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ABSTRACT

This paper describes an intervention in two Algebra II classes in which the graphing calculator was incorporated into the curriculum as often as possible. The targeted population consisted of high school students in a growing middle to upper class community located in a suburb of a large city. The problem of a lack of understanding of the capabilities of the programmable graphing calculator were documented through student surveys, a graphing calculator pre-test, and direct teacher observation. Analysis of probable cause data revealed that students rarely used the graphing calculator the previous school year in their math courses. Other possible causes included a lack of both instructional materials and teacher in-service training related to the graphing calculator technology. Also, lack of students' "hands-on" time with the graphing calculator may account for an incomplete understanding of its capabilities. A literature review of solution strategies resulted in the selection of one major intervention: more "hands-on" time for students with the graphing calculator. Research has shown that increased use of the graphing calculator enhances students' understanding of mathematical concepts and improves problem solving abilities. Use of the graphing calculator also fosters positive attitudes among both students and teachers. Post intervention data indicated an increase in students' understanding of the functions and capabilities of the graphing calculator. The increase in understanding was evidenced by high homework, quiz, test, and alternative assessment scores. Post-test scores showed a marked improvement over pre-test scores. (Contains 12 references.) (Author)

IMPROVING STUDENT KNOWLEDGE OF THE GRAPHING CALCULATOR'S CAPABILITIES

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An Action Research Project Submitted to the Graduate Faculty of the School of Education in Partial Fulfillment of the Requirements for the Degree of Master of Arts in Teaching and Leadership

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This paper describes an intervention in two algebra II classes in which the graphing calculator was incorporated into the curriculum as often as possible. The targeted population consisted of high school students in a growing middle to upper class community located in the suburb of a large city. The problem of a lack of understanding of the capabilities of the programmable graphing calculator were documented through student surveys, a graphing calculator pre-test, and direct teacher observation.

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A literature review of solution strategies resulted in the selection of one major intervention: more "hands-on" time for students with the graphing calculator. Research has shown that increased use of the graphing calculator enhances students' understanding of mathematical concepts and improves problem solving abilities. Use of the graphing calculator also fosters positive attitudes among both students and teachers.

Post intervention data indicated an increase in students' understanding of the functions and capabilities of the graphing calculator. This increase in understanding was evidenced by high homework, quiz, test, and alternative assessment scores. Also, post-test scores showed a marked improvement over pre-test scores.

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CHAPTER 1

PROBLEM STATEMENT AND CONTEXT

Problem Statement

The students of the targeted algebra II classes exhibit a lack of understanding of the capabilities of the programmable graphing calculator. Evidence for the existence of the problem includes student surveys, test scores that could be improved, and direct teacher observation.

Immediate Problem Context

The targeted site is a high school located in a suburb of a large city. This is the only school in its district. Children from the ninth through the twelfth grade attend this high school. Since this site is the only school in its district, any information reported for the school would be the exact same information for the district. All information reported about this school was obtained from the 1996 State Report Card. The total enrollment at this school is 2,383 students.

White non-Hispanic, Black non-Hispanic, Hispanic, Asian/Pacific Islander, and Native American (American Indian/Alaskan Native) are the major racial ethnic groups in this state's public schools. White non-Hispanics represent the majority of the students at the targeted site.

Enrollments for the school are displayed in Table 1, and were reported as of September, 1995.

Table 1

Racial/Ethnic Background of Students

	White	Black	Hispanic	Asian/P. Islander	Native American
School	86.7%	1.8%	2.8%	8.4%	0.4%
State	64.0%	20.6%	12.2%	3.1%	0.4%

Low-Income students are from families receiving public aid, living in institutions for neglected or delinquent children, being supported in foster homes with public funds, or eligible to receive free or reduced-price lunches. Limited-English-Proficient students are those who have been found to be eligible for bilingual education. The targeted site contains a minimal amount of students who are considered low-income or have limited English proficiency. The dropout rate for students at this school is low and is based on the number of students in grades 9 through 12 who dropped out during the 1995-96 school year. This information is displayed in Table 2.

A perfect attendance rate (100%) means that all students attended school every day. The student mobility rate is based on the number of students who enroll in or leave a school during the year. Students may be counted more than once. Chronic truants are students who are absent from school without valid cause for 10% or more of the last 180 school days. The students of the targeted school have a high attendance rate with a low number of chronic truants as shown in Table 3.

Table 2

Low-Income, Limited-English-Proficient Students and Dropouts

	Low-Income	Limited-English-Proficient	Dropouts
School	2.1%	0.8%	1.5%
State	34.9%	5.9%	6.5%

Table 3

Attendance, Mobility, and Chronic Truancy

	Attendance	Student Mobility	Chronic Truancy	Number of Chronic Truants
School	94.9%	7.6%	0.8%	19
State	93.5%	18.8%	2.3%	42,974

The great majority (98.6%) of the teachers at the site are White with the remaining 1.4% of the teachers being Hispanic. The teachers are divided almost equally between males and females with 48.7% of the teachers being male and the remaining 51.3% being female. Table 4 describes the average years of experience and the educational levels attained by the teachers at the site. A large percentage of teachers at the targeted site have their master's degree as compared to the percentage of teachers in the state. This could be due to the fact that the teachers at the site receive a substantial salary increase upon completion of their master's degree.

The facility at the site is composed of two buildings: Building A and Building B. Freshmen attend classes in Building A, and upperclassmen go to Building B. Building A, the original high school, is more than 75 years old, and Building B has been in existence for more than 40 years. Recently, due to the increasing sizes of the freshmen classes, some of these freshmen have been forced to commute by walking between the two buildings. It has been impossible to hold all of the freshmen classes at Building A. Students who are forced to commute must be dismissed from their classes five minutes early.

Table 4

Teacher Characteristics

	Average Teaching Experience	Teachers with Bachelor's Degree	Teachers with Master's & Above
District	15.2 Yrs.	27.5%	72.5%
State	14.4 Yrs.	55.6%	44.2%

The targeted site has a variety of computer labs to which students have access before school, after school, and during their study halls. The site is connected to the Internet. Students who have been trained have Internet access in these computer labs. One of the computer labs at the high school is known as the Instructional Resource Center (IRC). In addition to computer access, the IRC offers the students a variety of other opportunities as well. Every period of the school day, a math teacher, a science teacher, and an English teacher are available to provide students with additional help toward their studies. Also, teachers are available before school and after school to answer students' questions. The IRC is a place where students can work together and help each other on school projects. This is different from a regular study hall in which students are required to remain silent.

The math department at the targeted site also has a variety of resources available to the students. Every math classroom has six graphing calculators available for student use, and each math classroom is equipped with an overhead demonstration unit. If more than 6 calculators are needed by the students, there are also sets of between 12 and 20 calculators which math teachers can sign out for use in the classroom. Graphing calculators are also available for overnight checkout by students.

Community Setting

The targeted school district includes four villages (Villages A, B, C, and D), parts of a fifth village (Village E), and surrounding unincorporated areas. The district is approximately 35 square miles with a population of about 40,000. Table 5 illustrates demographic information for the targeted school district. This data was taken from the 1990 census. The majority of the people who reside in the community are white.

Two socioeconomic indicators for the communities which feed into the school district include median household income and per capita income. Those figures were also obtained from the 1990 census and are displayed in Table 6. The range of income varies widely between villages. This difference in income is especially evident between Village D and Village E.

The administrative structure of the targeted school district includes a superintendent, an assistant superintendent, and a principal. There is also an associate principal and two assistant principals. One assistant principal has responsibilities in the freshmen building, while the other assistant principal has responsibilities at the building which contains the upperclassmen.

Table 5

Racial/Ethnic Background for the Targeted School District

Race/Ethnicity	Percent of Population
White	92.8%
Black	0.5%
Hispanic	2.2%
Asian/Pac. Islander	3.6%
Native American	0.1%
Other Race	0.7%

Table 6

Income by Community

Community	Med. Household Income	Per Capita Income
Village A	$61,632	$25,428
Village B	$48,873	$20,625
Village C	$74,289	$29,501
Village D	$90,552	$70,925
Village E	$45,947	$16,950

The attendance, discipline, and guidance functions are combined into three Learning Support Teams. The freshmen students have one support team in Building A. The sophomore, junior, and senior students are a part of two Learning Support Teams divided alphabetically at Building B. Each Learning Support Team is made up of an assistant principal and/or team leader, counselors and/or facilitators, and a social worker. All three teams are supported by teachers, the school psychologist, the school nurse, and office personnel. Each support team works together to help the students take advantage of all the programs the school has to offer.

A problem that has been plaguing the school district is overcrowding. Enrollment, fueled by continued growth in housing, is expected to rise to 2,550 students for the 1996-97 school year. This number is far higher than the capacity of 2,150 formulated by a state study in 1988. A citizens committee has begun reviewing four possible sites for a new campus for the high school, hoping to ease the school's chronic overcrowding. However, over the years, three referendum proposals to expand the campus of the high school have been voted down. A fourth referendum, for life-safety renovations, also failed.

The booming enrollment has forced the school board to consider plans to cut back on the number of students in the classrooms at any one time. During the first week of February, 1997, the board approved plans to extend the school day as a way to free more classrooms. The school day will be extended from eight periods to nine periods. This program will begin in the fall of 1997.

National Context of the Problem

The use of the graphing calculator in the mathematics classroom has generated discussion at both the state and national levels. The National Council of Teachers of Mathematics (NCTM) issued a landmark publication in 1989 entitled Curriculum and Evaluation Standards for Mathematics. In this publication, NCTM endorsed the increased use of calculators, particularly graphing calculators, in mathematics instruction (Dunham & Dick, 1994; Williams, 1993). According to the NCTM document (as cited in Dunham & Dick, 1994), "Scientific calculators with graphing capabilities will be available to all students at all times" (p. 440). Research has shown that students who use calculators learn traditional arithmetic as well as those who do not use calculators (Lopez, 1993). Also, graphing calculators can empower students to be better problem solvers (Dunham & Dick, 1994; Lopez, 1993).

A problem that comes from this increased use of the graphing calculator is that students exhibit a lack of understanding of all of its capabilities. Graphing calculators free more time for instruction by reducing attention to algebraic manipulation. Also, graphing calculators supply more tools for problem solving, especially for students with weaker algebraic skills (Dunham & Dick, 1994). However, these capabilities are meaningless unless the students know how to take advantage of them. Mathematics teachers who wish to demonstrate the functions of the graphing calculator may have a difficult time imparting this knowledge to their students (Williams, 1993).

Williams (1993) has identified some areas of difficulty which students experience with the graphing calculator. One of these areas includes simplifying expressions by using the order of operations. In any algebra class, one of the first areas of difficulty that students experience is applying the order of operations. The graphing calculator has a multi-line screen with the ability to enter and edit a lengthy expression. Students could take advantage of this function and enter entire expressions in their natural order. However, students are often unsure when parentheses are necessary and how to enter complex expressions. Some students do not fully utilize the calculator's abilities but instead resort to the old practice of doing one operation at a time, as evidenced by their writing down immediate results (Williams, 1993).

Another area of difficulty for students is meshing algebraic and graphical knowledge (Williams, 1993). Due to its graphing capabilities, the calculator could be a great advantage to students because it could be used to check solutions which were obtained algebraically. However, students often do not use algebraic solutions and graphical solutions as checks against each other. If they do use both methods and arrive at different solutions, the students feel anxious. A graphing calculator has its limitations. For a calculator to give a correct solution, it must be adjusted to the correct settings. The students who feel that the calculator's abilities are superior to their own often believe the calculator screen instead of their algebraically determined solution, even if the calculator's limitations have been explained (Williams, 1993).

The two problem areas which have been described are not the only areas of difficulty which students experience with the graphing calculator. As of 1993 when Williams wrote her article, she had attended many professional meetings on new and creative ways to utilize the many functions of the graphing calculator. However, she had never seen any workshops that help prepare teachers for the new set of student errors that accompany new technology. Part of her reason for writing the article was to stimulate further research of this subject (Williams, 1993). Dunham and Dick (1994) also suggest that more research is needed on the graphing calculator. For example, one topic they suggest needs to be investigated is what factors account for student success or failure with the graphing calculator. By learning what knowledge students lack with regard to the calculator, teachers can better prepare them for the technical world of the next century (Williams, 1993).

CHAPTER 2

PROBLEM DOCUMENTATION

Problem Evidence

The students of the targeted algebra II classes exhibit a lack of understanding of the graphing calculator's functions and capabilities. In order to document the extent of this lack of understanding, a student survey was given (Appendix A), a graphing calculator pre-test was given (Appendix B), and an anecdotal record of students' comments were kept and recorded by the researcher. The survey asked students about their prior experiences with the graphing calculator. The pre-test contained actual problems to be solved using the graphing calculator. While the students were engaged in the pre-test and also upon its completion, their comments and reactions were recorded by the researcher.

<u>Student Survey Results</u>

Of the 41 students surveyed in the two algebra II classes, 85.4% of them claimed to own a graphing calculator. Students were also asked to rate how important they perceived the graphing calculator to be in an algebra II class on a scale of one to five, with five being "very important" and one being "not important." The results are presented in Table 7.

Over 75% of the students felt that graphing calculator importance rated a four or a five which indicates that they believe that the graphing calculator is an important part of the algebra II curriculum. None of the students felt that the graphing calculator is not important in an algebra II class. The general consensus of the algebra II students is that the graphing calculator is important in an algebra II class.

Table 7

Students' Perceptions of Graphing Calculator Importance

Level of Importance	Percent of Students' Responses in This Category
1 - not important	0%
2	2.4%
3	19.5%
4	58.5%
5 - very important	19.5%

Geometry is the course taken prior to algebra II. The algebra II students spent the previous school year in geometry. The graphing calculator survey given to the algebra II students also asked how often they used the graphing calculator in geometry class. The results are presented in Table 8.

The results show that 90% of the students indicated that they had used the graphing calculator at least once or twice a month in geometry class. Over a fourth of the students claimed to have used the calculator daily. Less than 10% of the students said that they never used the graphing calculator in geometry class.

Finally, the students were asked about their prior experiences with various functions and capabilities of the graphing calculator. A summary of the results are presented in Table 9.

Table 8

Frequency of Student Calculator Usage During Previous School Year

Frequency	Percent of Students' Responses
Never	9.8%
Once/Twice a Month	12.2%
Once a Week	17.1%
Two/Three Times a Week	34.1%
Daily	26.8%

Table 9

Students' Prior Experiences with Functions of the Graphing Calculator

Graphing Calculator Capability	Percent of Students with Experience	Percent of Students without Experience
Order of Operations	85.4%	14.6%
Graph Function	90.2%	9.8%
Trace Function	63.4%	36.6%
Table Function	48.8%	51.2%
Window Function	48.8%	51.2%
Matrix Function	9.8%	90.2%
Intersect Function	58.5%	41.5%

The students were asked about their prior experiences with seven functions and capabilities of the graphing calculator. Out of those seven functions, over half of the students surveyed claimed to have prior experiences with four of those functions. A little less than half of the students (48.8%) claimed to have experience with two of the calculator's functions. The matrix function was the only one in which only a small percentage of students (9.8%) claimed to have prior experience.

By analyzing the survey results, it is obvious that the large majority of students claimed to have prior experience with the graphing calculator and believe in its importance in an algebra II class. However, the results of this survey are negated by the results of the graphing calculator pre-test. While the students claimed to have some degree of familiarity with the calculator, the pre-test results indicated that the students actually do not understand the graphing calculator's functions and capabilities.

Pre-test Results

Students completed a graphing calculator pre-test which contained five different math problems worth a total of six points; one of the questions had two parts. The students were instructed to use the graphing calculator to complete the pre-test. Students without their own calculators were provided with one. Out of the 41 students who took the pre-test, each student received either a correct score of zero or one on the pre-test. These low scores clearly demonstrate that the students exhibit a lack of understanding of the graphing calculator's functions and capabilities. Although the students indicated that they had prior experience with the graphing calculator, they did not know how to apply that experience to solve actual math problems. The comments made by the students in regard to the graphing calculator pre-test also indicate a lack of understanding of the graphing calculator's functions and capabilities.

Anecdotal Record of Students' Comments

The researcher kept an anecdotal record of the students' comments during the pre-test and also upon its completion. While taking the graphing calculator pre-test students asked the researcher questions about problems on the pre-test. For example, some questions asked included:

What are range values?

What is a prediction equation?

These questions indicated a lack of knowledge of the functions of the graphing calculator. The students were unaware of the functions of the graphing calculator and how to use them.

After all the pre-tests were completed and turned in to the researcher, the students also made comments about the problems on the pre-test. Statements made by the students included:

I thought I knew more.

I didn't have much knowledge.

The pre-test was hard.

From these comments it is obvious that the students recognized their lack of knowledge in regard to the functions and capabilities of the graphing calculator. A student with thorough knowledge of the graphing calculator would not have found the pre-test difficult. The pre-test was constructed in such a way that a student with knowledge of the graphing calculator would be successful on the pre-test. This lack of success on the pre-test clearly shows evidence that the algebra II students do exhibit a lack of understanding of the functions and capabilities of the graphing calculator. The probable causes of this problem will be discussed in the next section of Chapter Two.

Probable Causes

The discussion of the probable causes of the students' lack of understanding of the functions and capabilities of the graphing calculator will be divided into two main sections. First, the targeted site will be analyzed to determine site-based causes. Then, a review of the literature will continue to address probable causes of the problem.

Analysis of the Targeted Site

At the targeted site a lack of "hands-on" experience with the graphing calculator during the two previous school years may account for students' lack of understanding of the calculator's capabilities. The prerequisite for the targeted algebra II classes is geometry. Geometry is a subject which requires minimal use of the graphing calculator. The current algebra II students spent the previous school year in geometry, a math course which requires little knowledge of the graphing calculator's capabilities. The prerequisite to geometry is algebra I, which also requires limited use of the graphing calculator. Therefore, without the "hands-on" experience of the graphing calculator, the current algebra II students lack the understanding of the graphing calculator's capabilities which are required to be successful in the math course.

The question may arise as to whether these algebra II students have a lack of understanding of the graphing calculator's capabilities due to a lack of teacher training on the functions of the calculator. At the targeted site this lack of training is not the reason behind the students' lack of understanding. The math teachers at the targeted site have all attended some workshops or training sessions on the graphing calculator and its functions and capabilities. There is a math instructor on staff at the targeted site who has taught some graphing calculator workshops and may be considered a "resident expert" on the graphing calculator's functions and capabilities. Probable causes of the students' lack of understanding of the functions and capabilities of the graphing calculator will continue to be discussed in a review of the literature.

Literature Review

A review of the literature on the probable causes of the students' lack of understanding of the graphing calculator's capabilities supports the data found at the targeted site. One of the causes stated in the literature is students' lack of "hands-on" experience with the graphing calculator (Williams, 1993). If students do not practice applying the functions of the graphing calculator, they will not fully understand its capabilities. Students who do not own or have "hands-on" access to a graphing calculator may especially be at a disadvantage. These students may have only seen demonstrations of the graphing calculator technology performed by instructors. According to Dodge (1991), "It is important that the graphing technology by used by every student, not just a 'show-them' demonstration by the teacher" (p. 2-3).

Students who lack graphing calculator experience may misunderstand its role in the mathematics classroom. These students tend to think of the calculator as the ultimate authority, rather than just another mathematical tool. Many students lack confidence in their mathematical skills and therefore feel that the calculator's abilities are superior to their own. These students believe the calculator screen instead of their algebraically determined solution, even if the calculator's limitations have been explained (Williams, 1993). According to Bruns (1993), it is the mathematics instructor's responsibility "to emphasize that no matter how powerful the calculator, it is only a tool, and the users' understanding of basic concepts is necessary" (p. 218). As students work more with the graphing calculator, they will come to know both its limitations and its capabilities (Williams, 1993).

Besides students' lack of "hands-on" experience with the graphing calculator, a review of the literature found other probable causes to explain students' misunderstanding of the graphing calculator's capabilities. According to Dunham and Dick (1994), there may be a lack of availability of course materials designed to take full advantage of the graphing calculator technology. Graphing calculators represent recent technological developments. Some textbook companies may still be trying to "catch up" in order to incorporate this graphing calculator technology. Those course materials which have been published and do emphasize the graphing calculator technology may be unattainable to some school districts due to financial constraints (Dunham & Dick, 1994).

The inadequacy of in-service education for teachers may also account for students' lack of understanding of the graphing calculator's capabilities. Teachers who do not fully understand the functions of the graphing calculator will not be able to impart this knowledge to their students. As stated earlier, graphing calculator technology is a recent development. Because the graphing calculator represents new technology, there may not be many in-service opportunities available for teachers to gain knowledge of the graphing calculator and its capabilities. Also, the in-service training which is offered may not be available to some teachers due to financial reasons within their school districts (Dunham & Dick, 1994).

The literature revealed one final probable cause for the problems students experience with the graphing calculator. This is poor attitudes of both teachers and students toward the technology. Mathematics instructors who have been teaching for some amount of time may believe that graphing calculators are unnecessary. For example, an algebra teacher may believe that he or she has been teaching the same way for ten years, and there is no need to change now. His or her teaching methods always worked in the past. Why change to incorporate new technology? Students may also have a poor attitude toward learning new technology. For students it may seem that learning the functions and capabilities of the graphing calculator requires more effort than they previously put forth in a mathematics class. Both teachers and students may feel an aversion to learning the new technology (Dunham & Dick, 1994).

To summarize, the previously stated causes can be placed into three major categories to explain students' lack of understanding of the graphing calculator's capabilities. The first major category involves students' lack of "hands-on" experience with the graphing calculator. Many students have only seen demonstrations of the graphing calculator rather than experiencing it themselves (Dodge, 1991). Students who do not have the technological experience tend to overemphasize the importance of the graphing calculator, rather than viewing it as a mathematical tool (Bruns, 1993; Williams, 1993). The second category of probable causes involves a lack of materials and in-service training for teachers on the graphing calculator and its capabilities (Dunham & Dick, 1994). Finally, poor attitudes of both teachers and students toward graphing calculator technology is a probable cause for students' lack of success with the graphing calculator (Dunham & Dick, 1994). Fortunately, there are solutions to this problem which will be discussed in Chapter Three.

CHAPTER 3

THE SOLUTION STRATEGY

Literature Review

There have been many advocates for increased usage of the graphing calculator in mathematics classrooms (Dodge, 1991; Scariano & Calzada, 1994; Van de Walle, 1991). A 1989 landmark publication in the mathematics community was entitled Curriculum and Evaluation Standards for School Mathematics. It was put forth by the National Council of Teachers of Mathematics (NCTM). This publication called for the full use of technology in the classroom at all grade levels (Schielack, 1991). According to the NCTM document (as cited in Dunham & Dick, 1994), "Scientific calculators with graphing capabilities will be available to all students at all times" (p. 440).

Although there has been an enormous number of sources which call for the increased use of the graphing calculator, there have also been some detractors to the use of this new technology (Dunham & Dick, 1994; Van de Walle, 1991). Opinions toward the use of technology in the mathematics classroom range from avid enthusiasm to strong opposition (Scariano & Calzada, 1994). Even though these negative opinions toward mathematical technology do exist, substantial research evidence shows that the use of calculators does not interfere with the learning of necessary mathematical skills. Numerous studies have been conducted at all grade levels and have shown that the use of calculators does not interfere with the learning of basic number facts or forms of computation (Brenner, 1995). According to the National Research Council's publication entitled Everybody Counts (as cited in Lopez, 1993), "Students who use calculators learn traditional arithmetic as well as those who do not use calculators" (p. 253).

Increased Mathematical Understanding

Research studies have shown that student use of the graphing calculator has led to many positive developments. Research suggests that, in general, calculator usage has a positive impact on how students learn mathematics (Bruns, 1993; Lopez, 1993; Williams, 1993). Relating specifically to the graphing calculator, studies show that the visual impact of the graphing calculator on students greatly enhances their learning of mathematics (Demana & Waits, 1992). Because graphing calculators enhance visualization and invite self-discovery, students are able to relate to novel problem situations (Scariano & Calzada, 1994). According to Scariano and Calzada (1994), "Students begin to develop a unified understanding of basic mathematical ideas as well as an appreciation for the pervasive power of mathematics" (p. 61).

One study which showed how graphing calculators can increase students' understanding of mathematics was performed at eight institutions, including a community college and a high school. The Calculus Consortium based at Harvard University (CCH) designed a new syllabus for calculus. Preliminary versions of the core CCH materials were taught for the first time during the 1990-91 school year. One of the calculus instructors who participated in this study was George Bruns, an instructor at Nassau Community College in New York. He then wrote about his experiences in a 1993 article entitled "Calculator = CCH Tool." The project was based on the belief that three aspects of calculus should be emphasized throughout the course. These three aspects include graphical, numerical, and analytic. In order to include the graphical aspect of calculus, graphing calculators were regularly incorporated into the classroom (Bruns, 1993).

The use of graphing calculators shifted the emphasis of the calculus course from algebraic manipulation to the important concepts of calculus including limit, derivative, and definite integral. Analytic and numerical findings became more meaningful to students when a graphical solution was displayed. Students' opinions and comments in regard to the graphing calculator were solicited and recorded. According to Bruns (1993), one student stated the following:

> The graphing calculator takes some of the pressure off as far as technical problem solving and algebra, so I can concentrate on deeper meanings of the concepts. I feel like I am understanding calculus now rather than memorizing techniques and formulas. (p. 217)

The use of the graphing calculator in the classroom was an overall positive experience for both students and teachers. The graphing calculator introduced a beneficial "hands-on" learning dimension to the calculus course (Bruns, 1993). One specific area of mathematics where the graphing calculator has helped to increase students' understanding is problem solving.

<u>Improved Problem Solving Skills</u>

Research has shown that the use of the graphing calculator when teaching problem solving strategies led to significant increases in the achievement of students (Dunham & Dick, 1994). The calculator enables students to concentrate on the conceptual aspects of the problem and leaves the computation to technology (Dodge, 1991). According to Taylor and Watkins (1993), "These technological advances are changing the way mathematics is done, making previously unmanageable problems routine, and thus increasing the number of alternatives for successful problem solving" (p. 276).

One study which showed how graphing calculators can improve students problem solving skills was performed at Loyola University in Louisiana. In the five years prior to 1993, 58% to 62% of each entering freshman class tested into the Mathematics Basic Skills Program. This program consists of two one-semester courses: Math 091 and Math 092. Math 091 covers topics typically learned by students from kindergarten through the eighth grade. Math 092 is similar to a high school algebra course. Neither of these courses is worth a college credit. The students enrolled in these courses have been previously exposed to the material, but have not learned it well enough to be successful in college level mathematics. The purpose of these courses is to enable the students to do college level mathematics (Lopez, 1993).

Both Math 091 and Math 092 were restructured to regularly incorporate the graphing calculator into the math classroom. In the spring of 1993 the students in Math 091 were allowed to use a graphing calculator for the first time in the history of the course. In the fall of 1993 the students in Math 092 were given the same opportunity. Antonio Lopez was an instructor of these basic skills courses. He wrote about his findings in regard to students and their experiences with the graphing calculator (Lopez, 1993).

One major finding by Lopez (1993) was that students with poor arithmetic and algebra skills became better problem solvers with the increased use of the graphing calculator. In the spring of 1993, 32 students took the Math 091 course, and 2 failed. In the past the failure rate was 50% or more. The students were allowed to use their graphing calculators whenever they wanted. Therefore, the students could focus their attention on important mathematical concepts and could solve more complex problems than those normally found in the basic skills curriculum. Lopez and his colleagues (1993) "are convinced that this symbiosis between student and machine is helping our students develop a deeper understanding of real mathematics" (p. 260).

Two other instructors at Loyola University in Louisiana, Stephen M. Scariano and Maria E. Calzada, increased the usage of the graphing calculator in the classroom. They then wrote a 1994 article whose primary purpose was to encourage other mathematics instructors to also use the graphing calculator in the classroom because of its many benefits. These two instructors believe that the benefits of the graphing calculator technology will only be felt if students are allowed and encouraged to use the calculators both inside and outside of the classroom (Scariano & Calzada, 1994).

Scariano and Calzada (1994) have made many observations of students' experiences with the graphing calculator and have found those experiences to be positive. For example, they have observed that the usage of the graphing calculator gave basic skills students confidence in using both their mathematical reasoning and their problem solving abilities (Scariano & Calzada, 1994). This confidence enabled students to make connections to new problem situations and to communicate solution strategies to their peers. According to Scariano and Calzada (1994), "We are optimists, convinced that mathematical computing and graphing calculator technologies now provide more promise for successful mathematics education than ever before" (p. 60).

In 1992, Dick (as cited in Dunham & Dick, 1994) pointed out three ways that graphing calculators increase students' problem solving skills. With less attention to algebraic manipulation, calculators allow more time for actual instruction. As a mathematical tool, graphing calculators supply more functions and can serve as a monitoring aid during the problem solving process. Finally, students who are freed from algebraic manipulation can focus on the actual problem set-up and analysis of the solution. Dunham's 1993 review of the research on graphing calculators supported these claims (Dunham & Dick, 1994). One of the factors that contribute to increased mathematical understanding, including problem solving, is the fact that graphing calculators in the classroom help to provide a supportive exploratory environment.

Supportive Exploratory Environment

The use of the graphing calculator in the classroom allows students to feel comfortable trying new ideas and strategies. Such an environment makes it more likely for students to make conjectures and test ideas when they are using a graphing calculator (Schielack, 1991). Students are allowed to discover mathematics and therefore learn by doing (Dodge, 1991). According to a 1990 study by Farrell (as cited in Dunham & Dick, 1994), students became more active in classrooms in which graphing calculator technology was being used and spent more time on investigations and explorations. Due to this increased student involvement, more quality time was devoted to problem solving. Another positive aspect of the graphing calculator is that it improves students' attitudes toward mathematics.

Improvement of Students' Attitudes

The graphing calculator serves as a positive motivator among students because they seem to enjoy using it. According to Demana and Waits (1992), "Graphing calculators can make the study of mathematics fun and can give students excellent learning experiences" (p. 95). In a review of the research, Dunham and Dick (1994) found that students who used graphing calculators were more willing to engage in problem solving and stayed with a problem longer. Students also believed calculators improved their ability to solve problems (Dunham & Dick, 1994).

George Bruns (1993) conducted a study during the 1990-91 school year which also showed evidence that students who use graphing calculators display a positive attitude toward mathematics. Time saved because of the graphing calculator technology allowed students to solve problems related to realistic situations. These problems generated enthusiasm in students because they could see the relevance of mathematics to real-life situations (Bruns, 1993). Bruns also surveyed the students about their feelings toward the graphing calculator. Out of 61 students, 48 strongly agreed or agreed that they liked using the graphing calculator. Also, 42 strongly agreed or agreed that the calculator gave them a sense of confidence (Bruns, 1993).

Summary

To summarize, it seems obvious that increased use of the graphing calculator will lead to an increased understanding of its functions and capabilities. Despite some opposition to graphing calculator technology, research has shown that the calculator can positively contribute in the classroom in a variety of ways. Usage of the graphing calculator in the classroom has a positive impact on how students learn mathematics. Problem solving, one of the most important topics of mathematics, is an area in which student achievement has improved because of the usage of the graphing calculator. Graphing calculators have also been shown to provide a supportive exploratory environment in which students feel comfortable making conjectures and testing ideas. Finally, the graphing calculator has been a positive motivator for students by improving their attitudes toward mathematics.

Because of all of these benefits of the graphing calculator, the researcher decided to implement the technology into the algebra II curriculum on a regular basis. In order to help the targeted algebra II students overcome their lack of understanding of the capabilities of the graphing calculator, the researcher implemented the "practice makes perfect" approach. The researcher incorporated graphing calculators into the classroom on a regular basis, giving the students plenty of "hands-on" opportunities.

Project Objective and Processes

As a result of increased instructional emphasis on the functions and capabilities of the graphing calculator during the period of late August 1997 to January 1998, the algebra II students from the targeted classes will increase their ability to apply graphing calculator skills when solving mathematical problems as measured by teacher-constructed tests and alternative assessment activities.

In order to accomplish the terminal objective, the following processes are necessary:

1. Lesson plans that foster graphing calculator skills will be developed.
2. Alternative assessment activities that measure graphing calculator skills will be developed and/or implemented.

3. Teacher-constructed tests will be developed and/or implemented.

Project Action Plan

The action plan is presented in outline form organized by the textbook chapters which will be covered during the first semester of algebra II. The targeted site has a set curriculum to be completed in the first semester of the school year. By the end of the fall semester the first five chapters of the textbook must be completed. The researcher intends to incorporate the graphing calculator within these five chapters whenever possible. Certain topics that must be taught during the first semester do not coincide with the functions or capabilities of the graphing calculator. In the following outline the researcher shows when and how the graphing calculator will be implemented in the first five chapters of the textbook.

I. Data collection to evidence the problem (Beginning week of Aug. 18th)
   A. Student survey on graphing calculator
   B. Graphing calculator pre-test
   C. Teacher observation of students working with graphing calculator

II. Begin algebra II content material (Beginning last week of August)
   Chapter 1: Equations and Inequalities
   A. Sect 1.1: Expressions and Formulas
      1. Develop lesson plan on simplifying expressions with the graphing calculator
      2. Give textbook assignment in which students use the graphing calculator
   B. Sect 1.3: Solving Equations
      1. Develop lesson plan on graphic method of solving equations rather than the algebraic method
      2. Discuss "INTERSECT" function of the graphing calculator

3. Give textbook assignment in which students use the graphing calculator

C. Sect 1.6: Absolute Value Equations

1. Develop lesson plan on the graphic method of solving equations with absolute value
2. Give textbook assignment in which students use the graphing calculator

D. Give test at end of chapter

1. Students are allowed to use calculator for entire test
2. Students must use calculator to answer three questions on test

III. Chapter 2: Linear Relations and Functions (mid September)

A. Sect 2.1: Relations and Functions

1. Develop lesson plan on applying vertical line test to graphs
2. Demonstrate how to use graphing calculator to find the value of a function
3. Give textbook assignment in which students use the graphing calculator

B. Sect 2.2: Linear Functions

1. Develop lesson plan on how to graph a linear function on the calculator
2. Discuss the definition of a complete graph of a linear equation in relation to the calculator
3. Give textbook assignment in which students use the graphing calculator

C. Sect 2.6: Scatter Plots and Prediction Equation

1. Develop lesson plan on how calculator gives the prediction equation

2. Give textbook assignment in which students use the graphing calculator
3. Give alternative assessment on prediction equations

D. Sect 2.7: Special Functions

1. Develop lesson plan on graphing an absolute value function on the graphing calculator
2. Give textbook assignment in which students use the graphing calculator

E. Give test at end of chapter

1. Students are allowed to use calculator on entire test
2. Students must use calculator to answer three questions on test

IV. Chapter 3: Systems of Equations and Inequalities (mid October)

A. Sect 3.1: Graphing Systems of Equations

1. Develop lesson plan on solving systems graphically using the calculator
2. Review "INTERSECT" function of the calculator
3. Give textbook assignment in which students use the graphing calculator

B. Sect 3.3: Cramer's Rule

1. Discuss "MATRIX" function of graphing calculator
2. Discuss "det" function of graphing calculator
3. Develop lesson plan on solving systems using Cramer's Rule and the calculator
4. Give textbook assignment in which students use the graphing calculator

C. Give test at end of chapter

1. Students are allowed to use calculator for entire test

2. Students must use calculator to answer four questions on test

V. Chapter 4: Matrices (beginning of November)

A. Sect 4.3: Matrices and Determinants

1. Review "MATRIX" and "det" functions of the calculator
2. Give textbook assignment in which students use the graphing calculator

B. Sect. 4.4: Multiplication of Matrices

1. Show students procedure for multiplying matrices on the calculator
2. Give textbook assignment in which students use the graphing calculator

C. Sect 4.5: Identity and Inverse Matrices

1. Show students procedure for finding the inverse of a matrix on the calculator
2. Give textbook assignment in which students use the graphing calculator

D. Sect 4.6: Using Inverse Matrices

1. Develop lesson plan on solving matrix equations by using inverse matrices on the graphing calculator
2. Give textbook assignment in which students use the graphing calculator

E. Sect 4.7: Using Cramer's Rule

1. Develop lesson plan on solving large systems of equations using Cramer's Rule and the calculator
2. Give textbook assignment in which students use the graphing calculator

3. Give alternative assessment on an application of solving systems of equations using matrices

F. Give test at end of chapter

1. Students are allowed to use calculator for entire test
2. Students must use calculator to answer 12 questions on test

VI. Chapter 5: Polynomials (end of November through winter vacation)

A. Sect 5.1: Monomials

1. Show students how to use scientific notation on the graphing calculator
2. Give textbook assignment in which students use the graphing calculator

B. Sect 5.2: Dividing Monomials

1. Show students how to divide numbers written in scientific notation on the graphing calculator
2. Give textbook assignment in which students use the graphing calculator

C. Give test at end of chapter

1. Students are allowed to use calculator for entire test
2. Students must use calculator to answer three questions on test

Upon returning from winter vacation on January 5, 1998, there will be six regular school days before final exams begin. Those six days will be spent by beginning the sixth chapter of the textbook and also reviewing for final exams. The topics that are covered in the beginning of chapter six do not coincide with graphing calculator activities. However, while studying for final exams, the functions of the graphing calculator which the students learned throughout the semester will be reviewed. Also, during one of those six days following winter vacation, part of a class period will be spent on the graphing calculator post-test.

Methods of Assessment

In order to assess the effects of the intervention, tests covering the content of the first semester, which includes graphing calculator skills, will be developed. In addition, homework assignments from the textbook will be evaluated, and alternative assessment activities which assess graphing calculator skills will be developed.

CHAPTER 4

PROJECT RESULTS

Historical Description of the Intervention

The objective of this project was to increase students' ability to apply graphing calculator skills when solving mathematical problems. This objective was accomplished through increased instructional emphasis on the functions and capabilities of the graphing calculator.

Throughout the duration of the project intervention, the students were taught concepts from the textbook. The researcher originally planned to incorporate graphing calculator functions throughout the first five chapters of the textbook in order. However, due to a few extra weeks at the end of the semester, the researcher was able to teach some graphing calculator functions found in Chapter Six. These functions included radicals and rational exponents.

Increased instructional emphasis was placed on the graphing calculator through a variety of different types of lesson plans. The functions and capabilities of the graphing calculator were demonstrated by the researcher on an overhead graphing calculator unit. Students were often given problems to try on their own while the researcher walked around and monitored student progress with the calculator. Also, some supplemental worksheets on the functions and capabilities of the graphing calculator were supplied to students. Due to the different types of concepts covered in each chapter of the textbook, the most graphing calculator activities were taught in Chapter Four, while the least amount of graphing calculator activities were utilized in the fifth chapter. Some topics covered in Chapter Four which utilize the graphing calculator include evaluating determinants, matrix multiplication, finding inverse matrices, and using Cramer's Rule. Certain mathematical concepts cannot be taught on the graphing calculator, and many of these kinds of concepts were covered in Chapter Five. Some examples of these topics which cannot be taught on the graphing calculator include dividing monomials, dividing polynomials, factoring, and synthetic division.

A variety of assessments were used to monitor students' progress with and understanding of the graphing calculator's functions. Homework was assigned from the students' textbooks which evaluated their graphing calculator skills. The students also completed two alternative assessment activities which assessed their graphing calculator skills. Finally, the students took teacher-constructed tests which also evaluated their skills with the graphing calculator.

To see how the students improved their graphing calculator skills throughout the intervention, a pre-test and the exact same post-test were given to the students. The researcher gave the graphing calculator pre-test at the beginning of the first semester and originally intended to give the post-test at the end of the semester. However, due to time constraints, the post-test could not be distributed to the students until the beginning of second semester. At the end of first semester, the researcher needed to teach a certain amount of material before the final exam. The researcher also wanted to take the last two days of first semester to review for the final exam. For these reasons, the graphing calculator post-test was delayed until the beginning of second semester. The results of the pre- and post-tests, along with the results of the homework assignments, quizzes, tests, and alternative assessments will be discussed in the next section of this chapter.

Presentation and Analysis of Results

In order to assess students' progress on their ability to apply graphing calculator skills, the researcher used a variety of methods. The researcher recorded homework scores, quiz scores, and test scores, and organized them by chapter of the text book. The researcher also gave two alternative assessment activities which focused on graphing calculator skills. Finally, the researcher gave a pre-test before beginning the graphing calculator intervention, and the exact same test was given as a post-test following the completion of the graphing calculator intervention. All of these methods of assessment will be discussed in this section.

Homework, Quiz, and Test Scores

Throughout Chapter One through Chapter Six of the textbook, homework was assigned to students on a daily basis, with very few exceptions. Daily homework scores were then totaled at the end of each chapter. Quizzes were given throughout each chapter, followed by a comprehensive test given upon the completion of the chapter. For each of the six chapters, the researcher computed the total number of A's, B's, C's, D's, and F's received on homework, quizzes, and tests combined. These raw totals were then converted to percentages. The percentage of students to receive each letter grade for Chapter One through Chapter Six are presented in Table 10. About half of the material taught during the first semester of algebra II utilized the functions and capabilities of the graphing calculator. Because such a large portion of the material related to the graphing calculator, it was not possible for students to earn a letter grade of A, B, or C if they did not understand the components of the calculator.

As Table 10 indicates, students' homework, quiz, and test scores were relatively high. The majority of students earned letter grades of an A or a B on all six chapters. In Chapter One, 62.0% of the grades were A's, while only 0.8% of the grades were F's. The lowest percentage of A's occurred in Chapter Five in which 37.1 % of the grades were A's. Incidentally, this chapter was also the one in which the students used their calculators the least often. The concepts contained in Chapter Five did not coincide with the graphing calculator's functions. The highest percentage of F's occurred in Chapter Six with 7.6% failing grades. Chapter Five also had a relatively high percentage of failures, with 7.5% failing grades. The next section will analyze the students' alternative assessment scores.

Table 10

Percentage of Students' Letter Grades on Quizzes, Tests, and Homework by Chapter

Grades	Chapters					
	Chap 1	Chap 2	Chap 3	Chap 4	Chap 5	Chap 6
A	62.0%	42.7%	57.1%	50.6%	37.1%	46.2%
B	22.3%	30.6%	28.9%	27.2%	31.4%	18.5%
C	8.3%	13.4%	5.8%	11.7%	11.3%	16.8%
D	6.6%	7.6%	3.8%	8.0%	12.6%	10.9%
F	0.8%	5.7%	4.5%	2.5%	7.5%	7.6%

Alternative Assessment Scores

During the researcher's intervention with the graphing calculator, two alternative assessment activities were assigned to the students. Both of these activities were completed individually by the students during a single class period. The first activity assessed the students' ability to find and interpret a prediction equation using the graphing calculator. This activity was worth six points. The second activity assessed the students' ability to work with matrices on the graphing calculator. It also was worth six points. The scores which the students received on these alternative assessment activities are presented in Table 11.

Table 11

Frequency of Students' Raw Scores on Alternative Assessments (n = 40)

Raw Score	Alt Assessment 1	Alt Assessment 2
6	31	16
5	9	14
4	0	7
3	0	3
2	0	0
1	0	0
0	0	0

As indicated in Table 11, the algebra II students performed better on the first alternative assessment than the second one. However, the majority of the students did earn a score of five or six on both alternative assessment activities. Since the alternative assessment activities assessed different skills, these scores may indicate that students found matrices to be a more difficult topic than prediction equations. Finally, students' pre- and post-test scores will be analyzed.

Pre-Test and Post-Test Scores

At the very beginning of the school year, the researcher gave the algebra II students a pre-test on graphing calculator skills. The test had five questions, one with two parts. The test was worth a total of six points. The researcher then began the graphing calculator intervention as described in the action plan of Chapter Three. The intervention continued throughout the first semester. At the end of the semester the students took their final exams. At the very beginning of the second semester, the researcher gave the exact same graphing calculator test that was given at the beginning of the school year. The researcher used this as a graphing calculator post-test. Table 12 gives the results of the students' scores on both the pre- and post-tests.

Table 12

Frequency of Students' Raw Scores on Pre- and Post-Tests (n = 41)

Raw Score	Pre-Test	Post-Test
6	0	4
5	0	4
4	0	4
3	0	11
2	0	9
1	27	8
0	14	1

As Table 12 illustrates, the students showed a marked improvement from pre-test scores to post-test scores. The highest score received on the pre-test was one out of six points. However, on the post-test, four students earned six out of six points. When the students took the pre-test, 14 of them received a score of zero. In contrast, only one student did not answer any questions correctly on the post-test. Because the scores showed such improvement, it is obvious that the students did master some graphing calculator skills. The scores on the post-test may have been even higher if the researcher had given the test at the end of the first semester. However, due to time constraints this was not possible. In the next section of this paper, conclusions will be drawn and recommendations made in regard to the graphing calculator intervention. These conclusions and recommendations are based on an analysis of the results of the graphing calculator intervention.

Conclusions and Recommendations

Based on an analysis of the results presented in the previous section, conclusions about the graphing calculator intervention will be discussed. Also, recommendations will be made on how to possibly improve the graphing calculator intervention.

Conclusions

Overall, the graphing calculator intervention was effective. This conclusion is based on three different sets of results. These three sets of results include relatively high letter grades throughout each chapter of the textbook, relatively high alternative assessment scores, and finally, a marked improvement of post-test scores over pre-test scores. Because the students did well on homework, quizzes, tests, and alternative assessment activities, the graphing calculator intervention was a success. Also, the large difference between the pre- and post-test scores demonstrates that the students did learn graphing calculator skills.

Although the post-test scores did greatly improve over the pre-test scores, they were not as high as the students' grades on homework, quizzes, tests, and alternative assessment activities. There may be a few different reasons for this. First, due to time constraints, the post-test was given at the beginning of second semester, rather than during first semester. All of the material needed to answer the questions on the post-test was taught during first semester. If the post-test had been given during first semester, the scores may have been higher.

Another reason that the students may not have scored as high on the post-test is that the post-test was a cumulative test which covered material that was taught throughout the entire first semester. In contrast, the homework, quizzes, tests, and alternative assessment activities only covered material within a single chapter. The post-test was an all encompassing test, and therefore, was probably more difficult for the algebra II students.

For the most part, the scores which the students earned on homework, quizzes, tests, and alternative assessment activities were relatively high. However, there were some students who earned below average grades on these activities. Also, not everyone improved from the pre-test score to the post-test. For example, there was a student who earned a zero on the graphing calculator post-test. It is the researcher's opinion that these low scores are not due to weaknesses of the graphing calculator intervention. Instead, these low scores are due to individual students' weaknesses. Some students have difficulty learning mathematical concepts, or they may lack the motivation to do well. Those students who did not perform well on homework, quizzes, tests, and alternative assessment activities are those students who have mathematical weaknesses or low levels of motivation. Any ineffective points of the action research were due to individual students' weaknesses, rather than weaknesses of the intervention itself. Some examples of students' weaknesses include a lack of basic arithmetic skills, a lack of skills which should have been mastered in algebra I, and a low logical-mathematical intelligence. While the researcher does endorse the chosen graphing calculator intervention, some suggestions for improvement are possible.

Recommendations

The graphing calculator intervention described throughout this paper was effective, and therefore is endorsed by the researcher. However, there are certain facets of the intervention which the researcher would change, if possible. Following is a description of those recommendations.

If possible, all students of the targeted classes should own a graphing calculator. This would allow students to take their calculators home to work on homework assignments. If all students cannot own a graphing calculator, then calculators should be readily available in the classroom at all times. Those students who do not own a graphing calculator should be assigned one of the classroom calculators which they could use during class time throughout the entire school year. This would be helpful to both the teacher and the students because every day they know which calculator every student will use.

Another item which should be readily available in the classroom is the overhead graphing calculator unit. The instructor uses this unit to demonstrate how to perform certain graphing calculator functions. The students can look on the overhead and can see exactly what the teacher is demonstrating. The overhead graphing calculator unit allows students to be sure that their calculator screen matches the screen of the instructor. It is important that this vital piece of equipment be readily available for the benefit of both the instructor and the students.

Some schools may not have access to the overhead graphing calculator unit. Teachers who intend to teach the graphing calculator's functions without the overhead unit would have to make some adjustments. The instructor would need to write out the steps for applying a graphing calculator function either on the board or on an overhead. The teacher would also need to draw what the students should see on the screens of their graphing calculators. The teacher may want to put the students into groups of two or three when working with the graphing calculator. This would allow students to help each other to find the correct buttons on their calculators and to compare screens. The instructor could also walk around the classroom and give as much individual help as possible.

A final recommendation for the graphing calculator intervention is that the instructor and the students perform some fun exploratory activities, if the curriculum and time constraints allow. Students generally enjoy exploring and discovering the functions and capabilities of the graphing calculator. By allowing students some freedom with the calculator, the may enjoy and appreciate it more. The instructor may even want to demonstrate some capabilities of a more advanced graphing calculator, such as the TI-92, a graphing calculator made by Texas Instruments. These types of exploratory and discovery activities may help to "turn students on" to mathematics.

As a final conclusion, the graphing calculator intervention performed by the researcher was effective and beneficial for the targeted algebra II students. This fact is made evident by the presentation and analysis of the intervention's results. The researcher has made a few suggestions to increase the intervention's effectiveness. However, the researcher does strongly endorse the intervention and recommends that other math instructors could benefit by trying a similar action research project.

According to Chapter One of this paper, various problems are associated with an increased use of the graphing calculator in the mathematics classroom. These problems can be summarized into one large problem which is that students do not fully understand all of the graphing calculator's capabilities. The graphing calculator provides tools to aid in problem solving which is especially helpful for the weaker math student. However, these capabilities are meaningless unless students know how to take advantage of them. The researcher was aware that students do have difficulty utilizing the calculator's functions and capabilities. The action research described in this paper was designed with the purpose of alleviating this problem. The researcher used various methods to teach students how to correctly apply the functions and capabilities of the graphing calculator. Other researchers may be interested in continuing this research and devising other methods to help students understand the graphing calculator and its functions and capabilities.

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APPENDIX A

STUDENT SURVEY

Graphing Calculator Survey

Please answer the following questions by circling the appropriate response.

1. Do you own a graphing calculator? Yes / No

2. How important do you believe the graphing calculator will be in this algebra II class?

not important				very important
1	2	3	4	5

3. Have you ever used a graphing calculator to simplify a numerical expression by applying the order of operations (i.e. parentheses, exponents, multiplication, division, addition, subtraction)? Yes / No

4. Below is a list of some of the functions of the graphing calculator. Have you ever used these functions of the graphing calculator? Answer "yes" or "no." If you don't know what the function is, answer "no."

The "GRAPH" function	Yes / No
The "TRACE" function	Yes / No
The "TABLE" function	Yes / No
The "WINDOW" function	Yes / No
The "MATRIX" function	Yes / No
The "INTERSECT" function	Yes / No

5. Please rate how often you used the graphing calculator in geometry class.

Never	Once/Twice a Month	Once a Week	Two or Three Times a Week	Daily

APPENDIX B

GRAPHING CALCULATOR PRE- AND POST-TEST

Name______________________

Graphing Calculator Assessment

Use your graphing calculator to complete the following exercises.

1. Evaluate $2\left[5 + \frac{4(3 + 7)}{5}\right] + 13$

Answer____________

2. Use your graphing calculator to graph the equation y = -8x + 32. State the range values that you used to view a complete graph of the equation.

Range Values____

3. The table below shows the years of experience for six encyclopedia sales representatives and the amount of sales during a given period of time.

Amount of Sales	$9,000	$6,000	$4,000	$3,000	$5,000	$8,000
Years of Experience	6	5	3	1	3	6

a. Write a prediction equation from this data.________________

b. Predict the amount of sales for a representative with 8 years of experience.__________________

4. Use your graphing calculator to solve the following system of equations. Determine the x- and y-coordinates accurate to six decimal places.

$$2.1x + 3.2y = 4.3$$
$$1.4x - 1.8y = 1.6$$

solution________________

5. Let $B = \begin{bmatrix} 5 & -2 & 6 \\ 4 & -7 & 1 \end{bmatrix}$ and $C = \begin{bmatrix} 1 & -5 \\ 4 & -3 \\ 4 & -8 \end{bmatrix}$.

Find det BC.______________

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