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A study of the impact graphing calculators have on the achievement in high school pre calculus

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A STUDY OF THE IMPACT GRAPHING CALCULATORS HAVE ON THE ACHIEVEMENT IN HIGH SCHOOL PRE CALCULUS

by
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ABSTRACT

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The use of graphing calculators in high school mathematics has long been debated. The transformation of function, in particular, parabolas, was studied and it was shown that there was no loss of achievement in Pre-Calculus classes with the use of graphing calculators. Assessments examined the impact of the graphing calculator on the conceptual knowledge of the topics by testing the students without the graphing calculator and with the graphing calculators. Five classes of pre calculus students (two classes who used graphing calculators and three who did not) were used in the study. The same students were used in the before and after assessments to more accurately analyze the impact of the graphing calculator on learning. After the second assessment, the students were given a survey using Likert-type items to investigate the attitude towards the graphing calculator as a teaching tool. This survey was divided into two parts; the ability to use a graphing calculator and the effect graphing calculators has on the mathematics experience.

ABSTRACTETTE

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CHAPTER ONE

INTRODUCTION

There have been discussions regarding the benefits of using graphing calculators in school classrooms since they were introduced 20 years ago. Educators both pro and con cite research to defend their respective positions. Since the debate over graphing calculator use continues, the research of their use must also continue. With more advanced graphing calculators being introduced, it has become more important to weigh the benefits of calculator usage in a changing and more technological mathematics classroom. Opinions vary on how much students should rely on a graphing calculator to do homework, class work, and assessments in all levels of high school mathematics. Graphing calculators serve as a tool for the student to associate the links between algebraic and graphical representations. They can help to build the connections between process and concept (Graham & Thomas, 2000).

Graphing calculators were found to have a positive impact on general Algebra performance and in particular the understanding of functions. The use of graphing calculators is more in line with the constructivist theories with a more exploratory approach to problem solving than the traditional approach which has the student do many problems on paper. This switch in teaching methods could mean a revamping of the mathematics curriculum, but only if the research warrants such a change. By developing problem solving skills with the graphing calculator, the student enhances their conceptual knowledge as well as the computational skills (Texas Instruments, 2003).

Statement of the Problem

Secondary math teachers generally have been cautious about calculator use. Some teachers think that students might rely too much on calculators of any type and that those who use a graphing calculator to arrive at the solution to a problem simply push a sequence of keys that the teacher gave them and do not understand the questions or process involved. Other educators believe that graphing calculators enhance learning by showing the connections between algebraic and graphical representations (Smith & Shotsberger, 1997). Often teachers, who are opposed to using graphing calculators, feel uncomfortable using them. Educators become at ease in their chosen approach to teaching mathematics and they do not want to change their methods to incorporate the graphing calculator or other technology, if they are not already using it. By utilizing the graphing calculator, the present curriculum has to be revised to incorporate the technology as well as revising the assessments to include the use of a graphing calculator while testing the student's knowledge of the concept. This is something teachers may not want to do. Others feel it takes up too much class time to instruct students in the proper use of a graphing calculator. While this is true initially, the potential for growth in conceptual knowledge is well worth the class time.

Earlier studies found that students who used graphing calculators were better able to understand algebra conceptually as opposed to students who were taught in the traditional manner, without the aid of technology. Ruthven's study (as cited in Smith & Shotsberger, 1997) shows that the students who used some type of hand held graphing utility had higher academic performance levels than the students who did not use graphing calculators. The student has an opportunity to visualize the functions and their properties when a graphing calculator is used. They also allow the student to examine more examples and to arrive at different conjectures through investigations instead of being told these concepts by the teacher. This discovery method enables the student to have a deeper understanding of the concept and therefore remember it.

Later studies show that there is little significant difference in the overall performance by students who use graphing calculators. However, upon further analysis there are significant differences with the conceptual performance when the overall performance is separated into procedural performance and conceptual performance (Cassity, 1997). Procedural knowledge are the rules to complete the process of solving functions and their applications where conceptual knowledge has the student link the process and the rules for a greater understanding of the concept. The student can remember the steps in solving a problem, but not the reasons they are using those steps.

One of the main differences between arithmetic and algebra is the variable. Some students have a hard time understanding this concept and therefore the transition from arithmetic to algebra is difficult. In order for students to use variables effectively, they have to understand their versatility. The graphing calculator facilitates deeper understanding by not only showing the specific answer after substitution, but also a connection to a family of equations (Graham & Thomas, 2000).

By using a graphing calculator the student has the opportunity to see how changing the value of the variable changes the function. While this can be achieved without a graphing utility, more examples can be investigated on the same screen and those examples can be graphed more accurately. The student then can arrive at a conjecture which can be verified by the teacher instead of just relaying the information to the student without investigation. This enhances the student's conceptual knowledge creating a deeper understanding of the topic. The procedural knowledge is also deepened with the repeated investigations and the student gains overall knowledge of the concept.

Significance of the Study

By its nature the graphing calculator reinforces the connection between the graphic form and the symbolic form. Students look for a graphical approach to the problem and try to make new conceptual connections. (Texas Instruments, 2003) "Although the use of graphing calculators has become extensive in high school, community college, and university mathematics classrooms in the last few years, little is known about how and why graphing calculators make a difference in mathematical understanding" (Cassity, 1997, p.488). There has been more research in recent years on the general performance of students in a mathematics classroom focusing on the reason students perform better when instructed with a graphing calculator.

It is common practice for students to be shown the process of using a variable but not the concepts behind the process. This does not give the student the whole picture. The graphing calculator allows the student to see what happens to the function when the variable is changed. Granted, this can be accomplished without the use of a graphing calculator, but using one enables the teacher to demonstrate more examples and guide the student to the conclusion. The student plays a more active role in the educational process. Since there are teachers on both sides of calculator usage as an instructional tool, the research on its benefits has to continue (Texas Instruments, 2003). More research is needed to determine if the graphing calculator does have an impact on achievement and understanding. The research would give the teacher evidence needed to use graphing calculators or the evidence that graphing calculators do not make a difference.

Purpose of the Study

The purpose of the study was to establish the impact of graphing calculators in Pre-Calculus classes with respect to conceptual learning and attitude towards learning. The subjects in this study investigated quadratic functions and determined what affect the ‘a’coefficient had on the graph of the function as well as what determined a shift of the parabola horizontally and vertically.

Most of the research involving graphing calculators was done with college level mathematics. There has been more research in recent years directed at the secondary level, but more research is needed to further ascertain the benefits of the graphing calculator since there are teachers on both sides of using the graphing calculator as an instructional tool.

Assumptions and Limitations

Pre-Calculus classes were chosen because of the curriculum content and how graphing calculators can be used. The classes were taught the effect of different transformations on the basic quadratic function. Two different teachers were asked to participate in this study, one who uses graphing calculators on a regular basis and one who does not. This allowed for a comparison of how effective the use of graphing calculators was in teaching quadratics. By using a graphing calculator, a connection between the procedural knowledge and conceptual knowledge could be demonstrated by illustrating several iterations of the problem on the screen at the same time.

The population to be studied is very limited. It consists of five Pre-Calculus classes taught at Washington Township High School during the 2006-2007 school year. Three of the classes were taught with out the graphing calculator and two with the use of graphing calculators. There were members of non-calculator group that owned a graphing calculator and used a graphing calculator for homework but not the assessment. The students who use a graphing calculator will be given a survey to self assess math confidence and personal opinion of the effectiveness of the graphing calculator. To assess academic achievement, each group will be given the same pre- and post-test. The pre-test consists of questions to determine the level of understanding before the actual lesson was taught. The post-test was administered to determine the level of procedural and conceptual knowledge after the lesson was taught. The comparison of the results will determine the effectiveness of the use of graphing calculators.

Operational Definition of Important Terms

1. Pre-Calculus: The fourth year of math generally taught to juniors and seniors. It consists of a semester of instruction on functions and a semester of instruction in Trigonometry.

2. Conceptual Knowledge: Understanding the relationship between different concepts in math. The student understands how each step of the solution is connected.

3. Procedural Knowledge: Familiarity with the symbol representation system and rules, algorithms and procedures (Cassity, 1997). Learning takes place by rote with little understanding of why. Procedural knowledge is found more in the traditional approach to teaching math.

4. Graphing Calculator: A special type of calculator that is able to display and analyze graphs of functions. For the purpose of this study, the students will be using TI-84 family of calculators.

6. Operational Skills: The skills necessary to solve problems on a test.

7. Computational skills: Problems solved through paper and pencil skills.

8. Meta-analysis: The analysis of the results of studies that have a common topic.

9. Pre-test: Assessment given before instruction on the procedural and conceptual knowledge of the subject matter.

10. Post-test: Assessment given after instruction on the procedural and conceptual knowledge of the subject matter.

Research Questions

The following questions will be addressed in this study:

1. Does the use of graphing calculators in the classroom enhance students' conceptual understanding of quadratic functions?

2. Do graphing calculators create a difference in the attitude toward math of the students?

Hypothesis

There is no significant difference in the conceptual knowledge of Pre-Calculus students in the study of quadratic functions and their graphs when graphing calculators are used in instruction. In addition, there is no significant difference in the attitude toward math of the students when graphing calculators are used for instruction.

Organization of Remaining Chapters of the Report

Chapter two includes a review of the research literature and how the literature is relevant to the study. This section includes the history of graphing calculator use in secondary schools and how a change in standards is bringing about a change in teaching techniques.

Chapter three defines the study by detailing the methodology used, describing the population to be studied and how the study is to be conducted. The student groups involved will be defined as those used graphing calculators for instruction and those who did not. Also included is the instrumentation of the study and how the data was collected.

Chapter four analyzes and explains the data collected. The results of the surveys and assessments are detailed in the chapter. Statistical analysis is used in an attempt to address the research questions and make a determination of the soundness of the hypothesis.

Chapter five makes conclusions based on the data collected and summarizes the results. Here the research questions are answered and recommendations for further study are made.

CHAPTER TWO

REVIEW OF LITERATURE

History of Graphing Calculator Use

In 1986, the National Council of Teachers of Mathematics (NCTM) recommended that graphing calculators be integrated into all levels of mathematics and into all aspects of mathematics (Dion, Jackson, Liu, Wright, & Harvey, 2001). Integration would include lessons, class work, homework and assessments. In 1989, the NCTM repeated the recommendation that calculators, in particular, graphing calculators should be allowed at all levels of mathematics and should be made available to all students (Dion et al., 2001). In 1998, NCTM also recommended that assessments must recognize the availability and access of calculators and be constructed in such a way to incorporate their use (Dion et al., 2001). In 2000, the NCTM in their *Principles and Standards for School Mathematics* continued to advocate graphing calculator use at all grade levels and all levels of mathematics.

Students and teachers were spending too much time on paper and pencil calculations. Calculators gave the students a way to do more problems in the same time. This enabled the student to make conjectures and test them out more readily. The student became a more active part of the learning process. The graphing calculator gave the student the opportunity to visualize what they were studying, opening them up to a more conceptual understanding of the topic rather than a procedural one. The student is actively involved in the problem solving process. With the graphing calculator, they are able to review similar problems and develop an understanding of the concept (Waits and Demana, 1998).

From the teacher's standpoint, the graphing calculator allowed them to demonstrate more problems in less time. It also allowed the student and teacher to discuss more complex applications of the concepts being taught and then make generalizations to gain understanding of the concept (Waits and Demana, 1998).

The next logical step was for graphing calculators to be incorporated into all standardized tests. In 1994, calculators were allowed but not required on the Scholastic Aptitude Test (SAT). In 40% of the questions on the SAT II Mathematics level 1C and 60% of the questions on the SAT II Mathematics level IIC, graphing calculators would be useful if not essential in solving the problem (Dion et al., 2001). Not all graphing calculators were allowed for use on the test. The Education Testing Service (ETS) considers any device that has a QWERTY keyboard to be a computer. Since computers are not allowed on the SAT, any calculator with a QWERTY keyboard is not permitted. This is still the basis for calculator use on standardized tests today, including SAT and Advanced Placement.

Graphing calculator capabilities increased with each new generation of calculators to the point where they can help solve equations, factor polynomials, and expand polynomials. The increase in functionality has impacted the difficulty and type of questions on assessments. The use of calculators in the mathematics classroom is still evolving. Teachers have to redesign curriculum and assessments to include the use of graphing calculators, but their use has to be in conjunction with the understanding of mathematical concepts not just pushing buttons to get an answer. This is where the teacher has to guide the student to an appropriate use of the calculator. There has to be a combination of calculator use and solving the problem analytically with paper and pencil (Waits and Demana, 1998). This is a challenge that some teachers do not want to take and one of the reasons graphing calculators are not more widely used in high school.

It is common practice for the student to be shown the process of using a variable in a mathematics classroom but not the concepts behind the process. The graphing calculator can help build the connection between process and concept by displaying several solutions of functions. This connection helps to build a solid foundation for Algebra. The teacher can explore, with the student, different ways to solve a problem, numerically, graphically, and analytically. The calculator can help to demonstrate the process in solving the problem by using a table or a graph. The student can confirm the results analytically with paper and pencil. This builds a foundation of conceptual understanding of the subject matter which might not be as evident if taught in the traditional manner (Graham & Thomas, 2000).

Standards

"Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning" (NCTM, p. 11). According to the NCTM standards, students can develop a better understanding of the concept with a graphing calculator than without one. The graphing calculator eliminates the tedious and time consuming paper and pencil calculations and allows the student to visualize what is being taught.

The *New Jersey Core Curriculum Content Standards* (NJCCCS) has a similar view of calculators. Calculators are not supposed to take the place of pencil and paper skills, but enhance a deeper understanding of mathematical concepts. Graphing calculators in particular can help the student explore properties of functions by examining graphs and making connections to functions.

Every school in New Jersey is encouraged to adhere to the NCTM standards. However every school in New Jersey has to adhere to the NJCCCS since the standardized tests given at various grade levels are all standards-based tests. Lessons are aligned to the standards and technology is included in the standards. Textbooks are now written with the NCTM standards and individual state standards in mind and have increased the amount of technology used. The standards use a balanced approach to learning mathematics with skill work and modeling real world applications part of the curriculum. The emphasis has switched to applications and the graphing calculator allows the student to solve more complex problems (Waits and Demana, 1998).

Achievement

Success in the classroom may be influenced by teaching methods as well as technology (Graham, Headlam, Honey, Sharp, & Smith, 2003). Most researchers agree that graphing calculators do not hinder achievement in mathematics classrooms (Smith & Shotsberger, 1997). Results indicate that a revised curriculum and the use of graphing calculators lead to a greater conceptual understanding of the content than a more traditional curriculum (Texas Instruments, 2003). There has to be a balance in the approach to calculator use in the classroom. In using the graphing calculator in the classroom, the teacher has to define the extent of using a graphing calculator. There has to be a balanced approach to teaching with technology. Students need to know the concept or theory behind the solving a problem. There are problems that the student can solve analytically using the traditional pencil and paper, and then confirm the solution with the graphing calculator. There are also problems that are solved first with a graphing calculator and then are solved with traditional methods to see if the results are the same.

With the graphing calculator, the student can look for solutions to problems using tables and a numeric approach. These solutions can be confirmed with a graph or with paper and pencil. A student can model, simulate and solve a problem on the graphing calculator, followed by an analytic approach in the traditional manner. There are some problems that can not be solved analytically. In these cases the graphing calculator proves to be enormously helpful in gaining the solution and conceptual understanding of the concept (Waits and Demana, 1998).

The differences in understanding are more evident with conceptual knowledge than with procedural knowledge. Conceptual knowledge is the connection of ideas to solve problems whereas procedural knowledge focuses on the symbolic representation of the problem. Greater understanding of the problem comes with a deeper understanding of conceptual knowledge. When graphing calculators are used as a tool to demonstrate algebraic functions, there is an improvement in conceptual mathematical performance (Cassity, 1997).

Ellington concluded in her meta-analysis that when graphing calculators are used in instruction but not used for the test, there was no change in the computational skills of the student. She also concluded that when calculators are used in both instruction and on the test, all skills improved except being able to select the appropriate problem solving skill (Ellington, 2003).

It has also been shown that if the calculators are used for the entire year as opposed to one or two topics, the student develops a better understanding of functions whether they are graphing or non-graphing (Texas Instruments, 2003). Teachers find it difficult to justify using graphing calculators for the entire year because they are not sure of the benefits. Some still feel that graphing calculators do the work for the student and that the student does not learn. Research has shown that this is not true. As reported in the meta-analysis conducted by Ellington, students showed improvement when they used graphing calculators in the understanding of graphical representations, understanding the relationship between the function and the graph and the visualization of the spatial relationships between the graph and the function.

There is improvement in achievement when the graphing calculator is used. By its nature the graphing calculator can be used to reinforce the connection between the graphic form and the symbolic form. Students look for a graphical approach to the problem and can make new conceptual connections (Texas Instruments, 2003)

Part of this learning is from spatial visualization. The graphing calculator enables students to see the functions and to understand the connections. A classic example is the transformation of functions. The student can see the effects of changing the function, draw conclusions and make generalization based on what they observe on the graphing calculator. However, the graphing calculator alone does not result in a greater understanding of function. There has to be a curriculum that reinforces the understanding of functions. The teacher is still a valuable tool in the learning process. The student can then use the graphing calculator to further investigate functions on their own to clarify the conceptual understanding. This is ideally what the teacher would like to happen. This would create a desirable learning experience for the student and hopefully lead to more independent investigations (Ellington, 2003).

Students gain more confidence in understanding spatial visualization as well as a better understanding of the conceptual knowledge of functions by using a graphing calculator as a tool of learning (Cassity, 1997). There were more positive attitudes about mathematics with the students who used graphing calculators. Studies showed that there was the most impact when the graphing calculators were being used as part of the curriculum for the entire year as opposed to a few topics here and there (Ellington, 2003). This impact was not only in the general skill level, but also with the conceptual understanding of functions without the loss of computational skills. There was also a positive impact on the achievement of high risk students and the amount of time teachers had to spend on teaching problem solving due to the ability of the graphing calculator to visually demonstrate spatial relationships (Texas Instruments, 2003).

Graphing Calculators and Pre-Calculus

Algebra has been studied for centuries, most obviously without the benefit of calculators. Pre-Calculus brings together the skills learned in Algebra and Geometry. The graphing calculator allows the student to visualize different functions. The student still has to know the domain and range of a function in order to see the entire function on the screen. Students are made more aware of the connection of the domain and range to the function by observing the calculator screen and how different functions have different domains and ranges. The teacher's role changes to that of a guide, helping students through various investigations on the calculator. The lesson generally begins with a discussion about the function to be studied. With carefully crafted questions, the student is directed through situations where they have to evaluate mathematical misconceptions.

In the present study, the concept of transformation of functions, in particular, the parabola is being studied. With the graphing calculator, the teacher is able to show students the relationship between the changes made to the function and the graphs of the function, including shifting horizontally or vertically and reflecting over the x- or y-axis. Students can investigate how the changes to the coefficients and constant of the function affect the shape and placement of the function in the coordinate plane by graphing numerous quadratics and comparing their graphs.

With some revisions to the curriculum the teacher is able to take the traditional lesson of exploring functions with paper and pencil and make it into a discovery lesson using a graphing calculator. When some students do not understand the connection between a graph, an equation and a function, the calculator is able to connect the different representations of a function (VanDyke & White, 2004). Graphs are still difficult for students even with a graphing calculator, mainly because the student has not yet developed the necessary visual thinking skills. A major goal in a Pre-Calculus class is for the student to obtain a greater understanding of functions and make the connection between the function and its graph. The student makes the transition from concrete examples to more abstract understanding of mathematics. The graphing calculator, used as a learning tool, allows students to understand the relationship of a function and its Cartesian connection (Graham & Thomas, 2000).

Assessment and the Graphing Calculator

Assessments need to be modified to include the use of graphing calculators. They should be constructed to have problems that allow for graphing calculators and those that do not permit the use of a graphing calculator. There are three types of questions in an assessment; calculator inactive, calculator neutral, and calculator active (Beckmann, Senk, & Thompson, 1999). In creating assessments, the teacher has to be aware of the capabilities of calculators and the student familiarities of the graphing calculator used in the classroom and create questions that will challenge the students' understanding of the concept.

There are different levels of graphing calculator use: quasi-scientific (using the graphing calculator as a scientific calculator), semi-proficient (some of the graphing calculator's capabilities are used), proficient (the student is aware of most of the capabilities of the graphing calculator) (Graham et al., 2003). There needs to be a mix of questions including some where students not only have to give the answer, but explain or justify the answer. Teachers look for the process of solving a problem to be as significant as or more important than the answer (Graham et al., 2003).

Many detractors of calculator use feel that students just push a memorized set of keys without any actual understanding of the material. While this may have been true at one time, students, with lessons including the graphing calculator, now can see the connection between the algebraic and graphic representations. Questions posed on tests and quizzes need to be changed to include assessing the knowledge of this connection. Questions about quadratics might be; to determine the domain and range of a function, to evaluate a function, to determine how the vertex of the function changes as transformations are applied. Explaining or justifying answers should be part of the assessment. This would test the students' conceptual knowledge of quadratic function.

When graphing calculators are used in instruction as well as testing, the student showed better results in conceptual knowledge and problem solving skills than with the use of a scientific calculator. Operational and procedural skills benefited from any type of calculator. (Ellington, 2003)

Summary of Literature Review

It has been said that nothing is as constant as change. For calculators to be incorporated into the learning process, they must be found to be effective in helping that process. Some students do not trust the answer arrived at with a calculator. Others feel it takes too long to solve a problem using a graphing calculator. Once a student understands how to use a graphing calculator, they are generally more likely to use a graphing calculator and are confident in the results (Graham et al., 2003).

Calculator use varies among different teachers. This difference comes from a lack of knowledge on how to use a graphing calculator in class effectively. Some teachers have the opinion that a calculator does too much for the student and that their basic skills are lacking. Others see the benefit of the graphing calculator as another tool in the classroom. Teachers need to design lessons that incorporate discoveries with the graphing calculators to strengthen conceptual understanding (Ellington, 2003). However, some teachers are set in their teaching strategies and do not want to waiver from the traditional method of teaching. These teachers feel that there is not enough proof that using a graphing calculator will increase the conceptual or procedural knowledge of the student and they remain resistant to changing their teaching strategies.

This difference of opinion also carries over to college classrooms although there does seem to be more graphing calculator use at the college level than at the high school level. This could be the result of the fact that most of the research looks at the affect graphing calculator have at the college level. High school is where the student needs to develop a strong base in understanding mathematical understanding and skills to carry through to college mathematics. Research needs to continue to determine the effect graphing calculators have on the understanding and manipulation of functions. It needs to be determined what the appropriate use of graphing calculators is in the classroom. One result of research might be the development of curriculum specifically written with technology in mind. In order for graphing calculators to be used effectively, lessons that involve a more investigative approach to learning may provide better results. This different approach to learning may also have an effect on the attitude of the student to mathematics.

CHAPTER THREE

METHODOLOGY

Purpose and Construction of Study

This study analyzes the effect graphing calculators have on the conceptual understanding of the transformation of functions, specifically parabolas. Students' understanding of the concept were tested and analyzed after instruction by two different teachers and under two different circumstances, with and without the use of a graphing calculator for instruction. The purpose of the study is to determine the affect graphing calculators had on achievement.

Demographic Information of the Study

The study was conducted at Washington Township High School in Sewell, NJ. The school is a 9–12 high school with approximately 3086 students in attendance. The student population is divided as follows: freshmen–817, sophomores–771, juniors–766, seniors–732 (Washington Township School District, 2006). The New Jersey Department of Education (2000) listed the District Factor Group (DFG) for Washington Township as "FG," based on the 2000 Decennial Census data. The DFG measures the socioeconomic status (SES) of the community with rankings from "A" to "J." The higher letter classification reflects a higher SES. The DFG is used to compare standardized testing in similar SES districts.

The physical complex of the high school consists of three sections, 9/10 wing, 11/12 wing, and the Core. The building is approximately three tenths of a mile from end to end. There are Executive Assistant Principals and Vice Principals for the 9/10 and 11/12 wings with the office of the Executive Principal housed in the Core. Guidance is also centrally located in the Core (Washington Township School District, 2006).

The math department consists of approximately 30 teachers and is managed by a department supervisor. Math teachers at Washington Township High School generally have two different subject matter preparations. All teachers have access to TI–83, TI–84, TI–86, or TI–89 graphing calculators as well as scientific calculators. Some students have their own graphing calculator and some use the calculators available for use in the classroom. Some teachers allow calculators to be used as part of classroom instruction and others do not use calculators.

Population and Sample Selection

The population for this study was the students of Washington Township High School in Sewell, NJ. The convenience sample for this study consisted of seniors and juniors enrolled in Pre-Calculus. Two classes were being taught with the graphing calculator by Teacher A, while three being taught by Teacher B did not use a graphing calculator. Of the students who participated in the study, 45 were Pre-Calculus students who used a graphing calculator and 55 were Pre-Calculus students who were not taught with graphing calculators. Pre-Calculus is a fourth year math class in the college prep curriculum. Students in this course either go on to college mathematics or to a fifth year of math in the high school.

Instrumentation

The assessments used were created by the researcher and designed to test the student before and after instruction on the graphing calculator. The lesson focused on the transformation of a parabola in the form of $f(x)=a(x-h)^2+k$. The students investigated the differences in the parabola after a change in *a, h,* and/or *k*. The concept was developed over the course of one week beginning with a pre-test (Appendix C) given to all students to assess the level of achievement before instruction. Teacher A then instructed her students in the effects of transforming quadratics with the use of a graphing calculator. These students were able to graph the parent function and observe the different parabolas after the transformations were applied. They were able to observe the effect the "a" coefficient had on the width and orientation of the parabola. They were also able to see a connection between changing the "b" coefficient and the placement of the vertex. A similar plan was implemented in Teacher B's Pre-Calculus class, but graphing calculators were not part of the planned discussion. In the non calculator classes, the students graphed the variations of the parabolas by hand using techniques learned in Algebra II. They were able to graph the change in the axis of symmetry and the change in the vertices of the parabola. This study tried to determine if using a graphing calculator gave a more conceptual understanding of the transformation of functions. A post-test (Appendix C) very similar to the pre test was administered at the end of the lesson.

The initial questions on both the pre- and post-tests were constructed to test the understanding of a single transformation of a parabola by asking how the graphs of the functions differ. The final question asked the student to find the equation of a parabola with a given axis of symmetry and minimum or maximum point. Both the pre- and post-tests used by the teachers were reviewed and piloted by other members of the mathematics department to check for reliability and validity. It was determined that the assessments would give a picture of the students' conceptual understanding of the material with and without the use of a graphing calculator. To further investigate the impact of the graphing calculator, a survey (Appendix D) was given to the students who participated in the study. This survey consisted of four parts: Demographic Information, Ownership of a Calculator, Operation of a Graphing Calculator, and Graphing Calculator Use. The first section asked for information regarding gender and grade level. The next section inquired about ownership of a calculator, if they had a calculator and if so what kind. The survey also asked if this was the first time that they used a graphing calculator in math class. This was followed by the students' ability to operate the calculator as suggested by previous research (Smith & Shotsberger, 1997). The questions were limited to functions and the ability to evaluate, graph, and interpret functions using the graphing calculator including being able to program the calculator to achieve the answer. The same research was the source of statements concerning the students' opinion of the usefulness of the calculator in a Pre-Calculus class. The survey also inquired about the students' comfort level in using the graphing calculator in the classroom and on assessments. The survey also investigated the effect graphing calculators had on the conceptual understanding of functions.

Following approval from the Institutional Review Board of Rowan University (Appendix A), pilots were conducted on the assessments and the survey. A professor at Rowan checked the assessments and survey for validity and reliability. This math educator concurred that the assessment tested the conceptual knowledge of the student with respect to this specific Pre-Calculus skill.

Data Collection

Permission was requested and granted from the Executive Assistant Principal of Washington Township High School 11/12 Wing to use specific Pre-Calculus classes and to survey the students on the use of graphing calculators. The students were given the assessments (Appendix C) over two days in November and December, 2006. The survey (Appendix D) was given to the students in March, 2007. There was a delay in giving the students the attitudinal study to give them more opportunities to use a graphing calculator in class and on assessments. Students were given a consent form before the pre-test, post-test and surveys were completed. The pre- and post-tests were graded on a six point scale. The questions were either right or wrong with no partial credit given. Grades for the assessment were recorded without the students' name, allowing for a blind study. The tests were numbered to allow for a direct comparison of the change in achievement. The survey consisted of 25 Likert-type statements with choices for five opinions, "Strongly Agree", "Agree", "Neither Agree or Disagree", "Disagree", and "Strongly Disagree".

Data Analysis

After the data were collected it was analyzed using Statistical Package for the Social Sciences (SPSS) and Microsoft Excel. The independent variable was determined to be the number of students involved in the study. The dependent variable was the results of the tests and the attitudinal survey.

The mean scores for the pre- and post-tests of the traditional classroom and those from the experimental classroom were compared using paired samples test. The average gain of each group was also compared to test for any significant gain or loss. Frequency tables were developed from the data of the surveys. Corresponding percentages, means and medians were calculated for the survey using statistical software. Any outliers were taken into consideration. Conclusions were then made on the achievement and usefulness of a graphing calculator in understanding transformations of functions.

CHAPTER FOUR

FINDINGS

Profile of Study

The subjects for this study were selected from students at Washington Township High School, Sewell, NJ enrolled in Pre-Calculus classes. Pre-Calculus is a fourth year math class and students are either juniors or seniors. The 93 students involved in this study were given a test before and after instruction on the transformation of functions. The purpose of the pre-test was to establish a knowledge base of the transformation of functions before instruction. The results of the post-test were used to compare the achievement level of the students after instruction on the transformations. A survey was given to these students after the post-test to measure the impact the graphing calculator had on the students' self perception of their learning experience. Ninety students (96.8%) completed both a pre- and post-test, however only 84 students (90.3%) completed and returned a survey. There were 41male (43%) students, 43 female (46.2%) students, 57 (67.9%) juniors and 27 (29.8%) seniors who completed the survey. The students were told that the responses to the survey would in no way affect their grades.

Table 4.1 shows the students' experience with scientific and graphing calculators. The ownership of a calculator may affect the conceptual knowledge and interest in the subject matter for the student. Having a graphing calculator would enable the student to complete assignments without manually drawing the functions. This study attempted to evaluate the benefits of using the graphing calculator in instruction and on assessments.

Although Teacher B did not use technology in the instruction of his students, some students did own their own graphing calculator and were neither encouraged nor discouraged from using it.

In Class A, 83.9% of the students had a scientific calculator and 77.4% had their own graphing calculator. It was the first time for 61.3% of these students to use a graphing calculator. In Class B, 66% of the students owned a scientific calculator, 49.1% owned a graphing calculator and 37.7% were using the graphing calculator for the first time.

Table 4.1

Percentage of students who own a scientific or graphing calculator and who are using a graphing calculator for the first time in class.

Item	Yes %	No %
Ownership by class		
Scientific		
Class A	83.9	16.1
Class B	66.0	34.0
Graphing		
Class A	77.4	22.6
Class B	49.1	50.9
First time use		
Class A	61.3	38.7
Class B	37.7	62.3

Analysis of the Data

Research Question 1: Does the use of graphing calculators in the classroom enhance the student's conceptual understanding of the transformation of functions?

The students were given a pre-test to determine the students' level of knowledge before the concept was taught. Prior to instruction, none of the students had been introduced to the transformation of functions this year. The students should have had some knowledge of transformation of functions from Algebra 2. After the pre-test, the students were instructed on how to transform functions using a graphing calculator with Teacher A and without using any technology in instruction with Teacher B. Table 4.2, displayed below, shows the mean scores of the pre- and post-test which were administered before and after instruction on transformations of functions. Teacher A taught two Pre-Calculus classes with graphing calculators and Teacher B taught three classes without graphing calculators. The tests were scored on a scale of 6. The questions were either right or wrong, there was no partial credit. As shown in Table 4.2, the mean score on the pre-test for Teacher A was 2.33. The post-test for the same teacher yielded a mean of 4.10. The pre-test mean for the non-calculator classes was 1.57 and the post-test mean for these same classes was 3.12. The median scores showed a similar result. The pre-test median was 2 and the post-test median was 4 for those classes using technology. The pre-test median for the non-graphing calculator classes was 1 and the post-test median was 3.

Table 4.2

The means for pre- and post-test scores of the Pre-Calculus students in both Class A and Class B

	Test Mean		Std. Deviation		Median	
	Pre-	Post-	Pre-	Post-	Pre-	Post-
With Calculators						
Class A	2.33	4.10	1.767	1.294	2	4
Without Calculators						
Class B	1.57	3.12	1.500	1.986	1	3

While the overall mean and median did show an increase from the pre- to post-test, not every student saw an increase in the test scores. Of those students using a graphing calculator, 27 students (69.2%) showed an increase in their score, nine students (23.1%) showed no change, and two students (5.1%) showed a decrease. Of those students not using technology in the classroom, there were 36 students (70.6%) with an increase in scores, seven students (13.7%) had scores that were unchanged, and eight students (15.7%) showed a decrease in scores. Some students had a dramatic change in their scores. Seven students (18%) who used graphing calculators showed an increase in their scores of 4 or more and ten students (19.6%) did not using graphing calculators showed the same increase. Of those students who had a decrease in their scores, two students (5.1%) used calculators and eight students (15.7%) did not use calculators.

Table 4.3

A comparison of the difference of the means between pre- and post-tests given to students with and without graphing calculators. $(\alpha = .05)$

Paired Samples	Mean	d.f.	Calculated t-value	Expected t-value
Pre-Test to Post-Test With Calculators	-1.769	38	-5.953	1.960
Pre-Test to Post-Test without Calculators	-1.549	50	-5.107	1.960
Differences in mean scores with and without calculators	.718	38	1.536	1.960

In a direct comparison of the pre-test and post-tests mean scores (Table 4.3) of Teacher A (with calculators), the difference of the means is -1.769 which is indicative of the post-test scores being higher than the pre-test scores. In performing a paired sample test on the scores of the pre- and post-tests, the calculated t-value was -5.953 also indicating that there was a significant difference in the pre- and post-test scores since this t-value fell outside the critical region. A similar comparison was performed on the test scores of Teacher B's classes. In comparing the difference of the means, the results also showed an increase in the post-test scores (the difference of the means is -1.549). The paired sample test conducted on the scores of the pre- and post-test from Teacher B resulted in a calculated t-value of -5.107, also indicating that there was a significant difference in the scores since the t-value was outside the critical region. These values are indicative of a significant difference in the conceptual knowledge of the students before and after instruction whether or not graphing calculators were used. This increase in conceptual knowledge is expected when comparing pre- and post-test scores.

The next step in the analysis of this study is to compare the means of the differences of the pre- and post-test of the two sample spaces. In analyzing these differences it was found that the calculated t-value was 1.536. This does not fall within the critical region and therefore the null hypothesis can not be rejected. That is, there is no significant difference in the conceptual knowledge of Pre-Calculus students in the study of quadratic functions and their graphs when graphing calculators are used in instruction. Both groups showed an increase in scores from pre- to post-test, however, the increase was not significantly different for each group. It did not matter if the student used a graphing calculator for instruction.

The students were also asked, in an attitudinal survey, about their knowledge of specific tasks on the operation of a graphing calculator relevant to the assessments, as shown in Table 4.4. In a comparison of the ability to operate a graphing calculator by group, 96.8% of the students who used a graphing calculator for instruction (Class A) could graph a line using a graphing calculator while only 86.8% of the students who did not use a graphing calculator for instruction (Class B) could draw a line with a graphing calculator. In Class A, 93% can use the table feature on their calculator, 64.5% can graph a quadratic equation, and 67.7% can evaluate a function. In Class B, 73.6% can use the table feature, 28.8% can graph a quadratic and 20.8% can evaluate a function on a graphing calculator.

Table 4.4

The percentages of students' self perception of their ability to operate a graphing calculator.

	Strongly Agree %	Agree %	Neither Agree or Disagree %	Disagree %	Strongly Disagree %
Graph a line					
Class A	90.3	6.5	0	0	3.2
Class B	60.4	26.4	7.5	1.9	3.8
Use the table					
Class A	74.2	19.4	0	3.2	3.2
Class B	49.1	24.5	13.2	11.3	1.9
Trace a function					
Class A	61.3	22.6	9.7	3.2	3.2
Class B	20.8	20.8	30.2	15.1	13.2
Graph quadratics					
Class A	41.9	22.6	16.1	12.9	6.5
Class B	3.8	24.5	24.5	26.4	20.8
Evaluate Functions					
Class A	38.7	29.0	19.4	12.9	0
Class B	5.7	15.1	39.6	18.9	20.8

Table 4.5

The results of an independent samples test on the total scores of the attitudinal survey given to Pre-Calculus students after the post-test.

	Class A Mean Score	Class B Mean Score	Mean Difference	Calculated t-value	Expected t-value
Operation of a graphing calculator	20.10	24.68	4.58	3.555	1.960
Attitude toward graphing calculator	40.97	42.62	1.65	1.197	1.960

Research Question 2: Do graphing calculators create a difference in the mathematical attitude of the students?

An independent samples test was performed on the total scores for the attitudinal survey (Table 4.5). This sum was divided in two groups; the self perception of their ability to use a graphing calculator and the self perception of the effect graphing calculators have on their experience in math class. The calculated t-value for the ability to use a graphing calculator was 3.555. The expected t-value for this analysis was 1.960. This analysis revealed that there was a significant difference in the operation of a graphing calculator between the group that used graphing calculators for instruction and the group that did not use graphing calculators which supports the percentages found in analyzing the survey.

In the second part of the survey, the students were asked about their attitude towards graphing calculators, the impact graphing calculators had on the class and their ability to understand various concepts. There were differences in the students' attitude toward the graphing calculator as listed in Table 4.6. Of the students who used a graphing calculator as part of instruction (Class A), 83.8% liked to use a graphing calculator, 77.4% were confident using a graphing calculator and 79.2% want to use the graphing calculator more often. Approximately 74.2% of the students in Class A thought that the graphing calculator helped them to understand Pre-Calculus better, 67.8% thought they had more confidence in their math ability and 74.2% thought they were able to visualize function better. In comparing these same questions to Class B, 67.9% liked to use a graphing calculator, 54.7% were confident using a graphing calculator and 71.7% wanted to use a graphing calculator more often. In addition, 64.1% thought they understood Pre-Calculus better, 56.6% had more confidence in their math ability and 60.4% were able to visualize functions. More of the students (71.7% as opposed to 64.6%) who did not use a graphing calculator thought that assessments were easier with the use of a graphing calculator. Only 6.4% of the students who used a graphing calculator for instruction thought that graphing calculators confused them, while 28.3% of the students who did not use graphing calculators thought they were confused. The results of this part of the survey involving attitudes towards using a graphing calculator for Class A and Class B only showed a minor difference as opposed to the operation of a graphing calculator which showed a greater difference.

In an independent samples test performed on the scores of the second part of the survey, the calculated t-value for comparing the students' total score in Class A and Class B was 1.197, which falls within the critical region. This indicated that there was no significant difference in the attitude of the students towards mathematics when comparing the non-calculator group to the calculator group.

Table 4.6

Partial results of the attitude study given to Pre-Calculus students assessing their self perception of the effect graphing calculators have on their experience in math class.

	Strongly Agree %	Agree %	Neither Agree Disagree %	Disagree %	Strongly Disagree %
Likes using a graphing calculator					
Class A	67.7	16.1	12.9	0	3.2
Class B	43.4	24.5	28.3	0	3.8
Confident using graphing calculator					
Class A	41.9	35.5	19.4	0	3.2
Class B	18.9	35.8	22.6	17.0	5.7
Graphing calculators confuse me					
Class A	3.2	3.2	35.5	35.5	22.6
Class B	17.0	11.3	32.1	28.3	11.3
Use more often					
Class A	45.2	12.9	38.7	0	3.2
Class B	34.0	37.7	26.4	0	1.9
Understand Pre-Calculus better					
Class A	48.4	25.8	19.4	3.2	3.2
Class B	35.8	25.3	24.5	9.4	1.9
Assessment easier					
Class A	32.3	32.3	29.0	3.2	3.2
Class B	34.0	37.7	17.0	1.9	7.5
More confidence in math ability					
Class A	35.5	32.3	9.7	0	3.2
Class B	32.1	24.5	30.2	7.5	3.8
Makes math more interesting					
Class A	19.4	19.4	35.5	6.5	0
Class B	20.8	18.9	43.4	11.3	3.8
Makes math harder to understand					
Class A	3.2	0	19.4	25.8	32.3
Class B	3.8	1.9	18.9	60.4	13.2
Able to visualize functions					
Class A	48.4	25.8	3.2	0	3.2
Class B	26.4	34.0	22.6	5.7	9.4
Use a graphing calculator in a regular basis					
Class A	51.6	19.6	6.5	0	3.2
Class B	32.1	32.1	13.2	11.3	9.4

CHAPTER FIVE

SUMMARY, DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

Summary of the Study

This study investigated the use of graphing calculators in Pre-Calculus classes with respect to conceptual learning of the transformation of functions and attitude towards mathematics with and without the use of a graphing calculator. The subjects for this study were selected from students at Washington Township High School, Sewell, NJ in November 2006. The study measured differences in the knowledge base of the students as well as the attitude of the students towards graphing calculators and the impact graphing calculators had on their learning experience.

The study consisted of an assessment and a survey developed by the researcher. The assessment contained six questions on the transformation of functions. The students were asked questions to determine their conceptual knowledge of the transformations. The scores ranged from 0 to 6 with no partial credit given.

The survey first asked for demographic information; name, grade, gender and ownership of a calculator. The second part of the survey assessed the student's ability to perform basic procedures with the graphing calculator. The third part was comprised of 13 Likert type questions concerning the student's attitude towards graphing calculators. There were 93 students involved in the study. Ninety students completed the pre- and post-tests, however only 84 students completed the survey.

Descriptive statistics in the form of measures of central tendency and inferential statistics in the form of t-test values were used to analyze the results of the study. The raw data were evaluated using the Statistical Package for the Social Sciences (SPSS) software, the Microsoft Excel program and the statistical capabilities of the TI-84.

Discussion of the Findings

Overall, the students in both groups performed better on the assessment after instruction was given on the transformation of functions. In both cases, with and without graphing calculators, improvement was apparent on the conceptual level. Visualizing the function and any transformation performed on the function, helps the student understand the effects the transformations have on the graph of the function. Even though the graphing calculator should make it easier for the students to visualize the changes made to the function, the students without the graphing calculator also showed improvement, implying that they were also able to visualize the changes. The students had to demonstrate knowledge of shifting quadratics horizontally and vertically. They also had to exhibit understanding of reflections and the effect the coefficient"a"has on the width of the parabola.

The process of graphing the function on the calculator and examining the table of values did not lead to a better conceptual understanding of the transformation of functions. This is contrary to what Adams suggested in his study (Adams, 1994). The students still had to decide on key data to put into the graphing calculator. In *Mathematics Teacher*, Van Dyke and White (2004) stated that the graphing calculators increased the student's visual thinking skills by showing how a function is represented graphically. The students, in the present study, were able to make mathematical decisions based on what was on the graphing calculator. This was shown to be true as indicated by the rise in assessment scores on the post-test. However, the students who did not use a graphing calculator for the assessment were also able to make these same mathematical decisions on the relationship between the quadratic function and its graph. Both groups showed a significant increase in their conceptual knowledge of the transformation of functions as indicated by the t-test performed on the pre- and post-test means. In addition, when a t-test was performed on the paired difference of the scores with and without graphing calculator use, the calculated t-value indicated that there was not a significant difference in the increase in the scores and no trends seem to be evident in the affect of using a graphing calculator.

The attitudinal statements of the survey indicated that the graphing calculator did not adversely affect the performance of the student. This supports the work of Smith and Shotsberger (1997) who found that students were not opposed to using the graphing calculator. In the present study, there was no significant difference in the effect graphing calculators had on the overall experience in math class and the perception of the effect a graphing calculator has on the students' ability to understand the conceptual and procedural knowledge. There were some individual differences such as the student being confused on the use a graphing calculator. This is not surprising since the more a student uses a graphing calculator the less confusing its operation becomes. This study indicated that the students in both groups were agreeable to using the graphing calculator more often and that the students wanted to learn more about the calculator. It was also found that there was a significant difference between the groups in the self perception of performing basic graphing skills on the calculator. The students in both groups were able to perform basic numeric operations on the graphing calculator; however there was a significant difference in being able to graph a line, use the table feature, trace a function, graph quadratic functions and evaluate functions. The group that used a graphing calculator for instruction was more adept at performing these tasks.

Conclusions

The results of this study are inconclusive as to whether or not graphing calculators enhance the conceptual learning in high school mathematics. Teaching mathematics is evolving and there is an increasing use of graphing calculators to try and enhance a student's experience in the classroom. The results of this study showed that students who used a graphing calculator were more adept at the procedural process, but there was not a significant difference in the self perception of the advantage to using a graphing calculator in the classroom. Smith and Shotsberger (1997) state that graphing calculators allow the student to see the connection between algebraic and graphic representations. However, in this study it was not clear if the graphing calculator allowed the student to see that connection any better than the student without the graphing calculator. Both the calculator and non-calculator groups showed a significant increase in their conceptual knowledge of the transformation of functions.

Any tool that allows a teacher to increase the conceptual knowledge of students should be thoroughly examined. It was not evident in this study that the graphing calculator positively impacted the achievement in the Pre-Calculus classes since this same increase in achievement was evident in those students who did not use a graphing calculator. What was observed by the examiner was that the student was more engaged in the classroom activities when the graphing calculator was used as part of instruction.

This study examined the use of graphing calculators for one concept, the transformation of functions. The limitations of this study, namely investigating only one topic, may not truly represent the benefits of using a graphing calculator. To obtain a more accurate appraisal of the benefits of the use of a graphing calculator in Pre-Calculus, a larger study should be conducted. This study should include examining the benefits of using a graphing calculator over the entire Pre-Calculus curriculum by comparing the achievement of classes that use a graphing calculator to those who do not use technology.

The students in Class A (calculator) reported feeling more confident in their math ability as a result of using a graphing calculator. The students, who did not use a graphing calculator as part of instruction, but own a graphing calculator and may have used the graphing calculator to complete homework assignments also felt more confident in their math ability. Students are open to learning in new ways and the teacher needs to be open to teaching with new tools and techniques. The graphing calculator is one instrument of the new technology. It has the potential to enhance the role of the teacher, at least part of the time, to that of a guide while the student is able to investigate mathematical properties and concepts on the graphing calculator, building the confidence level and a better attitude towards mathematics. Students in this study gained confidence in their abilities with and without a graphing calculator and therefore performed equally as well on the assessment. The lack of evidence in this study that graphing calculators increase the conceptual understanding of mathematics may be due to the fact that the use of graphing calculators was investigated on one topic only.

Recommendations for Practice and Future Research

Based on the findings of this study, the following ideas are presented for submission:

1. More studies should be made at higher levels of high school mathematics on the use of graphing calculators as part of the curriculum and assessments.
2. Another study could be done investigating the benefits of using a graphing calculator over the course of an entire year.
3. Further studies should be conducted to investigate the use of graphing calculator on assessments.
4. Teachers should collaborate to locate new material to use with the graphing calculator.
5. Teachers of the same subject should work together to create assessments that reflect the use of graphing calculators.
6. Teachers should attend workshops to obtain a greater understanding of the operation of graphing calculators in the classroom.

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APPENDIX A

Institutional Review Board Disposition Form

OK
consent
vol 1
con't

Rowan University
INSTITUTIONAL REVIEW BOARD
HUMAN RESEARCH REVIEW APPLICATION

INSTRUCTIONS: Check all appropriate boxes, answer all questions completely, include attachments, and obtain appropriate signatures. Submit an **original and two copies** of the completed application to the Office of the Associate Provost.
NOTE: **Applications must be typed.**
Be sure to make a copy for your files.

FOR IRB USE ONLY:
Protocol Number: IRB- 2007 - 138
Received:_______ Reviewed:_________
Exemption: ___Yes ___ No
Category(ies): 2/9/07
Approved ________ (date)

Step 1: **Is the proposed research subject to IRB review?**
All research involving human participants conducted by Rowan University faculty and staff is subject to IRB review. Some, but not all, student-conducted studies that involve human participants are considered research and are subject to IRB review. Check the accompanying instructions for more information. Then check with your class instructor for guidance as to whether you must submit your research protocol for IRB review. If you determine that your research meets the above criteria and is not subject to IRB review, **STOP**. You do not need to apply. If you or your instructor have any doubts, apply for an IRB review.

Step 2: **If you have determined that the proposed research is subject to IRB review, complete the identifying information below.**

Project Title: A study of the impact graphing calculators have on the conceptual understanding of parabolas

Researcher: Marsha Brumberg

Department: Educational Technology Location: Washingtion Township High School

Mailing Address: 175 Dorado Ave (Street)
Sewell, NJ 08080 (Town/State/Zip)

E-Mail: mbrumberg@comcast.net Telephone: 856-589-6903

Co-Investigator/s:

Faculty Sponsor (if student)* Louis Molinari
Department Elementary Education Location: Educational Building
E-Mail: lmolinari@rowan.edu Telephone: 856-881-0585

Step 3: Determine whether the proposed research eligible for an *exemption* from a full IRB review.

Federal regulations (45 CFR 46) permit the exemption of some types of research from a full IRB review. If your research can be described by one or more of the categories listed below, check the appropriate category(ies), complete questions 1-5, and complete the Assurances on the last page of the application.

If your research cannot be described by any of these categories, your research is not exempt, and you must complete the entire "Human Research Review Application."

__X__ **Category 1** - Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as: (a) research on regular and special education instructional strategies; or (b) research on the effectiveness of, or the comparison among, instructional techniques, curricula, or classroom management methods.

_____ **Category 2** - Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior, unless: (a) information obtained is recorded in such a manner that the human participants can be identified, directly or through identifiers linked to the participants; and (b) any disclosure of the human participants' responses outside the research could reasonably place the participants at risk of criminal or civil liability or be damaging to the participants' financial standing, employability, or reputation.
(Note: Exemption for survey and interview procedures does not apply to research involving children. Exemption for observation of public behavior does not apply to research involving children except when the investigator does not participate in the activities being observed.)

_____ **Category 3** - Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under Category 2 above if: (a) the human participants are elected or appointed public officials or candidates for public office; or (b) federal statute requires without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

_____ **Category 4** - Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available or if the information is recorded by the investigator in such a manner that participants cannot be identified, directly or through identifiers linked to the participants.

_____ **Category 5** - Research and demonstration projects which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (a) public benefit or service programs; (b)procedures for obtaining benefits or services under those programs; (c) possible changes in or alternatives to these programs or procedures; or (d) possible changes in methods or levels of payment for benefits or services under those programs.

_____ **Category 6** - Taste and food quality evaluation and consumer acceptance studies: (a) if wholesome foods without additives are consumed; or (b) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe by the Food and Drug Administration or approved by the Environmental Protection Agency or the Food Safety and Inspection Service of the U.S. Department of Agriculture.
(Note: Exemption categories cannot be applied to research involving fetuses, pregnant women, human in vitro fertilization, or prisoners.)

Please answer Questions 1-5 below

1. WHAT IS THE OBJECTIVE OF THE RESEARCH?

The objective of the research is to compare the achievement in the conceptual understanding of parabolas with and without instruction using a graphing calculator.

2. DESCRIBE THE DESIGN OF THE RESEARCH INCLUDING WHAT WILL BE REQUIRED OF SUBJECTS (ATTACH ADDITIONAL SHEET IF NECESSARY):

The subjects will be given a pretest of the content material. Teacher A and B will instruct their students on the properties of parabolas. Teacher A will use graphing calculators and Teacher B will not use graphing calculator. The subjects will then be given a post test to assess the change in achievement.

3. DESCRIBE THE SUBJECTS WHO WILL BE PARTICIPATING (NUMBER, AGE, GENDER, ETC):

The subjects participating are juniors and seniors in high school Pre Calculus classes

4. DESCRIBE HOW SUBJECTS WILL BE RECRUITED (e.g. ADVERTISEMENTS, ANNOUNCEMENTS IN CLASS, E-MAIL, INTERNET)

Subjects will be recruited from the class lists of the Pre Calculus classes

5. WHERE WILL THE RESEARCH BE CONDUCTED:

The research will be conducted at Washington Township High School, 529 Hurffville-Crosskeys Road, Sewell, NJ 08080

NOTE: IF THE RESEARCH IS TO BE CONDUCTED IN ANOTHER INSTITUTION (e.g. A SCHOOL, HOSPITAL, AGENCY, etc.) A PERMISSION LETTER FROM AN ADMINISTRATOR ON THE LETTERHEAD OF THAT INSTITUTION MUST BE ATTACHED.

IF THE RESEARCH IS TO BE CONDUCTED AT ANOTHER UNIVERSITY, A SIGNED COPY OF THE IRB APPROVAL FORM FROM THAT UNIVERSITY MUST BE ATTACHED.

ATTACH THE CONSENT FORM TO THIS APPLICATION. The Consent Form must address all of the elements required for informed consent (SEE INSTRUCTIONS).

NOTE: IF THE ONLY RECORD LINKING THE SUBJECT AND THE RESEARCH WOULD BE THE CONSENT DOCUMENT, AND THE RESEARCH PRESENTS NO MORE THAN MINIMAL RISK OF HARM TO SUBJECTS, YOU MAY USE AN ALTERNATIVE PROCEDURE FOR CONSENT. IF YOU WISH TO REQUEST PERMISSION FROM THE IRB TO USE AN ALTERNATIVE PROCEDURE, ATTACH A COPY OF THE FIRST PAGE OF YOUR RESEARCH INSTRUMENT OR A LETTER WITH THE REQUIRED INFORMATION (see Instructions).

If you are requesting an exemption from a full IRB review, STOP. Complete the last page of this application ("Certifications"), and forward the completed (typed) application to the Office of the Associate Provost for Research, The Graduate School, Memorial Hall.

F YOU CANNOT CLAIM ONE OF THE EXEMPTIONS LISTED ABOVE, COMPLETE ALL OF 'HE ABOVE AS WELL AS THE FOLLOWING ADDITIONAL QUESTIONS FOR A FULL IRB ¿EVIEW.

)oes your research involve a special population?

____ Socioeconomically, educationally, or linguistically disadvantaged racial/ethnic group
____ Pregnancy/fetus
____ Cognitively impaired
____ Elderly
____ Terminally ill
____ Incarcerated
____ No special population

\t what level of risk will the participants in the proposed research be placed?
Note: "Minimal risk" means that the risks of harm anticipated in the proposed research are not greater, :onsidering probability and magnitude, than those ordinarily encountered in daily life or during performance)f routine physical or psychological examinations or tests. The concept of risk goes beyond physical risk and ncludes risks to the participant's dignity and self-respect as well as psychological, emotional, or behavioral ·isk.)

_____ Minimal Risk _____ More than Minimal Risk _____ Uncertain

|. HOW WILL SUBJECTS BE RECRUITED? IF STUDENTS, WILL THEY BE SOLICITED FROM ⊐LASS?

____
____
____
____

2. WHAT RISKS TO SUBJECTS (PHYSIOLOGICAL AND/OR PSYCHOLOGICAL) ARE INVOLVED .N THE RESEARCH?

____
____
____
____

3. IS DECEPTION INVOLVED IN THE RESEARCH? IF SO, WHAT IS IT AND WHY WILL IT BE JSED?

____
____
____
____

WHAT INFORMATION WILL BE GIVEN TO THE SUBJECTS AFTER THEIR PARTICIPATION? IF 'ECEPTION IS USED, IT MUST BE DISCLOSED AFTER PARTICIPATION.

. HOW WILL CONFIDENTIALITY BE MAINTAINED? WHO WILL KNOW THE IDENTITY OF THE UBJECTS? IF A PRE-AND POSTTEST DESIGN IS USED, HOW WILL THE SUBJECTS BE DENTIFIED?

. HOW WILL THE DATA BE RECORDED AND STORED? WHO WILL HAVE ACCESS TO THE)ATA? ALL DATA MUST BE KEPT BY THE PRINCIPAL INVESTIGATOR FOR A MINIMUM OF 'HREE YEARS.

ERTIFICATIONS:
owan University maintains a Federalwide Assurance (FWA) with the Office of Human Research Protection (OHRP), U.S. Department of Health & Human Services. This Assurance includes a requirement for all research taff working with human participants to receive training in ethical guidelines and regulations. "Research staff" defined as persons who have direct and substantive involvement in proposing, performing, reviewing, r reporting research and includes students fulfilling these roles as well as their faculty advisors.

lease attach a copy of your "Completion Certificate for Human Participant Protections Education for Research eams" from the National Institutes of Health.

f you need to complete that training, go to the Web Tutorial at http://cme.nci.nih.gov/

esponsible Researcher: I certify that I am familiar with the ethical guidelines and regulations regarding the rotection of human participants from research risks and will adhere to the policies and procedures of the owan University Institutional Review Board. I will ensure that all research staff working on the proposed roject who will have direct and substantive involvement in proposing, performing, reviewing, or reporting this esearch (including students fulfilling these roles) will complete IRB approved training. I will not initiate this esearch project until I receive written approval from the IRB. I agree to obtain informed consent of participants 1 this project if required by the IRB; to report to the IRB any unanticipated effects on participants which ecome apparent during the course or as a result of experimentation and the actions taken as a result; to ooperate with the IRB in the continuing review of this project; to obtain prior approval from the IRB before mending or altering the scope of the project or implementing changes in the approved consent form; and to naintain documentation of consent forms and progress reports for a minimum of three years after completion of 1e final report or longer if required by the sponsor or the institution. I further certify that I have completed aining regarding human participant research ethics within the last three years as indicated below my ignature.

ignature of Responsible Researcher: ______________________________ Date: ______________

aculty Advisor (if Responsible Researcher is a student): I certify that I am familiar with the ethical uidelines and regulations regarding the protection of human participants from research risks. I further ertify that I have completed training regarding human participant research ethics within the last three years s indicated below my signature (attach copy of your "Completion Certificate for Human Participant rotections Education for Research Teams" from the National Institutes of Health).

ignature of Faculty Advisor: ______________________________ Date: Jan. 31, 2007

APPENDIX B

Principal Permission and Subject Consent Form

District Approval: Informed Consent Form

As part of a research project involving graphing calculators and their impact on learning in a Pre Calculus, Rowan University requires that I receive permission from the building principal to conduct research within our building. I want to check the achievement of Pre Calculus classes regarding functions particularly parabolas.

The purpose of this project is to compare the achievement of Pre Calculus students in the study of parabolas when the group does not use a graphing calculator and when graphing calculator are used. An assessment developed by the researcher will supply the data to quantitatively ascertain which group, if any, performs better.

I will also survey the students to get their opinion on calculator use and if it is related to their achievement and confidence in math class. The survey will also be completed in class by the students.

Since some of the students involved are minors, their parents will be asked to sign a consent form informing them of the research. I am just looking at the results of a test so there is no need for any names of students to be used and this information will solely be used for my research paper and will not impact their grade.

If you will allow me to proceed with this research, please sign the form below and return it to me as soon as possible.

I agree to allow Marsha Brumberg to observe and survey Pre Calculus students at Washington Township High School as part of her research project on the effects graphing calculators have on academic achievement.

Signature — 11/20/06 Date

Informed Consent Form: Testing and Survey

As part of my research project through Rowan University, I will be comparing tests results of your child after instruction either with or without a graphing calculator. The University requires that I obtain your consent for your child to participate in this study.

The purpose of this study is to determine is there is any benefit to approaching the Pre Calculus curriculum with a graphing calculator. Besides a researcher generated pre and post test, your child will also be given a survey concerning his math confidence with and without a calculator. This study will in no way influence your child's grade in Pre Calculus.

If you are willing to let your child participate in this study, please fill in the form at the bottom of the page and return it to your child's teacher.

I agree to have my child ____________________ participate in the study being performed by Marsha Brumberg.

____________________ ____________________

Signature Date

APPENDIX C

Assessments

Pre Test Quadratic Functions Number________

Grade ________ Circle one: Male Female

I have a graphing calculator. Yes No

Consider the function $f(x) = x^2$

1a) Find *g(x)* such that the graph of *g(x)* is the graph of *f(x)* shifted two places to the left.

b) Find *g(x)* such that the graph of *g(x)* is the graph of *f(x)* reflected over the x axis.

c) Find *g(x)* such that the graph of *g(x)* is the graph of *f(x)* shifted two units down.

2a) How do the graphs of $f(x) = x^2$ and $g(x) = \frac{1}{2}x^2$ differ?

b) How do the graphs of $f(x) = x^2$ and $g(x) = -x^2$ differ?

3. Find *h(x)* such that the graph of *h(x)* is the graph of *f(x)* with an axis of symmetry at x = 2 and a minimum value at (2, 3)

Post Test Quadratic Functions Number______

Grade ________ Circle one: Male Female

I have a graphing calculator. Yes No

Consider the function $f(x) = x^2$

1a) Find *g(x)* such that the graph of *g(x)* is the graph of *f(x)* shifted three places to the right.

b) Find *g(x)* such that the graph of *g(x)* is the graph of *f(x)* reflected over the x axis.

c) Find *g(x)* such that the graph of *g(x)* is the graph of *f(x)* shifted two units up.

2a) How do the graphs of $f(x) = x^2$ and $g(x) = 2x^2$ differ?

b) How do the graphs of $f(x) = x^2$ and $g(x) = -x^2$ differ?

3. Find *h(x)* such that the graph of *h(x)* is the graph of *f(x)* with an axis of symmetry at x = 3 and a minimum value at (3, -1)

APPENDIX D

Survey

CALCULATOR SURVEY

Name:	
Grade:	
Gender:	

1. I own my own scientific calculator   Yes   No
2. I own my own graphing calculator   Yes   No
   Type of graphing calculator ________________
3. This is the first class where I am using a graphing calculator.   Yes   No

For each question below, circle the number to the right that best fits your opinion on the importance of the issue. Use the scale to match your opinion.

Question	Attitude towards Calculators				
	Strongly Agree	Agree	Neither Agree or Disagree	Disagree	Strongly Disagree
Operation of a graphing calculator					
1. I can perform simple calculations with a graphing calculator.	1	2	3	4	5
2. I can graph a line with a graphing calculator.	1	2	3	4	5
3. I can use the table feature on a graphing calculator.	1	2	3	4	5
4. I can trace a function with a graphing calculator.	1	2	3	4	5
5. I can graph a quadratic with a graphing calculator.	1	2	3	4	5
6. I only use my graphing calculator perform basic mathematical operations.	1	2	3	4	5
7. I can evaluate a function using a graphing calculator	1	2	3	4	5
8. I can program my calculator to evaluate different formulas such as slope and the quadratic formula.	1	2	3	4	5
9. I know how to use the equation solving capabilities of my calculator (Equation solver, Poly Solve, or Solve)	1	2	3	4	5
Graphing Calculator Use					
10. I like using a graphing calculator.	1	2	3	4	5
11. I feel confident operating a graphing calculator.	1	2	3	4	5
12. Graphing calculators confuse me	1	2	3	4	5
13. I only use a graphing calculator to play games.	1	2	3	4	5
14. I would like to use a graphing calculator more often to help me with Pre Calculus.	1	2	3	4	5
15. I understand Pre Calculus better when I use a graphing calculator.	1	2	3	4	5
16. I would like to learn more about the graphing calculator.	1	2	3	4	5
17. I have a graphing calculator, but I never	1	2	3	4	5

think to use it in math class.					
18. The assessment was easier with the graphing calculator.	1	2	3	4	5
19. I have more confidence in my math ability with my graphing calculator.	1	2	3	4	5
20. I still prefer to use a scientific calculator.	1	2	3	4	5
21. If given a choice, I prefer to use a graphing calculator	1	2	3	4	5
22. Graphing calculators makes math more interesting.	1	2	3	4	5
23. Graphing calculators make math harder to understand	1	2	3	4	5
24. Graphing calculators allow me to visualize functions	1	2	3	4	5
25. I use a graphing calculator in class on a regular basis	1	2	3	4	5