula function...

9. Do you approach math problems differently when you use the graphing calculator, than the way you do when you don't have the graphing calculator?

10. How do you think other students in the class feel about using graphing calculators in the classroom? Do you feel like all of them enjoy using graphing calculators, or are some of them really turned off and don't like it? What do you think?

What do your parents think about the graphing calculator?

11. Do you think there is any difference in the way the guys and the girls in your class feel about using the graphing calculator?

12. Are there any drawbacks to using the graphing calculator?

13. Do you think being able to use a graphing calculator has made a difference in the grade you are getting in this class? In what way?

14. Do you plan to take mathematics when you go to college?

15. If given a choice, when in college to take a mathematics class where graphing calculators were used and one where they were not, which one would you choose? Why?

16. Would you recommend for other mathematics students to buy a graphing calculator? Why?

17. Right now you have a ____ graphing calculator, and I know that your teacher uses a ____ a lot in class, and maybe you have seen some of your friends use ____ or other graphing calculators, if you could buy a different calculator would you do that, or stick with the one that you have?

18. What advice would you give to a teacher who is just starting to teach a class who has never used graphing calculators before and now they are going to be using graphing calculators?

APPENDIX C

Composite Transcript of Student Interviews

Composite of Interviews
Using Graphing Calculators in the Classroom
(Not all repsonses are included in this composite)

1. What is your favorite subject in school?....Why?

F12 My favorite is probably also my hardest, and that would be my AP Chemistry class.
F14 Spanish, because I like to learn different languages and expand my vocabulary and be able to communicate with different people.
F 1 7 History, because he's a really good teacher, and it's a book course.
F37 It's probably be my math classes actually. I really liked algebra. Precalculus is a lot tougher. I've always liked math, and I get the best grades in there.
F 4 9 Biology...because it is just what I like to do...I like animals and plants and everything to do with that.
F 5 1 Science..because I like experiments and stuff like that. I like Biology a lot.
F52 Probably music or art, because I'm able to use my creative skills and it doesn't take technical formulas.
F96 I'd have to say English. Especially because I'm really interested in literature and also it depends a lot on the teacher.
F 9 7 I'd probably have to say history I guess, I really don't know.
F 1 0 2 Chemistry...because it deals with things like little details and you have to think a lot about things and you cannot really see what's going on.
F 1 2 2 Probably science. Just because I enjoy science and working with animals mainly.
F127 Actually, my favorite subject is Precalculus because I have always liked math ever since eighth grade.
M2 Physics, I think is my favorite subject because I'm good at math, but I like physics because you are actually trying to find something real. I like it a lot. It is just fun.
M 5 Probably math, because I'm a very detailed person and math requires detail.
M 6 Probably Chemistry, because I like working with chemicals and stuff.
M9 Does band count? Basically because my dad is a band director, so I've spent my whole life being influenced by music, so band.
M27 Mathematics. Because I like to use a logical mind to work out problems.
M29 Definitely math class. I just like numbers and figures and working with numbers and stuff like that.
M 3 9 The sciences because they are easy for me.
M42 I'd have have to go for Spanish, because I enjoy trying to learn...just the challenge of learning to speak it.
M44 It would have to be math, because I'm really good at it and it's easier to do than some of my other subjects.
M45 Math, because I've always been somewhat good at it, and I guess there's really no actual explanation about it.

2. Do you know what you would like to be doing in 10 years?

F12 10 years from now I'll probably still be in college. I've been looking into Forensic Psychology or perhaps being a lawyer for the ACLU. I don't know, maybe something like that.
F14 Yeah, I'd like to either be a botanist or a movie producer.
F17 Yes, I'd like to be an elementary teacher.
F37 I think that I would like to be an accountant.
F49 Well, I'd really like to be making money. I just want to be happy at what I'm doing. I want to be in some kind of environmental field.
F51 Not really, I plan to go to college. Get a field having something to do with Biology and Math.
F52 No.
F96 I hope to be a psychologist.
F97 I'd like to be an elementary school teacher.
F102 I would like to either be in medical school or doing an internship.
F122 In ten years, I'll just be getting out of college-veterinary school. And I'll probably be starting up my own veterinary clinic.
F127 Yes, I'd like to be a Veterinarian.
M2 I know what I want to do. I would like to be an actor....or...I thought maybe about computer graphics for advertising.
M5 Well, I'd either like to be a math teacher, or maybe go into the journalism field.
M6 Something in the recording industry.
M9 Sure. Head up some computer science...I don't know...I'm going into computer science, so head of some business having to do with computers.
M27 Probably be a chemical engineer.
M29 In ten years I'd like to be flying around in a Harrier jet. I always thought that I would like to be a pilot but I will go to college and get an engineering degree, either electronic engineering or computer engineering.
M39 Yes, I want to be a doctor.
M42 Not exactly. I'd like a job in an office, something that I won't get bored with, something that changes.
M44 I like to go into some kind of a field having to do with Biology.
M45 Either a mathematician or neuroscience.
M64 Probably teaching elementary school.

3. What type of graphing calculator do you use?
Do you have your own calculator or do you borrow one?

F12 A T-1-81 or something like that, it is blue. I have my own now.
F17 I use a TI-81. It's the school's.
F51 Umm...I don't know...a TI-something...it's blue. It belongs to the school.
F102 A Casio 7700 something. It's my own.
M2 I have a T 1 82 or something like that. It's blue. I borrow one from the school.
M5 A Texas Instrument. A blue one. I borrow one from the school.
M6 A TI-81. I borrow one from the school.
M9 It's a Texas Instrument, whatever the numbers are, I don't know. It's blue. I borrow one from the school.
M27 A TI-81. I have my own.
M29 A Texas Instruments TI-85. I use my own that I bought with my own money.
M42 A T-1-85. I have my own.
M44 A TI-85 and it's my own.
M45 A TI-81. I use the school's.
M64 A Casio...Yes, I have my own.
M113 I have a Texas Instruments 85. It's mine.
M120 A TI-82. It's my own.

4. Have you used a graphing calculator before this year?
When did you start using one?
In what classes have you used it?

F17 No, I just started using one at the beginning of this year. I use it in math, I would use it in Chemistry, but we're not allowed because of the programs.
F52 No, I just started in September. I use it in math and biology.
F96 Yes. I started using one last year. I've used it in Algebra II and Precalculus.
F97 Yes, I started using one my sophomore year (she is now a senior). Geometry and algebra II and precalculus.
F102 Yeah, I started using one my sophomore year [currently is a senior]. Geometry, Algebra II, Precalculus, Chemistry and Physics.
F122 Yes. I started my freshman year and I'm a junior now. Math and chemistry.
F127 Yes. In the ninth grade. [She's currently a junior]. In all of my math classes; Algebra II, Geometry-well actually I didn't use it as much in Geometry-but I did use it somewhat.
M9 No. I've used it in trigonometry and analytic geometry and any other class where I need to use it.
M27 Yes. I started using one last year. I've used it in Transition Mathematics and Precalc.
M29 Yeah, we had them like our freshman year and stuff. (*He's a senior now*). We used the school's TI-81's then. I'm a senior now. I've used them in algebra and precalc, and all the math classes that I have had. And I use it in physics and chemistry too.
M42 Yes. I started using one my sophomore year (he's a junior now). Algebra II, Geometry, Chemistry, Advanced Chemistry and Advanced Math and Trig.

5. How do you feel about using the graphing calculator?

F 1 4 Well, I like it because it helps you with your answers and you don't have to think as much and take a chance at getting it wrong. But then again you have to make sure that you know how to use it...I have a terrible, terrible time getting my calculator to do the right things.
F 1 7 I like it for Trig and Analytic because it's visual.
F 3 7 It makes things a lot easier for me.
F 4 9 I don't know very many of the functions. I just know what I need to know to get through the class.
F 5 2 I feel pretty unsure about a lot of things.
F 9 6 I don't think that I could do most of the tests without it.
F 9 7 As long as it keeps it simple, I pretty much understand it.
F 1 0 2 I like it....well...sometimes I don't always know how to use it.
F 1 27 I feel comfortable with them. I'm not as talented with them as some people.
M 2 I like it because I can see everything that I've already done and stuff, and it helps me out on most of my work.
M 5 Well, I really don't use it to do my answers, I just use it to check my answers after I've done my work manually.
M 6 It makes it a lot easier.
M 9 I didn't like it at first, because I didn't understand all the buttons and stuff, but yeah, I like using it more than the regular kinds of calculators.
M 2 7 I think that it helps shorten up some of the things that might have been a little more drawn out.
M29 I'm comfortable with it. I like it...I mean...a lot of things that I couldn't do algebraically on paper I can do on there. It's almost a lazy type of thing.
M 3 9 I really like it and I think it is helpful.
M 4 2 I enjoy using it.
M 4 4 I like it a lot, it helps me to see things. I'm not very good at drawing lines sometimes and it helps me to see it.
M 4 5 It helps out a lot.
M 64 I think that it is helpful.
M 1 1 3 I like it. I like it a lot and I use it a lot. It can do a lot of stuff that I want to do.
M 1 2 0 I like it a lot.

Has it affected your attitude toward mathematics?

F 1 2 Oh definitely. I think that it made everything a whole lot easier, because I'm so terrible in math.
F 1 4 Oh yeah, yeah. I like it better because it's not so distracting and you're not so worried about having the right answer, because you have a backup.
F 3 7 No, not really.
F 4 9 Yes, I feel a lot more confident when I get an answer on the calculator.
F 5 2 It seems more confusing, sometimes. But I'm curious to learn how to use it better, because I would like to be able to use it better, like you use computers.
F 9 6 Yes. It gives me a lot more confidence.
F 9 7 I think it makes it easier.

Has it affected your attitude toward mathematics? cont...,

F 1 0 2 Yeah..well like maybe everything doesn't seem like it is so impossible.
F 1 22 Yeah, I believe it has. It's made algebra a lot easier.
F 1 27 No, I think I still would have liked math anyway, even without the calculator.
M 2 I don't think so. I can't really tell.
M 5 Well, yes it has. With it math is a lot tougher.
M 9 No, I don't think so.
M 2 7 Yeah, it takes out some of the negative things.
M29 I don't know that it has really affected my attitude. I always pretty much liked math anyway, but I think that it helps. It's a visual perception of math instead of just numbers on paper. It helps to visualize what the numbers are doing in an equation.
M 4 2 Yeah...it has...because before I was allowed to use graphing calculators, I didn't like it because it was a pain to work out all the details, but now if I get the concepts, all of the work is done. It's easier to, especially if we're doing graphs, then we can just put in the equation and graph it and see how it looks. Then we can change the equation to see how it changes the graph. It makes it a lot easier to do that.
M 4 4 Well, yes, it helps me a lot.
M 4 5 To an extent, yeah. Just, some things that you can normally not understand, it can do them for you. Just like helping you out a lot.
M 64 Uhmmmm... maybe a little bit...yes. I like it better.
M 1 1 3 No, I don't think that it really has.

Now, math homework and math classes, do you like them better when you are allowed to use graphing calculators?

F 1 4 Not exactly. It's just that some of them you have to use the calculator because they're so complex you can't possibly do them in your head.
F 1 7 Yeah..Yeah..because I would never understand it if it were not for it.
F 5 1 I think that the graphing calculator helps.
F 5 2 No, actually I think it becomes easier as I learn how to use it.
F 1 22 No, I don't like them any better. It helps with homework.
F 1 27 Uhmmm...I think that graphing calculators make the math work easier.
M 2 Yeah...yeah...I like it better.
M 5 I like them better when we are not using graphing calculators.
M 6 Yes, I like it better.
M 9 Yes, definitely.
M 2 7 Yes.
M29 Yeah
M 3 9 It doesn't really matter to me.
M 4 2 Definitely.
M 4 4 Yes.
M 4 5 Yeah.
M 64 Yes, definitely.
M 1 1 3 I like it better when I am allowed to use it.
M 1 2 0 Yeah.

Are you permitted to use them on tests or not?

F 1 2 Yes, we are, but in chemistry we are not allowed to have any programs in there for the tests.
F 1 4 Yeah we have to. If we don't bring it we can't take the test.
F 9 6 Most of the time.
F 9 7 Uh huh.
F 1 22 Sometimes.
M 2 Not in physics, but in the other classes I can.
M 2 9 Yeah, like we are allowed to use them on the chapter tests and stuff, but like the ACT and the Ohio Math League Test we are not allowed to use them on tests like that.
M 4 4 Yes, except for a couple having to do with graphing.
M 4 5 Yes, unless you are actually graphing, which is understandable.
M 64 Yes we are.
M 1 1 3 Yes, on most tests we are allowed to use them.
M 1 2 0 For most of them.

6. If you were planning on being a math teacher, would you plan on using graphing calculators in the classroom?

F 1 2 Absolutely.
F 1 4 Probably, because it is a lot easier. Like if you hook it up to the projector you can show how equations will look when you are done with them, and it helps the students visualize more.
F52 No, I don't think that I would.
F 9 6 Most definitely. I think that it gives an overall feeling for most students that they are more comfortable with having something that...well, that they can see something visually.
F 1 22 Yes, I think they show you a lot more than you could learn otherwise, and you can check your work.
M 5 Yes I would. Because it would eliminate all the extra thinking you have to do.
M 9 Well, that depends on the classes I guess. It's not necessary in the lower math classes. If it is an advanced class, it's obvious, if you need it, you just need it and that's it. Like in some of the classes I'm taking now, we have to graph certain things, and I wouldn't be able to understand what I'm doing without them.
M29 Sure. I think it helps people see visually what's happening with the numbers, and if you can't figure out a problem or something, I think that the graphing calculator really helps. We use them a lot. The teacher has an overhead that she uses during her instructing and I think that that helps a lot.
M 3 9 Yes, I probably would in certain classes. Classes like geometry, precalculus and the sciences.
M 4 4 Yes, I definitely would.
M 1 1 3 I probably would because they is such a proliferation of them now.

7. How does the graphing calculator help you? How do you use it? How often do you use it?

F 1 2 Oh, it's just great. The regular calculators, you have to do everything in so many steps, and this one, you can just put everything in at once, and it most always does what you tell it. It's really easy to use. Everyday, at least...at least once a day.
F 1 4 Oh I use it more to see what my equations look like because I'm more of a visual learner, so if I don't see it, I don't learn it. If I have just a bunch of numbers I can't put it all together. I use it more than once a day.
F 1 7 If you don't really know how to do the problem, you can graph it and usually you can figure it out. Everyday.
F 3 7 Just like a lot of the graphs...some of the simpler graphs I can handle myself, but when it gets to like the sine and cosine and stuff like that, it gets pretty confusing, and it helps you figure out where you are starting out before you do the transformation. Everyday.
F 4 9 Just makes me feel more confident about my answer. Kind of like it's just like an extension and if you put the numbers in there right then there's a lot less room for error. I use it every time I go to math.
F 5 1 Well, when you graph things, you can see the graph, and its got a big screen so you can put whatever you want on there. I use it everyday for Math and Chemistry.
F 5 2 I've noticed that a lot of people seem to be able to remember formulas because they've put them into their calculators. I like to use it to help me do matrices, which is really a problem. I probably use it 75 to 85% of the time on my homework.
F 9 6 Well, with most problems, you could just type in the parent function if you didn't remember it, and you could graph that, and then from there you could move it, and move it up and down, and vertical stretches and other stuff. I use it everyday.
F 9 7 Basically I just use it to graph. It helps me find the points and stuff. Ummm....not too much (*in response to "How often do you use it?"*). Yes...I might use it everyday.
F 1 0 2 Just like when I'm graphing problems, instead of like trying to graph it by hand you can just graph it on the calculator and I think that maybe it is more accurate than by hand, because of sometimes like human error. I use it everyday, in class and then on homework.
F 1 22 I mainly use it to find the sine, cosine and tangent and stuff like that, since we don't use charts anymore. I use it everyday.
F 1 27 It allows you to visualize your problem situations. I use it everyday, on my homework everyday.
M 2 I like it, because like I said before it is nice because I can see everything that I have done and that way I can see my work. I probably use it every time I do my math and physics homework.
M 5 Well, I use it to check my answers. I probably use it one out of every two questions.
M 6 The programs. I don't have to work everything out by hand. It just automatically does everything for you. I use it everyday.

M 9 Well, that's a toughy. Well, there's a lot of different functions and stuff I use it for. Well, there's a lot of programs and stuff you can use that just makes things a whole lot easier than doing things manually or with a regular calculator. It's just so much easier to use. Well, I use it everyday for my class.
M 2 7 Probably, just that that way I can picture all of the things that we are doing, and if someone messes up in class then the teacher can come over and correct it and help them see what they were doing wrong. Everyday.
M29 Just being able to see things. I use them all the time. At least once everyday, and probably more.
M 3 9 It helps me a lot with the sine, cosine and tangent and stuff like that. And other problems where you can just put the whole problem in with parenthesis and all and you don't have to break the problem down and do it a part at a time. That really helps. I use it about 3 times a day.
M 4 2 Well mostly I use it for computation and stuff like that. I use it every day and sometimes in more than one class.
M 4 4 I use it a lot as a general calculator, but it helps a lot and saves a lot of time when I am graphing. I use it probably at least 6 days a week.
M 4 5 Like with the sine, cosine and tangent and everything when there is a graph, or just values of angles. I use it nearly every day, probably six days a week, since I do homework on weekends.
M 64 It helps me see what we are learning...with the graphs and stuff ...and I can get some homework problems done faster when I use some of my programs. I use it about every other day.
M 1 1 3 I can set up graphs. I can solve equations-polynomial and linear equations- and I can deal with complex numbers, sine, cosine, and tangent functions. I use it everyday.
M 1 2 0 For a lot of different things, really. I use it mostly with graphing right now, but there are a lot of functions that make it quicker. And before I have used it for matrices, lists, and all of that stuff. Well, as far as using it in a way other than in experimenting, probably every other day.

8. What features of the graphing calculator do you use the most, overall, in all of your classes? The normal adding, subtracting, multiplying and dividing, or the graphing, or the formula function...

F 1 2 We use it mostly for for solving equations with logarithms-inverse logs and natural logs and stuff like that.
F 1 4 Oh, probably graphing would be most of it.
F 1 7 Right now probably the programs.
F 3 7 This year is was just mostly graphing.
F 4 9 Probably sine, cosine and tangent stuff. [*Note: currently she's studying trigonometry in her advanced math class.*] And when they throw in matrices too, I like to check matrices on it.
F 5 1 Well, basically whatever we are doing in my classes. Like right now we are doing sine, cosine and stuff in math so I'm using that a lot.
F 5 2 Well, probably the normal things like adding and subtracting and stuff, but it just depends on the section that we are working on, because we spent a lot of time on graphing and we were always using them to graph.
F 9 6 Probably the tables.

F 9 7 I'd say graphing.
F 1 0 2 Probably the adding and subtracting.
F 1 22 Probably graphing.
F 1 27 Generally I use it to graph situations, because often there is more than one way to solve the problem, and with the graphing calculator it can always provide another solution.
M 2 It's probably all the normal stuff-adding, subtracting, and stuff like that overall.
M 5 Probably cosine, sine and stuff, and matrices.
M 6 The basic function stuff.
M 9 Well, I'd say just the regular number things like division and stuff like that.
M 2 7 Right now it is kind of hard to say, because throughout the year we use different things more at different times, but graphing and trig functions are definitely the top two.
M29 Depending on what we're doing, mostly the graphing part. If I just need a quick solution to an equation, I might use the solver function. As far as scientific stuff, a little bit in physics and stuff, but not as much as the graphing I would say.
M 3 9 I would have to say that I use the normal adding, subtracting, multiplying and dividing stuff the most....I would think that that would be the way it is for everyone.
M 4 2 Computation mostly, and then second would be solving equations.
M 4 4 Probably the normal adding, subtracting, multiplying and dividing is what I would use it the most for. I like the solving equations feature also.
M 4 5 Mostly right now just for sine, cosine and tangent, and stuff like that.
M 64 I'd say the functions of it...[sine, cosine, tangent, log, e, etc.].
M 1 1 3 I probably use the graphing and the equation solving the most.
M 1 20 Graphing.

9. Do you approach math problems differently when you use the graphing calculator, than the way you do when you don't have the graphing calculator?

F 1 2 Yes I do. Because when I was out of trig, I didn't have it anymore-this was before I bought my own, and I was back to using my normal calculator and I forgot totally how to use it. It was awful. I think it is much easier to use graphing calculators.
F 1 4 No, usually I just use it to check my answer.
F 3 7 I'd say I approach them the same, but it just makes them easier, because you don't have as much to figure out on your own.
F 4 9 Yeah...I do. I just feel like I can at least try a problem. You can test...do some trial and error with the calculator.
F 5 1 I don't think so.
F 5 2 Uhmmm...probably, because I have a better chance of guessing. You know, if you have no clue, you can try something on the calculator because it has so many different options.
F 9 7 Yeah...I think I take a shorter route so I can put it into the calculator.
F 1 0 2 I don't know. I guess maybe...but I don't know how. If I didn't have the calculator, I would probably think about the problem more, but since I have the calculator, I think now how would I get this into my calculator.
F 1 22 Yes. I'm trying to think of an example. I guess I can't think of a particular example.

F 1 27 Oh...yeah...of course.
M 2 Yeah...sometimes I think I probably would. Like sometimes if you have to do a graph in physics or something, you can do it manually and then check to see if you are on the right track.
M 5 No, I really don't. I concentrate on both ways.
M 6 Yes. I don't know it just seems to make it easier somehow.
M 9 Yes, well, only in the fact that I know that it is a definite advantage having it, and there's just more uses.
M 27 Yeah. I think I go into it a little more confident, even though I know what I'm doing anyway, it is sort of an insurance policy.
M29 Definitely. Because sometimes you know even if you don't have an algebraic method, you could use a graph to solve an equation, if you don't need to work it out on paper.
M 39 Yes, I would say that I do. For example, with graphing trig problems I can try different things very quickly and it is easy to do.
M 42 Yeah...some problems I can graph it and look at it, rather than solving it algebraically.
M 44 Yes, because it is easier to see things on the big screen so it is easy to check what you have done. On a regular calculator you cannot do that.
M 45 Yeah...pretty much, because you may take the harder way, knowing that you can put all of the math into the calculator.
M 120 Yes. Ummm...I use a table more often when I'm using a calculator.

10. How do you think other students in the class feel about using graphing calculators in the classroom? Do you feel like all of them enjoy using graphing calculators, or are some of them really turned off and don't like it? What do you think?

F 1 2 I think that most of them liked it. The only part that was hard about it was when you had to learn new equations and new functions and when to turn on what function. That was the only hard part.
F 1 4 Well, it's a required part of the class, so I couldn't really speak for anybody else.
F 1 7 Everybody likes it.
F 37 I think that everyone likes to use them...it helps them out.
F 49 I think that everybody uses it to help themselves. I don't think that anybody really has a problem using them.
F 51 I don't know...you know it's just kind of hard to tell.
F 52 I think that the majority of the people understand them a lot, but I know that I feel like the minority because I don't sometimes.
F 96 Most of the people in our class really enjoy using the graphics calculators
F 97 I think that some of them just use it because they have to.
F 102 Ummm...I think that most people like them.
F 1 22 It seems to me that everyone likes them, mainly because it makes the work easier.
F 1 27 I think that everybody in my class enjoys using graphing calculators. A lot of them are really into mathematics and they enjoy the programming and stuff.
M 2 I think that some people really like it, but I know...or I'm pretty sure that there are people that don't, because they get really frustrated when they don't know what is going on-what functions or second or whatever to push-to keep up with the class.

M 5 There's probably some people who don't like it, but most of the people in my class I would say like it.
M 6 I think that the most of the people like using them.
M 9 Yeah, I think that there is a difference because a lot of kids kind of get frustrated because they don't understand the abbreviation for this or that, and when to press the second function key for this or that. Even I get confused sometimes, like with the second function key and the tangent button how does that compare to tangent to the negative one power and stuff like that. But I'm sure that there are a lot of kids that love using it.
M 2 7 I think that pretty much all of us like them. Because if she says we're not going to be using graphing calculators today, there is kind of a sigh, because we like to use them. And that's good because like we'll play around on the calculator with different equations to try and find out what they do, and we probably even pick up something while we are playing.
M29 I think that most of the kids in class have one and pretty much use one. I don't know if they get excited about using it, but I'm sure that it helps them understand what we are doing. But there is a few people that I would say...they don't really understand how to use it...so it not knowing how to use it, it doesn't become a useful tool. It becomes more of a pain in the rear than anything. But I think that the people who are well acquainted with the machine like it, and can get a lot of use out of it.
M 3 9 Most people like them, but like there are some people who don't understand who to use them very well, who don't like them as much.
M 4 2 I think that the general feeling is that people use them because it is easier than figuring it all out on paper, but people don't really like using them at all.
M 4 4 I think that almost everybody likes them, but like some people are afraid generally of computers and don't know how they work sometimes, and so they mess up sometimes, then they don't like to use them.
M 4 5 They seem to use them a lot, and appreciate the help it gives them.
M 64 I'd say that most of the guys really like it, but most of the girls I would say are maybe a little afraid of it, but a lot of them [girls] don't like to use them.
M 1 1 3 Oh yes, most of them like it. Most of them have their own and use it a lot.
M 1 2 0 There are probably some who don't like it, but I don't know who they are.

What do your parents think about the graphing calculator?

F 1 2 The only comment they made was when I came home with it and they said, "*That really cost $68?*"
F 1 7 I don't think that they care either way.
F 3 7 I think they've seen me use it a few times, and it's confusing to them.
F 5 2 My mom wishes that she would have had one of those when she was in school.
F 1 22 My dad couldn't get it to add. He doesn't understand any of it.
F 1 27 They think that it is a helpful tool.
M 2 Yeah. My dad said that he was kind of surprised, like how on regular calculators if you like 1 times 2 and keep on doing it, it goes 2, 4, 6, 8 and so on, but on the graphing calculator it goes 2, 2, 2, 2. That is about the extent of his comments.
M 9 I think my mom at one time said "Oooo...what's that?", but just because it had the big screen on it.
M 2 7 I think that they are interested in it.

M29 Oh, sometimes I'll find out something that it does and I'll show it to them and my dad will think that it's really neat. They like the idea of it. I saved my own money to buy it, so it is kind of my thing. My parents never tried to discourage me or my sister.
M39 It doesn't really make any difference to them.
M42 Well, they don't use it. They never see it because it's always at school or with me.
M44 My dad liked it so well he went out and bought one for himself.
M45 It's really a little too advanced for them to understand.
M64 They don't mind it, but they don't really enjoy it.
M113 I don't believe that they have actually seen me use it. They're the ones who bought it for me, so they know that I have it, I just don't think that they've seen me use it.
M120 Just that they don't understand it, and they would rather use a conventional calculator.

11. Do you think there is any difference in the way the guys and the girls in your class feel about using the graphing calculator?

F12 I don't know. I really never thought about it. Probably not. I think that they are both the same.
F14 Yeah. The guys are more like into computers and stuff and like think this is cool and are always programming weird programs into it and stuff like that, so they have a lot more fun with it, and the girls are like well this helps us do our math...while the guys are having fun with it.
F17 I don't think so.
F37 Probably not.
F49 I've never really noticed a difference.
F51 No.
F52 The girls, as far as I can tell, they use them, but they are not really into it like the guys are. The guys are more into using them to their maximum capabilities.
F96 You mean besides the guys just playing with them a lot more? I don't know, but I think for the majority, a lot more of the guys in our class will do a lot more research on them, and put a lot more games and programs in them, and then us girls get them from them.
F97 Yeah...(a brief laugh)...Yep. The guys sit there and play around with the programs and functions and stuff while us girls are trying to go with the teacher and do the problems and stuff.
F102 No, not really.
F122 Yes. I notice that the guys use them a lot more. They usually do a lot more with them. They use things programmed into them, and play with them in study hall and stuff, and I don't see many girls doing that.
F127 The guys seem to uh.....well, the girls probably use it for the problems that are presented to them, but the guys like to go the extra mile and do the programming more and explore the graphing calculator more.
M2 Well, in my class it is usually the girls who have questions...or like...need another explanation on how to use a certain function.
M5 I think the girls get upset a lot more when they can't get their answer on the calculator, and the guys are more laid back and don't care really.

M6 No.
M9 No. No, I really don't think so.
M27 I think that we...the guys...are a little more experimental with them.
M29 I'd have to say that most of the guys, in my class specifically, being an advanced class they really use them. I know one guy that programs his to do all kinds of things and I use programming on mine to solve equations and stuff. I write programs just so that I don't have to enter an equation every time and like my sister, she doesn't really like to use the calculator. She'll use it if she has to, but it is the kind of thing where she could do it on paper and like it just as much or more. So, overall I would say that the guys use them more and are more familiar with using them. I'm sure that there are some girls that are good with using them too, but I think that the guys use them a lot more than the girls do.
M39 Yes, I do. The guys use them a lot more and differently, while a lot of the girls try to work things out on their own first without using the graphing calculator.
M42 Yeah, it seems like the girls seem to use them less and to like it less.
M44 Yes, the guys do a lot more with it than the girls do. The girls do what they are told, the guys do more than that...they explore and try new things with it.
M45 The guys tend to try to put games on them, while the girls just do their homework and that's all.
M64 The guys they maybe like to play around with it more and use it more.
M113 Uhmmmm...I think that the guys generally play more games on them than the girls do, but other than that the attitudes are the same.
M120 I don't think so.

12. Are there any drawbacks to using the graphing calculator?

F12 No, the only one that I can think of is that you have to be careful and watch what function you are in-like if you are in scientific when you should be in normal, and stuff like that. (*She's referring to the Mode*).
F14 Yeah, it encourages people not to do the calculations in their head. You know they don't learn how to really do it, because you can just punch it in and then you lose your basic algebra skills, because you rely too much on it.
F17 Yeah....like you lose your multiplication skills.
F37 For like the TI-85's, some of them program games into them and stuff, and no one can tell if they are really working on their math or if they are playing the games.
F49 Other than not knowing all of the functions that it has and how to use them, no. In the beginning, it was difficult learning how to use it.
F51 Umm...not really.
F52 If you understand how to use them in every situation, you know with every problem that you come up against, then its all right. But if you don't really understand how to use it, it's easier to know how to figure it out on your own, or at least to know the formula or the process on your own.
F96 I can't think of any.
F97 Maybe just because it doesn't make you think as much. You just type it into the calculator and expect for it to give you the answer.
F102 Yes, like when you have problems and you have to set the range. Or when you go to graph something and the graph doesn't show up on your screen and you have to fool around and try to get the range, it is very frustrating.

F 1 22 Yes, sometimes you don't really learn anything. You just put it into your graphing calculator and let it do the work.
F 1 27 Only if your teacher wanted you to learn another way to solve a problem and you were so dependent on your graphing calculator that you couldn't learn another way.
M 2 You might become too dependent on it and like if I wouldn't be able to buy one of my own in the future and I might be stuck and not understand how to do something on my own.
M 5 No, I can't.
M 6 It's complicated and hard to understand. It takes awhile to get used to it.
M 9 The only negatives that I have gotten through it is through physics class. We're not allowed to use them in there, and in a lot of other classes because it can be used to cheat because you can write in them and stuff.
M 27 No.
M29 I like to know how things work and to work them out on paper. I think with my graphing calculator I get a little lazy sometimes, and just use it for graphing everything. And then I think, if I had to do it algebraically, could I do it? But I think, as long as I can brush up on how to do it with paper it's ok.
M 39 Just if you don't know how to use it very well.
M 42 No, not really. Oh yeah, cheating on tests, I forgot about that.
M 44 No, I can't think of any.
M 45 Well, like the TI-81, it doesn't have too much memory. Like, as they progress they put more memory into them, and that helps out a lot.
M 64 Uhmmm...I'd say that some of the games are kind of a distraction.
M 1 13 The only drawback is that you don't get a lot of the intermediate steps that you might need to know for later things. But other than that, no.
M 1 20 I suppose that there is some loss of speed and just being worse at calculations.

13. Do you think being able to use a graphing calculator has made a difference in the grade you are getting in this class? In what way?

F 1 2 Yes, because I didn't do very well in trig at all. Algebra was my strong suit, and I didn't do that badly in geometry. I didn't do particularly well in trig, but I'm sure that I would have done much worse if I hadn't had the graphing calculator.
F 1 4 Yeah. Well, because if I can't use my calculator, then I get really nervous because I don't think that the answer is right, so I have to go back and check it.
F 1 7 Yeah...it raises it. If I had to do Trig or Analytic without my calculator I would be lost.
F 37 Probably, I'd say a little bit. Because it helps me get things done a little bit quicker. Because I know that on tests and stuff it would take me a lot more time to figure it out by hand rather than using the graphing calculator.
F 49 I definitely think it has. Yeah, I think I'll be getting a better grade because I used it.
F 51 Umm...not really.
F 52 It probably will. It will probably be higher, because I'll learn those processes that I need to, and they will save a lot of mind work that could drive you crazy.
F 96 Yes. Just because it makes me more comfortable, and it gives me the extra added incentive, just to be able to say...'Hey...I can do this!'.
F 97 Yeah...I think that I'll be getting a better grade because I can use the graphing calculator.

F102 Well, I don't know. If she didn't use calculators, then she would teach us how to do it without calculators, and then I would probably learn it that way.
F122 Yes. It helps me to remember stuff, because it does half the stuff for me, so there is not as much stuff to remember.
F127 I think that my grade would probably be the same.
M2 No, I don't really think so.
M5 Yes, I do. I think it's better.
M6 Yes. I think it's better. I don't always understand all of the mathematical concepts, but the graphing calculator helps.
M9 Yeah. Well, yeah, it's better...for all the same reasons I've already said.
M27 I don't know. I think that we all pretty much know what we are doing.
M29 Well, I usually have a fairly high grade, but I do think that I use my graphing calculator enough that it contributes to having the higher grade. I use it on tests and stuff, where if I didn't have it I might make more small errors. It's like a security blanket. It makes me feel better about my work, and not that I can't do it without it, but I like to use it.
M39 No, not really.
M42 I think that it would have been the same, with or without a graphing calculator. It would have just taken longer to do the problems.
M44 No, I don't think it is any different than it would have been.
M45 I'd have to say yeah. Pretty much just helping out with some things that you can't do in your head.
M64 If any, not very much, no. I'd say that maybe with the calculator it might be a little bit better.
M113 Yeah...I think that it improved it.
M120 No, probably not, it just makes things quicker.

14. Do you plan to take mathematics when you go to college?

F12 Oh, I don't know. I'll probably have to.
F14 I'm trying to test out of it.
F49 I'm sure that I'll have to have it.
F51 Probably, but I don't really know.
F52 I probably will have to.
F102 Yes. I mean, I don't want to, but I know that I will have to.
F122 Yes.
F127 Yes.
M2 Yes, some type of math I'm sure.
M5 Yes.
M6 Most likely.
M39 Yes, I'm sure that I'll have to.
M42 Yeah.
M44 Yes.
M45 Yes, definitely.
M64 Yes, I do.
M113 Yes, I do.
M120 Yeah.

15. If given a choice, when in college to take a mathematics class where graphing calculators were used and one where they were not, which one would you choose? Why?

F 1 2 I'd choose the one with the calculator, because I'm helpless without one. I'm a fool without it.
F 1 4 I would probably choose the one with the graphing calculator because I get really worried about when I am taking my tests if I got a problem right or not, and if I can't check it somehow then it takes me a lot longer to get the test done and stuff.
F 1 7 I would choose the one with calculators, because if that was the type of thing that was going to be your job, you would be able to have a calculator with you.
F 3 7 I'd pick the one that lets you use the graphing calculator because it's easier.
F 4 9 I'd take the calculator class.
F 5 1 I don't really see how it would make a difference.
F 5 2 Will they be providing it, or would you have to have your own? (Interviewer response- *"You would have to have your own?"*). Well, I'd probably put out the extra money to get one because I'd want to be in a class where I'd be working with what I was accustomed to using in high school and I could see where it would save a lot of time in college.
F 9 6 Definitely the one where I could use the graphics calculator. Just because it makes me feel more comfortable.
F 9 7 I'd choose the one with the calculators because it makes it easier.
F 1 0 2 The one with graphing calculators, just because it makes things easier and quicker.
F 1 22 I'd take the one with the calculator, just because I already have it so I might as well use it.
F 1 27 I would choose the one where it is required.
M 2 I'd probably take the one where you wouldn't have to use them. Because I would rather be able to understand it manually and then learn how to use the graphing calculator later, so that I know both ways.
M 5 Yes, I'd take it with a graphing calculator, because I'm familiar with it and stuff.
M 6 I'd choose the one where you could use the graphing calculator. It makes it easier.
M 9 Well, using the calculator, of course.
M 2 7 I'd prefer the one with the graphing calculator, because if you're using it just for your homework, and not in class or on tests, I don't think that you would get the same feel for it.
M29 If the graphing calculator class taught the same things as the other class, and they taught you how to work it out on paper and actually showed you how to work it out on paper, then I would take that one. Because I would still want to know how to do it on paper, but I would feel more comfortable in using the calculator. But if it was a deal where they just used the calculators and they didn't show you how to work it out on paper, then I would definitely take the paper one. I want to know how to do it both ways.
M 3 9 If the teacher showed us how to use them, I would take the class where the graphing calculators were used.
M 4 2 I'd take the class with the calculator, because I really don't like doing all of the computations by hand or in my head.

M44 I'm not sure. Probably the one with graphing calculators, because I am used to it.
M45 I'd have to say the graphing calculator one, because the other one may give you more experience and more knowledge and everything, but for most people that is just too much to grasp.
M64 Uhmm...probably the one with calculators. Because I think that they are a little more interesting to use and plus the technology is getting a little better.
M113 I'd probably choose the one that uses the graphing calculator, just because of the idea that I've used it all through high school and I feel comfortable using it and I like the features.
M120 It depends on what it is. I'd use the one using the calculators, because I'm more confident when I can use it.

16. Would you recommend for other mathematics students to buy a graphing calculator? Why?

F12 Absolutely. I think if they are just in a basic math class, that it is not really necessary, and you don't need to spend the money. But, if you are in a higher level math class, then I would definitely say yes.
F14 Only if they are going to need it for a class.
F17 Yes, because it helps.
F37 Probably, yeah.
F49 I think if you're going to college it would be to your advantage to buy one.
F51 Yeah probably, if you're going to use it when you go to college.
F52 It depends on their course. But if they got to a course where they would need it, that would be the only reason, if you would really need it.
F96 Yes, very much so. Just because I think that it helps you so much.
F97 Yes, I think it gives you confidence in your math, so you feel more confident, so therefore you want to do your math homework and you feel better about it all.
F102 Not unless they needed it, because it is kind of expensive.
F122 Yes, because they really help. I just got one for Christmas and before that I was always borrowing my friends because I can't hardly graph without it.
F127 I would recommend it for people who reach a certain level. Once you have reached Calculus, I think that you have learned the other concepts that the graphing calculator would help you out with, that you would have to know otherwise. So then, it is just a helpful tool and there is no need to do the other methods.
M2 *I forgot to ask him this question...the lunch bell had rung.*
M5 Honestly, I wouldn't. It's too expensive and it doesn't do that much more stuff than you can do with a regular calculator.
M6 If they were going to take a math course where they needed it.
M9 Well, depending on the class. It is really unnecessary for lower level math classes. But otherwise, if you're in trigonometry then yes. But it should be provided by the school anyway.
M27 Yes, because it is a big time saver.
M29 Yeah. Certainly. It's helpful and enjoyable.
M39 Yes, because it helped me a lot and makes things easier.
M42 Yeah, because you can use it all the way from Algebra I through college and it's really helpful.

M44 If they're going into higher maths and sciences yes, because they will probably need it.
M45 Yeah, because just like it helps you out on everything for the most part.
M64 Yes, because there is getting more and more technology in classes so if you own your own, you will know it better.
M113 Yes. Well....I would the TI-85, not the 81's or 82's. They're not up to speed and I don't think that it is worth buying them. So maybe the 85, or one of the HP's or a Casio or something.
M120 Well, I'd say past Algebra I, probably. Because it opens...well, it's made me understand a lot of the operations better. How they actually work, and just the speed factor.

17. Right now you have a ____ graphing calculator, and I know that your teacher uses a ____ a lot in class, and maybe you have seen some of your friends use ____ or other graphing calculators, if you could buy a different calculator would you do that, or stick with the one that you have?

F12 (Currently using a TI-81) I'd probably buy the same one that I have now, because I know how to use the one that I have now.
F14 (Currently has a TI-81) I'd probably get a CASIO. My friend has one and it has a lot more functions on it and it shades in your graphs if you have inequalities and stuff and it has colors. It really brings the concepts out more, especially when it's in color not just black and white. And it has smooth lines instead of jagged lines so it's more accurate when you are trying to trace to find numbers and stuff.
F17 (Currently using a TI-81 that belongs to the school) I'd buy a TI-85.
F37 (Currently using a TI-81 that belongs to the school) I'd probably buy the same one that I have now, because I know how to use it.
F49 (Currently using aTI-81that belongs to the school) I'd figure out which one had the functions on it that I would need, and I would just buy for what I would need.
F51 (Currently is using a TI-81 that belongs to the school) I don't know any of the differences in them.
F52 If money were no problem I would probably go for the TI-85 because I've seen with other students the possibilities of all the things that they can do.
F96 (Currently has a TI-82) I think that I would stick with the same one that I have now.
F97 I guess there's some new one out that has a flip up top or something. That is probably the one that I would buy.
F102 (Currently has a Casio) I'd buy a TI-85 because most of my friends have those, and I bought mine several years ago before they were really big.
F122 (Currently using a TI-82) I'd probably buy a different one, because the reason I bought the one I have now is because of money. It was a little bit cheaper model and yet it still did the things I needed. If money wasn't a problem I'd probably get an upgraded one, like today I was looking a someone's Hewitt Packard and it was great...wonderful memory... but it costs around $300.

F 1 27 (Currently using a TI-81) I think that I will probably keep my TI-81when I go off to college because that is what I have been using for the past four years, and it is what I'm used to, and I wouldn't want to have to take the time to learn all the new things that I would have to with a new calculator.

M 2 (Currently using a TI-81) I'd probably just buy the same kind that I am used to. I don't know. I just like it better.

M 5 (Currently using a TI-81 borrowed from the school) I would buy the same one, because I'm familiar with it. I know where all of the buttons are and how to set the programs in and stuff like that.

M 6 (Currently using a TI-81) I'd probably get a more expensive one that could do more.

M 9 (Currently using a TI-81 that belongs to the school) The one I have now. It's the one I'm the most familiar with, so that is the one I would stick with.

M 27 (Currently uses a TI-81) I'd buy a TI-85. It just has a lot more things that you can do with it. A lot more shortcuts and stuff like that.

M 29 (Currently using a TI-85) I'd buy a TI-85. I partial to Texas Instruments, because that is what I have and I am used to using it, but I have some friends that have some Casio's and stuff, and they are ok, but I would say the ease of use of the Texas Instruments is far greater than any of the other graphing calculators that I have seen. Even though some of the Casio's may do some things that my TI-85 won't do, I think that I have them beat in the long run. I'm comfortable with using it, and I wouldn't change.

M 39 (Currently using a TI-81) I'd buy the most up - to- date one-the highest number of the TI calculators. The one with the most features on it.

M 42 (Currently has a TI-85) I'd definitely wouldn't buy a TI-81 or a TI-82. I like the TI-92's because of all of the features that they have, but they are so big.

M 44 (Currently using a TI-85) I'd buy one of the new ones, I think it is a TI-92- I heard they are really neat and have a lot of features. Other than that I would stick with my TI-85.

M 45 (Currently using a TI-81 that belongs to the school) Well, I haven't seen the TI-92 yet, but from what I hear about it, it has a whole lot more on it, and it's just like a new level of graphing calculator.

M 64 (Currently using a Casio) I'd probably take the new TI-92 because it is really neat and has a lot more stuff with it.

M 1 1 3 (Currently using a TI-85) I'd probably just keep my 85, because the HP's are a lot better and so are the new TI-92's but I don't know how to use them, and it always seems to take forever to learn to use a new one.

M 1 20 (Currently using a TI-82) Well, I'd check first to see if the TI-85 had the things that I use a lot. But, I'd probably buy a TI-85 because the programming is easier, and you can use longer strings and stuff.

18. What advice would you give to a teacher who is just starting to teach a class who has never used graphing calculators before and now they are going to be using graphing calculators?

F 1 2 Oh, I don't know. Well, my teacher has a big poster up at the front of the room of the graphing calculator, and that helps a lot. When she says "go to your math button", you know where it is. I would just say keep your manual handy. That's what I do.

F 1 4 Well, don't assume that your students know anything about the calculators, because they probably don't. And it's pretty confusing...at least it was for me anyway and you have to go really slow. Take it one step at a time so that they can get it.
F 3 7 I know like our teacher has something that she puts on the overhead and she hooks the graphing calculator up to it. She also has some other things, like a big picture of the calculator so she can show us how to do different things.
F 5 2 I would start out right away with it. I wouldn't....I don't know....I wish they had started us a long time ago, kind of like they do with foreign languages...I wish they had started us on a complicated computer or a complicated calculator before, so we could really learn it.
F 9 6 I think that they should take at least a week or something like that, and have an actual class of showing how to use it and why it is a good idea to use it.
F 1 22 I like it when teachers teach you how to do it without a calculator and then when you know that, then they teach you how to do it with the calculator. So kind of like you can check your work.
M 2 I don't know except maybe just to combine learning how to do it manually and then using the graphing calculator. So that they know both ways and can do it both ways.
M 5 Well, I'd ask for them to be sure and take the time for all the students to know where all of the buttons are and how to do things. Sometimes they go too fast and they think that you know how to do things that you don't and then when it comes time to do homework you don't know which buttons to push.
M 6 Spend a couple of days just on the graphing calculator before you start to get into all of the math part of it.
M 9 Well, that's the toughest one you have given me so far. Well, actually a student shouldn't be giving a teacher advice, the teacher might get kind of mad, so I really don't know.
M 2 7 I'd tell them to take their time with it and be sure and explain all of the functions really carefully. Never take for granted that they know how to use it.
M29 I'm not sure. Just the more you use it, and the more familiar that the students become with it, then I think it helps them and it also, you might learn some things yourself. Graphing calculators aren't for everybody, some people just don't like it. They are not used to using computers, just like my parents. They're not computer people.
M 3 9 I would tell them to go very slow...very slow, and explain things very carefully. Make the students do it while they are explaining. I would also make the students take notes on how to use it, and make that count for a grade.
M 4 2 Probably to make sure that the students know how to use the calculators to do the problems in the class. And to make sure that the students learn how to do it without the calculator, before teaching them how to do it with the calculator.
M 1 2 0 Just explain everything very slowly and well.

APPENDIX D

Tables of Demographic Data

Table 20

Grades Students' Received in

Last Mathematics Class Taken

	N	%
A's	56	42
B's	50	37
C's	23	17
D's	5	4

Table 21

Student Responses to

How do you feel about using your graphing calculator?

	N	%
I use it because it's required.	3	2
I like to use it because it makes things easier.	89	66
I like using it and enjoy showing others how to use it.	15	11
I love using it and enjoy exploring and learning new ways to use it.	27	21

Table 22

Demographic Data for Individual Students

Student	Q#13	Q#14	Q#15	Q#16	Q#17	Q#18	CWCal
1	A	A	B	A	C	B	54
2	A	B	B	A	C	B	46
3	A	D	C	A	D	B	47
4	A	C	B	A	C	D	52
5	A	B	B	A	C	B	42
6	A	B	B	A	C	B	52
7	A	A	B	A	D	B	47
8	A	C	D	A	C	B	53
9	A	D	B	A	D	B	41
10	A	C	B	A	C	B	43
11	A	C	B	A	C	B	51
12	A	D	C	A	C	B	41
13	A	C	B	A	C	B	43
14	C	A	B	A	C	D	46
15	A	C	C	A	D	B	44
16	A	B	B	A	C	B	52
17	A	B	B	A	C	B	29
18	A	C	B	A	D	B	46
19	A	B	D	A	C	B	60
20	A	B	B	A	C	B	42
21	A	C	C	A	C	B	51
22	A	A	B	A	D	B	47
23	D	B	B	A	D	D	46
24	D	D	D	C	D	D	55
25	C	C	B	A	D	D	50
26	A	B	B	A	D	B	53
27	C	B	D	A	D	B	54
28	D	D	D	C	D	D	60
29	D	D	D	C	D	D	56
30	D	C	D	A	D	B	49
31	D	C	C	A	D	D	53
32	D	C	B	A	D	D	50
33	D	C	B	A	D	D	55
34	D	D	C	A	B	D	56
35	D	B	B	D	D	D	47
36	D	B	B	A	D	C	45
37	D	C	B	A	D	B	47
38	C	C	D	A	D	B	56
39	C	C	B	A	D	D	42
40	A	C	B	B	C	D	46
41	A	B	D	A	D	B	52
42	D	C	D	C	C	D	55

Table 22 (cont'd)

Student	Q#13	Q#14	Q#15	Q#16	Q#17	Q#18	CWCal
43	A	C	B	A	D	B	60
44	A	B	C	A	C	B	40
45	A	B	B	A	C	B	47
46	A	C	B	A	D	D	42
47	A	B	B	A	C	B	49
48	C	D	B	A	D	B	45
49	A	B	B	A	D	B	49
50	A	C	B	A	D	B	48
51	A	C	B	A	C	B	38
52	A	B	B	A	C	B	46
53	A	B	B	A	D	B	50
54	A	A	A	A	D	B	33
55	A	B	B	A	D	B	41
56	B	D	B	C	D	D	56
57	C	C	B	A	D	D	49
58	C	C	D	C	D	D	59
59	*	*	*	*	*	*	36
60	C	B	B	C	D	D	55
61	B	D	C	C	D	D	54
62	C	B	B	C	D	B	42
63	B	C	D	C	D	D	43
64	C	C	D	D	D	D	55
65	B	B	B	D	D	D	51
66	C	C	B	C	D	D	51
67	D	B	D	D	D	D	58
68	C	C	C	C	D	D	56
69	B	B	B	A	D	B	49
70	C	C	B	A	D	C	51
71	B	B	A	A	D	D	53
72	C	B	B	A	D	D	51
73	C	B	A	A	D	D	54
74	C	C	B	C	D	D	47
75	B	C	B	C	D	D	50
76	D	C	D	D	D	D	53
77	B	C	D	A	D	D	51
78	B	B	B	A	D	B	48
79	C	B	B	B	D	D	46
80	D	C	C	C	D	D	56
81	C	C	B	A	D	B	52
82	D	A	B	A	D	B	45
83	C	C	B	C	D	D	54
84	C	D	D	A	D	D	52

Table 22 (cont'd)

Student	Q#13	Q#14	Q#15	Q#16	Q#17	Q#18	CWCal
85	C	C	D	C	D	D	55
86	B	B	D	C	B	D	56
87	D	D	D	C	D	D	58
88	C	C	C	C	D	D	43
89	D	D	D	A	D	B	55
90	B	C	C	C	D	D	52
91	C	B	B	C	D	D	40
92	D	B	B	C	C	D	47
93	D	D	D	D	D	D	59
94	B	C	B	C	D	D	41
95	C	B	B	B	D	D	44
96	C	D	D	B	D	D	56
97	C	A	B	A	D	B	39
98	C	D	B	A	D	D	55
99	B	B	B	A	D	D	43
100	B	B	C	C	D	D	52
101	D	B	B	A	D	D	60
102	D	B	B	D	D	D	38
103	C	B	B	C	D	D	40
104	C	C	D	D	C	D	56
105	B	C	B	B	C	D	59
106	A	B	B	A	C	D	27
107	C	C	B	A	C	D	55
108	C	B	B	B	C	D	54
109	D	C	B	C	C	D	53
110	B	C	D	C	C	D	46
111	C	B	B	D	C	D	54
112	C	C	B	C	C	D	60
113	D	C	B	C	C	D	49
114	B	A	B	A	C	D	53
115	D	C	D	C	C	D	56
116	D	C	C	C	C	D	58
117	D	C	B	A	C	B	53
118	D	C	B	C	C	D	42
119	D	C	B	C	C	A	56
120	C	C	B	B	C	D	57
121	C	B	B	B	C	D	41
122	D	B	B	A	C	B	54
123	C	C	D	D	C	D	56
124	B	B	B	A	C	D	47
125	D	C	B	A	C	D	47
126	B	C	B	C	D	D	51
127	B	B	B	D	C	D	40

Table 22 (cont'd)

Student	Q#13	Q#14	Q#15	Q#16	Q#17	Q#18	CWCal
128	A	D	B	B	C	D	50
129	C	B	B	D	C	D	50
130	C	B	B	C	C	D	54
131	C	B	B	A	C	D	52
132	D	B	B	B	C	D	41
133	C	B	B	A	C	D	41
134	B	C	B	C	C	D	51

APPENDIX E

Individual Student Scores for Confidence Instruments, Spatial Skills, Visualization, and Grades

Table 23

Individual Student Data

Student	CW/OCalc	CWCalc	SS	VZ	Grade	OddsW/O	EvensW/O	OddsW	EvensW	Gender	Teacher	School
1	54	54	124	12.00	3	26	28	27	27	1	1	1
2	40	46	97	9.00	4	17	23	19	27	1	1	1
3	36	47	150	14.25	4	18	18	21	26	1	1	1
4	40	52	85	13.25	4	18	22	27	25	1	1	1
5	31	42	40	3.75	3	16	15	22	20	1	1	1
6	44	52	105	9.00	4	21	23	24	28	1	1	1
7	40	47	129	7.25	3	17	23	22	25	1	1	1
8	42	53	137	16.00	2	19	23	26	27	1	1	1
9	45	41	154	17.75	3	19	26	24	17	1	1	1
10	39	43	115	15.75	3	16	23	19	24	1	1	1
11	39	51	81	11.25	3	15	24	24	27	2	1	1
12	28	41	109	2.25	3	11	17	17	24	2	1	1
13	27	43	107	11.50	4	12	15	19	24	2	1	1
14	51	46	41	6.75	3	23	28	24	22	2	1	1
15	35	44	134	12.75	3	18	17	22	22	2	1	1
16	48	52	97	8.75	2	22	26	24	28	2	1	1
17	43	29	129	12.25	3	20	23	16	13	2	1	1
18	38	46	142	13.00	3	15	23	21	25	2	1	1
19	46	60	106	11.75	4	19	27	30	30	2	1	1
20	39	42	120	12.50	4	17	22	19	23	2	1	1
21	41	51	95	13.25	4	15	26	21	30	2	1	1
22	36	47	120	12.25	3	14	22	22	25	2	1	1
23	43	46	118	14.00	4	24	19	28	18	1	2	2
24	47	55	75	13.75	4	24	23	29	26	1	2	2
25	36	50	113	15.00	4	16	20	27	23	1	2	2
26	38	53	145	19.00	4	20	18	26	27	1	2	2

Table 23 (cont'd)

Student	CW/OCalc	CWCalc	SS	VZ	Grade	OddsW/O	EvensW/O	OddsW	EvensW	Gender	Teacher	School
27	49	54	157	20.00	4	27	22	30	24	1	2	2
28	43	60	144	12.50	3	18	25	30	30	1	2	2
29	49	56	154	18.50	4	25	24	30	26	1	2	2
30	43	49	149	12.75	3	22	21	25	24	1	2	2
31	44	53	150	11.25	3	23	21	28	25	1	2	2
32	38	50	119	12.00	3	20	18	30	30	2	2	2
33	44	55	96	14.50	4	22	22	29	26	2	2	2
34	52	56	147	10.50	4	24	28	30	26	2	2	2
35	38	47	71	6.75	2	17	21	26	21	2	2	2
36	31	45	110	15.50	4	12	19	26	19	2	2	2
37	38	47	119	17.00	3	20	18	25	22	2	2	2
38	51	56	92	5.25	3	27	24	28	28	2	2	2
39	44	42	122	11.75	4	22	22	20	22	1	3	3
40	43	46	110	13.00	4	18	25	21	25	1	3	3
41	33	52	126	11.25	1	15	18	27	25	1	3	3
42	48	55	144	16.25	4	22	26	26	29	1	3	3
43	60	60	160	20.00	4	30	30	30	30	1	3	3
44	35	40	96	12.00	2	16	19	18	22	1	3	3
45	42	47	121	3.75	2	15	27	20	27	1	3	3
46	34	42	118	11.00	3	15	19	19	23	2	3	3
47	34	49	98	14.00	4	14	20	23	26	2	3	3
48	39	45	59	12.50	3	19	20	23	22	2	3	3
49	39	49	70	7.25	3	18	21	23	26	2	3	3
50	44	48	90	14.00	2	24	20	25	23	2	3	3
51	39	38	74	15.50	4	17	22	14	24	2	3	3

Table 23 (cont'd)

Student	CW/OCalc	CWCalc	SS	VZ	Grade	OddsW/O	EvensW/O	OddsW	EvensW	Gender	Teacher	School
52	37	46	46	7.25	3	17	20	21	25	2	3	3
53	47	50	99	14.00	3	22	25	25	25	2	3	3
54	41	33	116	10.25	3	17	24	16	17	2	3	3
55	40	41	65	3.75	1	19	21	21	20	2	3	3
56	51	56	116	11.50	4	26	25	30	26	1	4	4
57	44	49	131	9.75	4	21	23	24	25	1	4	4
58	51	59	143	13.75	4	23	28	29	30	1	4	4
59	32	36	68	10.50	2	18	14	20	16	1	4	4
60	53	55	106	5.00	4	26	27	28	27	1	4	4
61	44	54	130	11.50	3	23	21	29	25	1	4	4
62	53	42	111	10.25	2	27	26	27	15	1	4	4
63	42	43	136	12.75	2	20	22	25	18	1	4	4
64	47	55	106	9.50	3	23	24	28	27	1	4	4
65	42	51	56	10.25	2	21	21	26	25	1	4	4
66	47	51	129	11.25	2	21	26	26	25	1	4	4
67	57	58	130	18.00	3	29	28	30	28	1	4	4
68	51	56	76	10.25	4	25	26	28	28	2	4	4
69	54	49	123	10.00	3	25	29	24	25	2	4	4
70	36	51	79	11.75	3	16	20	25	26	2	4	4
71	49	53	77	14.00	2	24	25	27	26	2	4	4
72	31	51	145	10.25	2	12	19	24	27	2	4	4
73	53	54	109	10.25	2	23	30	24	30	2	4	4
74	45	47	88	12.75	3	23	22	27	20	2	4	4
75	37	50	122	13.50	2	18	19	25	25	2	4	4
76	46	53	83	13.50	3	20	26	26	27	2	4	4

Table 23 (cont'd)

Student	CW/OCalc	CWCalc	SS	VZ	Grade	OddsW/O	EvensW/O	OddsW	EvensW	Gender	Teacher	School
77	51	51	89	6.75	1	26	25	27	24	2	4	4
78	40	48	144	16.00	2	18	22	24	24	2	4	4
79	46	46	112	13.00	4	21	25	26	20	2	4	4
80	52	56	127	12.50	4	27	25	29	27	2	4	4
81	33	52	111	11.75	3	17	16	27	25	1	5	4
82	31	45	115	15.00	3	14	17	23	22	1	5	4
83	45	54	160	10.50	3	22	23	28	26	1	5	4
84	39	52	106	10.50	2	18	21	30	22	1	5	4
85	51	55	98	11.00	3	28	23	28	27	1	5	4
86	53	56	82	16.75	4	27	26	29	27	1	5	4
87	55	58	114	11.00	3	26	29	28	30	1	5	4
88	34	43	122	12.50	3	16	18	19	24	1	5	4
89	35	55	119	9.00	1	17	18	27	28	1	5	4
90	46	52	116	16.00	1	24	22	26	26	1	5	4
91	34	40	150	14.00	2	14	20	19	21	1	5	4
92	43	47	132	10.25	3	20	23	23	30	1	5	4
93	56	59	158	18.75	3	26	30	29	30	1	5	4
94	37	41	90	2.00	2	18	19	22	19	1	5	4
95	41	44	75	10.00	2	17	24	24	20	2	5	4
96	24	56	96	5.75	2	12	12	27	29	2	5	4
97	37	39	117	8.50	4	18	19	19	20	2	5	4
98	45	55	76	10.75	3	23	22	29	26	2	5	4
99	42	43	95	12.25	3	20	22	20	23	2	5	4
100	48	52	35	7.75	2	20	28	24	28	2	5	4
101	51	60	122	12.75	3	21	30	30	30	2	5	4

Table 23 (cont'd)

Student	CW/OCalc	CWCalc	SS	VZ	Grade	OddsW/O	EvensW/O	OddsW	EvensW	Gender	Teacher	School
102	37	38	57	5.75	4	18	19	19	19	2	5	4
103	29	40	128	11.25	3	9	20	17	23	2	5	4
104	57	56	86	15.00	4	28	29	30	26	1	6	4
105	46	59	137	14.50	4	22	24	29	30	1	6	4
106	51	27	108	14.00	3	23	28	28	29	1	6	4
107	47	55	126	15.75	4	23	24	28	27	1	6	4
108	41	54	143	19.00	3	17	24	28	26	1	6	4
109	52	53	140	20.00	4	27	25	28	25	1	6	4
110	33	46	127	18.75	4	18	15	25	21	1	6	4
111	53	54	104	15.50	4	24	29	25	29	1	6	4
112	53	60	143	17.00	4	26	27	30	30	1	6	4
113	28	49	110	11.75	3	16	12	26	23	1	6	4
114	48	53	121	8.00	4	25	23	28	25	1	6	4
115	38	56	116	12.50	4	16	22	29	27	1	6	4
116	56	58	130	18.75	4	28	28	29	29	1	6	4
117	43	53	99	17.50	3	21	22	27	26	1	6	4
118	35	42	154	18.75	4	15	20	23	19	1	6	4
119	47	56	114	15.50	4	23	24	27	29	1	6	4
120	48	57	80	17.00	4	25	23	28	29	1	6	4
121	44	41	110	16.75	3	17	27	22	19	2	6	4
122	52	54	156	20.00	4	25	27	27	27	2	6	4
123	55	56	125	14.25	4	26	29	28	28	2	6	4
124	43	47	80	14.00	4	20	23	22	25	2	6	4
125	35	47	124	15.00	4	12	23	28	19	2	6	4
126	42	51	139	13.75	3	18	24	25	26	2	6	4

Table 23 (cont'd)

Student	CW/OCalc	CWCalc	SS	VZ	Grade	OddsW/O	EvensW/O	OddsW	EvensW	Gender	Teacher	School
127	45	40	71	12.00	3	17	28	28	12	2	6	4
128	47	50	151	18.00	4	20	27	24	26	2	6	4
129	41	50	123	14.25	4	19	22	25	25	2	6	4
130	48	54	84	12.25	4	24	24	27	27	2	6	4
131	45	52	131	14.00	3	23	22	26	26	2	6	4
132	41	41	91	14.75	4	20	21	23	18	2	6	4
133	40	41	112	8.25	4	22	18	24	17	2	6	4
134	36	51	78	12.75	4	17	19	26	25	2	6	4

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