CALCULATOR USE IN DEVELOPMENTAL MATHEMATICS IN A COMMUNITY COLLEGE

By

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DEDICATION

This is dedicated to my husband Mario and my family who supported me through the entire process.

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ABSTRACT

The purpose of this study was to examine instructor and student usage of calculators in basic mathematics and prealgebra courses at a community college. Researcher-created surveys were given to 54 instructors and 198 students. The results showed instructors were fairly evenly divided about policies regarding the use of calculators. The major reason for not allowing calculators was that students needed to develop basic skills, and the major reason for allowing calculators was to concentrate on learning concepts. Students used calculators mainly for computation and seldom reported instructors using calculators in class for any other reason. Students were more likely to see calculators as learning tools than were teachers, who saw calculators mainly as computation machines. The results also indicated that instructors were confused about department calculator policies, and students were confused about classroom calculator use policies.

CHAPTER 1

INTRODUCTION

> Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning (National Council of Teachers of Mathematics, 2000, p. 1).

Technology is an important piece of mathematics education. Much research has been done showing the usefulness of technology in the classroom (Hembree & Dessart, 1986; Adams, 1997; Boyd & Carson, 1991; Laughbaum, 2001; Ellington, 2003). The National Council of Teachers of Mathematics (2000) believes that technology is so important that it is one of the six principles for K-12 mathematics.

The American Mathematical Association for Two Year Colleges (AMATYC) created *Crossroads in Mathematics: Standards for Introductory College Mathematics before Calculus* (Cohen, 1995), a document similar to the *NCTM Principles and Standards* (National Council of Teachers of Mathematics, 2000). This document has seven standards for intellectual development. The sixth standard states:

> Student will use appropriate technology to enhance their mathematical thinking and understanding and to solve mathematical problems and judge the reasonableness of their results (Cohen, 1995, p. 11).

AMATYC further advocates that technology should be used to aid students in understanding mathematical concepts as well as be a tool for solving real world problems. Technology should not become the main focus of instruction but should be used if the expected learning gain is larger than the time required to learn the technology.

AMATYC's update to Crossroads is called *Beyond Crossroads: Implementing Mathematics Standards in the First Two Years of College* (2006). In this document, AMATYC further advocates that "Technology should be integral to the teaching and learning of mathematics" (Blair, 2006, p. 11), and instructors should integrate appropriate technology to "enhance conceptual understanding, while simultaneously improving performance in basic skills" (Blair, 2006, p. 56). The integration of technology should be based on research of successful practices and recommendations and standards of professional organizations.

Beyond Crossroads (Blair, 2006) does not just address technology in a general way but specifically states that technology should be a part of developmental mathematics. Developmental mathematic courses are defined as any college mathematics course below the first course that earns full college credit (Blair, 2006, p. 46). These courses traditionally consist of basic mathematics, prealgebra and introductory algebra courses. AMATYC states that developmental students should have experience using technology, including calculators, throughout all developmental courses and not just in one specific course.

In practice, not all developmental mathematics instructors believe that students should have access to calculators in their courses. Many believe that students should not be allowed to use calculators when the objective is to gain the skills that a calculator can perform (Vasquez, 2000).

In 2005, approximately 57% of the 1.3 million students enrolled in two-year college mathematics courses were in developmental mathematics courses (Blair, 2006). Calculator usage in developmental classrooms is an issue that needs to be investigated. Instructors need to understand how calculator usage affects students in their developmental classrooms.

Background of Study

Research on the use of calculators in college level developmental mathematics courses is very limited. The most recent studies focus on the use of graphing calculators in algebra courses (Adams, 1997;Hopkins & Kinard, 1998; Fox, 1998; Shore, 1999; Vasquez, 2003). Research on the use of four-function and/or scientific calculators at the college level is very sparse, as is research on the use of calculators in basic mathematics and prealgebra courses.

Most of the basic mathematics and prealgebra calculator research compares the basic mathematics skills of students using a calculator to students who are not using a calculator (Hector & Frandsen, 1981; Carson & Boyd, 1991; Vasquez, 2002). The basic mathematics skills of students consist of the computational and operational skills students use in completing mathematical problems. The results show that calculators do not hinder students' basic skill development. The students using calculators do not do better than noncalculator-using students but do seem to have a more positive attitude toward mathematics (Boyd & Carson, 1991).

The basic mathematics and prealgebra studies conducted in the 1980s and early 1990s do not tend to differentiate between types of calculators. Graphing calculators became available in the early 1990s, but widespread use of them did not occur immediately. The later studies differentiate between four-function or scientific and graphing calculators.

The developmental algebra research differentiates between graphing calculators and non-graphing calculators. Research without graphing calculators is very limited, but indicates that there is no difference in achievement between students who use a calculator and students who do not (Weitzle & Waits, 1976; Davidson, Donaldson, Hodge-Hardin, & McGill, 1996). This research also shows that students reported calculators helpful but did not specify how the calculators helped the students.

Research on the use of graphing calculators at the developmental level is also very limited. The research indicates that students using a graphing calculator either do as well as or better than students who do not when measuring achievement (Hopkins & Kinard, 1998; Fox, 1998; Shore, 1999). The students using a graphing calculator have better attitudes toward mathematics (Hopkins & Kinard, 1998; Fox, 1998; Ellington, 2004). Research shows that using a graphing calculator also encourages active learning and making connections (Hopkins & Kinard, 1998; Fox, 1998).

Because of the limited research of calculator usage at the college level, examining the results of K-12 research is prudent. The K-12 research is plentiful and well documented. Meta-analysis research studies (Hembree & Dessart , 1986; Ellington, 2003) indicate that when calculators are integrated into instruction, students' basic skills improve. The results also show that students using calculators have a better attitude toward mathematics (Hembree & Dessart , 1986; Ellington, 2003).

The K-12 research shows that calculators can make a positive difference in both students' skills and attitude. The developmental mathematics graphing calculator studies also show that using a calculator can increase student knowledge and encourage a more positive attitude toward mathematics. Limited research in prealgebra and basic mathematics courses shows that students' basic skill development is not harmed by calculator usage.

The limited research in prealgebra and basic mathematics does not help us understand why there was no significant change in skills. Changes in attitude were reported but only as a secondary consideration. The existing research did not look at the reasons why students use a calculator. The existing research also did not examine instructor attitudes and why instructors encourage or discourage calculator usage. Instructor and student attitudes toward calculator usage are important because attitude influences the educational process.

Theoretical Perspective

The theoretical perspective of this study is based on the AMATYC standards (Cohen, 1995; Blair, 2006) for mathematics education. These standards focus on using technology as a tool to teach mathematics and not as a replacement for an instructor. They promote the use of technology including calculators as a way for students to develop an understanding of mathematical principles. They also encourage technology to be used so that students can work on realistic mathematical problems. Adams (1997) states that "the power of technology and its application in mathematics can be realized when computers and calculators are used as tools for teaching and learning." This point of view is echoed by many educators.

Kaput and Thompson (1994) examined 25 years of *Journal of Research in Mathematics Education* articles and found very little technology research by mathematics education researchers in that Journal. As this journal is the leading journal in the field of mathematics education, the lack of focus on technology is significant. They found dozens of publications of a non-research-oriented nature which lead them to suggest that technology is "not part of the mainstream activity of mathematics education researchers" but more likely regarded as "the province of specialists in the development and use of these technologies" (Kaput & Thompson, 1994, p. 680). They theorized that one reason technology research is limited is because it is intellectually demanding, requiring the researcher to rethink pedagogical and curricular motives and contexts.

In the studies that Kaput and Thompson found, computer and calculator technology used as an aid to computation usually had a weak impact on student performance and attitude (Kaput & Thompson, 1994). Studies that involved the role of technology in cognition and how technology could support problem solving seemed to more deeply affect educational activities (Kaput & Thompson, 1994). They found three aspects of computer and calculator technology that deeply change the experience of learning mathematics: interactivity, control of the learning environment, and connectivity to a larger world.

This broad notion of technology provides a basis for looking at the narrower topic of calculator technology. Calculators promote interactivity by providing students with graphs and models. They allow students to change pieces of information and quickly see how that change affects their work. This interactivity allows students to explore ideas without having to concentrate on algorithmic computation. The calculator becomes an external processing agent, taking information and returning it in a different form, so that students can evaluate information without performing algorithmic computations (Shaffer & Kaput, 1999)

Calculators can be used to alter the learning environment of students. Calculators can take the emphasis off of memorization of basic facts and traditional algorithms. Developmental students have usually failed to learn algebra in high school, and a college course is unlikely to succeed in remediation if teaching techniques are not significantly different (Hopkins & Kindard, 1998). By using calculators, students can spend more time solving conceptual problems and devote less time and energy to actual calculation (Bracey, 1998).

Connecting mathematics to real life situations is made easier with the use of calculators. Modeling and using real world examples are possible because calculators can perform the computations and provide graphs efficiently. Graphing calculator technology allows students to see a "clear and pedagogically sound connection between input parameters and output results of mathematical relationships" (Laughbaum, 2001, p.1). The current mathematics curriculum at the community college level does not necessarily allow instructors to take advantage of calculators as a teaching tool because it emphasizes symbolic manipulations instead of encouraging conceptual understanding. Ginsberg and Gal (1996, p.28) stated that "all too often, students work on one skill at a time and are told what algorithm to apply to contrived or context-free problems." Students are required to know how to perform many algorithmic operations without showing any true mathematical understanding. Also, students seldom see how algorithmic operations relate to solving mathematical problems. For example, many students may be able to solve a linear equation but are unable to read an application problem and set up a linear equation to solve that problem.

Calculators can be used as a way of promoting mathematical understanding without requiring symbolic proficiency (Hopkins & Kinard, 1998). Calculators can perform symbolic manipulations but students need to understand the underlying concept before they can make use of the technology. This requires a change in teaching methodology as well as curriculum goals. Calculators can move the curriculum away from trying to produce students who only efficiently manipulative algebraic symbols towards students with a better conceptual knowledge of mathematics.

Technology, including calculators, can change mathematics education by changing the important topics in the curriculum (Romberg & Carpenter, 1986). It also can change the arrangement of curriculum: teaching concepts first and skills after (McCoy, 2001). This change would require instructors to place more responsibility on the student by having them actively engaged in the learning process. Students no longer must memorize algorithms but must understand the concept that requires the algorithm and how it relates to other mathematical concepts. For example, many developmental students memorize the algorithm for adding fractions without common denominators but seldom do they understand why common denominators are necessary. The concept of addition requiring like terms is important even for adding whole numbers but students seldom see the concept that links adding any type of numbers together. This lack of conceptual knowledge becomes more evident as students progress into algebra.

Some educators believe that using calculators does not allow students to develop traditional computational skills (Vasquez, 2000). The question that faces educators today is how much computational skill is necessary for conceptual understanding. Socrates argued that people should not be taught to write because it would destroy memory but most people would agree that while few people have the oral recitation skills of preliterate cultures the tradeoff has been worthwhile (Bracey, 1998).

We have had aids to computation for many years in slide rules and logarithms. Calculators can perform tedious computations, but they can not solve problems. Students with fluent conceptual knowledge of mathematics do not need to know computational algorithms to think about mathematical problems (Battista & Lambdin, 1994). Algorithms usually perform an operation efficiently but do not necessarily promote a conceptual understanding of the concept. Calculators can be used to develop a conceptual understanding by allowing students to quickly see the results of many computations (Ginsberg & Gal, 1996). Students need to understand the mathematical processes and concepts at a level where they know when it is appropriate to use the technology and when the technology does not provide an answer that is useable (Stacey, 2005).

Technology must be used in service of goals for students' mathematical knowledge (Rubin, 1999). We want students to be mathematically literate, able to comprehend mathematical information and engage in logical thought processes so that they can comprehend the information. Calculators should be used to encourage student thought processes as they make sense of mathematical information.

Technology changes so rapidly that it is hard to keep up with the latest innovations. Calculator usage in the classroom seems to be changing as well. Educators first viewed calculators as a computational tool and they now are finding that they are a teaching tool that if used correctly can lead to conceptual knowledge and increase problem solving skills (Ellington, 2003). Adams (1997) showed that introducing graphing calculators into the classroom enhanced problem solving activity as well as decreased requests by students for procedural step by step solutions. Research has not yet caught up to the rapidly changing uses of calculators in the classroom. More research needs to occur so that educators will have a sound research base to make informed decisions about calculator usage.

Purpose and Contribution of Study

The purpose of this study is to look at two specific developmental courses, basic mathematics and prealgebra, and examine calculator usage by students and instructors in these courses. Most of the calculator research in developmental mathematics has focused on student achievement (Hector & Fransden, 1981; Boyd & Carson, 1991; Davidson, Donaldson, Hodge-Hardin & McGill, 1996; Vasquez & McCabe, 2002). Studies of student attitudes toward calculators seem to be included only as a secondary consideration. Instructor attitudes tend to be discussed anecdotally but never researched. Instructor and student usage of calculators is seldom discussed at all (Vasquez & McCabe, 2002).

The K-12 and developmental research indicates that calculator use can have a positive effect on both achievement and attitude, except in the research for basic mathematics and prealgebra courses. This research indicates that calculator use causes no harm but seldom results in a statistically significant improvement. It is possible that instructor and student usage may play an important part in student attitude and achievement.

Instructor attitudes can affect student usage of calculators in a classroom. A British study (Warren & King, 1995) found that primary instructors were not using calculators in their classrooms. They surveyed instructors and found that the reasons the primary instructors gave for not using calculators provided insight into underlying fundamental conflicts that caused these British primary instructors to not use calculators in their classrooms. These instructors believe that calculators would hinder students basic skill development and they viewed the calculator as a "lazy option, rather than a tool which can be used to help children understand the number system and calculation" (Warren & King, 1995, p 3).

The present study examines instructor and student calculator usage in basic mathematics and prealgebra courses at the community college level. In surveying instructors and students about their calculator usage, information was collected on why instructors use or do not use calculators as well as how students feel about instructors calculator usage. Once we understand the current usage of calculators, we can use this information to promote change in the developmental classroom towards the vision of the AMATYC standards.

By examining instructor and student calculator usage, this study will begin to create a body of research on calculator usage in developmental education. For instructors to use research to guide their instruction, research first must be completed. The current research in basic mathematics and prealgebra is very limited and needs more studies to help create conclusions that instructors can use in their classrooms.

Research Questions

This study investigates instructor and student calculator usage in two specific developmental mathematics courses: basic mathematics and prealgebra. The guiding research questions are:

In basic mathematics and prealgebra community college courses:

1) Why do instructors choose to use or not use calculators?
2) What are instructors' perceived reasons for student calculator use?
3) How often do students use a calculator, and what are their reasons for calculator usage?
4) Do students and instructors believe that calculator usage affects grades?

To answer these questions, this study surveyed basic mathematics and prealgebra instructors and students at a large community college in the southwestern United States. All of the basic mathematics and prealgebra instructors at the institution were given a survey to gather information on why they allow or do not allow calculators in their courses, what they perceive as reasons for student calculator usage, and if they believe that calculator usage affects grades. Students in basic mathematics and prealgebra courses were surveyed to gather information on how often they used a calculator, why they used a calculator, and if they believe that calculator usage affected their grades. A more detail description of the study can be found in chapter 3.

CHAPTER 2

LITERATURE REVIEW

The first section of this review will examine the K-12 calculator research using meta-analysis results. The second section will examine the existing calculator research in developmental education. This section will be separated into graphing and non-graphing calculator research. The final section will address conclusions and questions raised by the research in this field.

K-12 Research

Much research has been completed examining the effects of calculator usage in K-12 settings. Researchers have looked at the effects of calculators at different grade levels and in multiple instructional and testing situations. They have evaluated four-function, scientific and graphing calculators. A multitude of research has been analyzed using meta-analysis techniques to determine when and how calculators should be used in K-12 classrooms.

Hembree and Dessart (1986) analyzed 79 research studies in a meta-analysis of the effects of hand-held calculators. Studies were required to be completed with students in K-12 mainstream mathematics programs and must have involved the use of hand-held or desk calculators that function like hand-held calculators. They also needed to have sufficient data for calculation of effect sizes, data on a continuous scale and at least 10 subjects or five classes.

Achievement and attitude were the major constructs. Achievement effects included any information about acquisition, retention and transfer of knowledge. The achievement effect sizes were further broken down into basic operational skills and problem solving skills. When it was not possible to break the effect size into basic operational skills or problem solving skills, a composite score was used. Attitude effects consisted of six dimensions: attitude toward mathematics, anxiety toward mathematics, self-concept in mathematics, motivation to increase mathematical knowledge, attitude toward instructors and perception of the value of mathematics in society.

The analysis revealed that students (except in grade four) who use but are not tested with calculators maintain their basic operational skills. The average student, as opposed to low- or high-ability students, actually significantly improved in basic operations after using calculators, even when not tested using a calculator. In grade four, basic computational skills were significantly hampered by the use of calculators when students were not allowed to use them in testing situations.

The use of calculators in testing produces much higher achievement scores in both basic operations and problem solving for all ability levels. This result appears to be due to improved computation and process selection. A large positive effect was found regarding the selection of correct problem solving strategies. In problem solving situations, low and high ability students seemed to benefit more than average students when using calculators.

Finally, students using calculators in all grade and ability levels possess a significantly better attitude toward mathematics and a better self-concept in mathematics. A non-significant effect was found for anxiety toward mathematics.

Ellington (2003) further investigated the effects of calculators on student achievement and attitude in K-12 classrooms by completing a meta-analysis of 54 studies completed from 1983 to 2002. Ellington found that the focus of K-12 calculator studies had not changed since the analysis by Hembree and Dessart. Studies still focused on the impact on student achievement and changes in attitude toward mathematics; therefore, the same categories and subcategories were used to complete this updated analysis. The studies were divided into elementary, middle and high school. An additional category looked at the use of the calculator. This differentiated between using the calculator for computational or pedagogical activities. This study also looked at students' attitudes toward the use of calculators in mathematics.

Ellington's results showed that when calculators were included in instruction but not testing, operational and problem solving skills improved for all grade levels. There were no changes in computational skills or skills used to understand mathematical concepts. When calculators were allowed in testing, students' operational skills, computational skills, problem solving skills and skills necessary to understand mathematical concepts all improved. This increase existed whether students took standardized or instructor-made tests, and with every type of calculator. Ability to select the appropriate problem-solving strategy was the only skill that did not improve with calculator use on tests. This selection skill was neither hindered nor increased with calculator usage. Students whose instruction included the calculators as an essential element in the teaching and learning of mathematics significantly outperformed non-calculator control groups.

Students who used calculators reported more positive attitudes toward mathematics than students not using calculators. The average student reported a 63% better attitude toward mathematics when compared with non-calculator using students. Small, insignificant effect-sizes were generated for students' self-concept in mathematics and attitudes toward using calculators in mathematics. No other attitude category was analyzed due to insufficient data.

The results of these two studies show that calculators can increase students' computational and problem solving abilities in K-12 classrooms. Students' attitudes toward mathematics also increase when calculators are used. An examination of the research on calculator usage at the developmental college level now follows.

Developmental Research

Research at the college developmental education level is divided into two types. The first type of research is about graphing calculators and how teaching with graphing calculators at the elementary and intermediate algebra level effects student achievement and attitudes. The second type is about basic mathematics and prealgebra students using calculators.

Developmental Education Graphing Calculator Research

Graphing calculator research at the developmental level is very limited. Most of the studies examine student achievement and some included attitude measures as well. Some of the studies include introducing nontraditional methodologies that are supported by the calculator.

Hopkins and Kinard (1998) studied one class of beginning algebra students who were taught using an approach that involved using algebraic manipulatives and graphing calculators to help build on students' intuitive understanding of mathematical principles and develop traditional algebraic techniques out of this understanding. In this semester-long course, students used TI-92 calculators to facilitate symbolic manipulations. The students took a faculty-created placement test to get into the course and a common final exam. The students were also given a mathematics attitude inventory at the beginning and end of the semester, as well as at the end of the following semester when they were enrolled in intermediate algebra.

The control group consisted of the other two classes of beginning algebra offered that semester. The results showed that the experimental group and the control group had no significant difference in initial placement test scores. However, the experimental group scored significantly higher on the common final exam. Results of pass rates of the next course were analyzed and the experimental group had a pass rate of 62.5% compared to the control groups pass rate of 6.8%. Pass rates for students in the next course from the prior year's students for both instructors ranged from 28% (experimental) to 33% (control).

The results of the mathematics attitude inventory indicated that the experimental group had a significantly more positive attitude compared to the control group at the beginning of the semester. Researchers theorized that the difference was due to the anticipation of the experimental group getting new calculators, or due to an insignificant lower ability of the control group as based on placement test scores. At the end of the semester, the control group did not experience a significant change from the beginning to the end of the semester. The experimental group had a significant increase in attitude by the end of the semester which carried over to the end of the next semester as well.

These results indicated that the graphing calculator and the new methodology created an increase in student achievement and attitude. Students who took the calculator course did better in the subsequent course as well. Anecdotal evidence showed that many students who took the calculator course were now entering fields that they previously believed they could not enter.

Fox (1998) studied three instructors, each teaching two intermediate algebra classes during the first seven weeks of a semester. Each instructor was randomly assigned one control and one experimental class. The 166 students took an algebra achievement test and an attitude test at the beginning and end of the seven weeks, as well as two chapter tests. All classes were taught using active learning techniques. Active learning is where students are actively engaged in the learning process, doing things and thinking about what they are doing (Fox, 1998). Students in the control group could use a scientific calculator. Students in the experimental group used TI-82 graphing calculators and the instructors used overhead graphing calculators for demonstration.

Results indicate that the control group and the experimental group had no significant differences on the pretest. There were also no significant differences on the chapter tests or the post-test. The control group had more students pass the course than the experimental group but the difference was not significant. The participants of the control and experimental group passed at a higher rate (58%) when compared to previous semester's students (48%) and to students in other similar classes in same semester taking traditional courses (42%).

The results of the attitude survey showed no significant difference between the control group and the experimental group on the pretest. There was also no significant difference on the post-test as well. The instructors reported anecdotally that students in the experimental group saw the calculators as "security blankets" (Fox, 1998, p.122). They also reported that the weaker students in the control group would give up while the students in the experimental group would think they still had a chance because of the calculator. Most advanced students used the calculator to check their work more; however, some students seemed to feel like using the calculator was cheating.

Shore (1999) studied beginning and intermediate algebra classes. Two instructors at each level were the control group and did not allow students to use graphing calculators, but required scientific calculators. The remaining three instructors allowed students to use graphing calculators and received training on the use of TI-85 or Casio 9850G calculators. Students in these courses were required to take a researcher-generated pretest and post-test in a testing lab.

The study found significant gains in procedural knowledge from the pretest to the posttest for both elementary and intermediate algebra when using graphing calculators but not when students were using scientific calculators. In elementary algebra there were significant conceptual gains for both the graphing and non-graphing calculator groups. However in intermediate algebra, the significant conceptual gain was only for the calculator group. The pass rates for both the elementary and intermediate algebra courses were not significantly different indicating that students in the graphing sections obtained more conceptual and procedural knowledge without a decrease in pass rates.

A researcher created questionnaire given at the end of the course indicated that both graphing calculator students and non-graphing calculator students believe that students should be able to use a graphing calculator in developmental courses. They thought it was the place to learn how to use this technology. The graphing calculator students also believed that the graphing calculator made the mathematics easier to understand and they spent less time memorizing and more time understanding the concepts.

These studies show that graphing calculators in developmental algebra courses can increase students' procedural and conceptual knowledge. Even though the studies used different types of graphing calculators for different lengths of time in different courses, the results showed improvement in student knowledge.

The results also showed that the attitudes of students toward mathematics positively increased with the use of graphing calculator technology. Students at this level seem to believe that calculators make math easier.

The studies did not address the effect of the instructors' knowledge and experience teaching with a graphing calculator upon students. Most of the instructors had some training with graphing calculators but did not have much experience using them in the classroom. It is possible that the instructors' enthusiasm for the calculator helped students' attitudes to improve. It is also possible that as instructors become more experienced in teaching with the calculator that students' knowledge would further increase.

Developmental Education Non-graphing Calculator Studies

At the basic mathematics and prealgebra levels, very little research has been done concerning calculators. The following five studies were either done at a community college or in developmental mathematics courses at a university.

Leitzel and Waits (1976) examined the effects of calculator usage in Ohio State University's freshman remedial mathematics course. Their remedial course covered elementary and intermediate high school algebra and coordinate geometry with an emphasis on problem solving. Students were required to use a calculator (four-function, six-digit, floating-decimal, algebraic-entry type calculator with a built-in repeat-operation capability) for classwork, homework, quizzes, and tests during a semester-long course. About 2,250 students responded to a four question evaluation. Ninety-one percent of the students either agreed or strongly agreed that having a calculator was helpful. Fifty-nine percent said that their attitude toward mathematics was favorable.

Hector and Frandsen (1981) studied 72 students enrolled in basic mathematics at Walters State Community College. The students were randomly divided into three groups after ability ranking. All of the students completed a slide-audiotape-workbook module on whole numbers and were required to restudy and retake the module exam until they could pass with an 80%. Upon completing the whole-number module, students were pretested with a subtest of the Stanford Diagnostic Arithmetic Test and with the Aiken Revised Math Attitude Scale. Students then completed their treatment and were post-tested.

The first group completed fraction modules without the use of a calculator. The second group completed a module on operating a calculator before the fraction modules and was allowed to use a calculator at any time. The third group completed the module on operating a calculator and was shown calculator algorithms for adding, subtracting, multiplying and dividing fractions instead of traditional algorithms. A multivariate analysis showed no significant difference among any of the groups. A significant pretest to post-test gain indicated that students were able to learn fraction computation using all three methods.

Boyd and Carson (1991) used two prealgebra sections at DeKalb College, an Atlanta community college. The control section, taught by Boyd, was not allowed to use calculators. The experimental section, team-taught by Boyd and Carson, was asked to bring a calculator to class and was encouraged to use it in class, on homework and on tests. Instruction in calculator use was provided as necessary. The use of the calculator led naturally to an emphasis on problem solving as the instructors emphasized the difference in exact and approximate results as well as estimation. It also led to more active learning, as students compared their different results and tried to reconcile the outcomes.

When comparing SAT math and verbal scores, as well as Basic Skills Exam (state placement test) scores, the experimental group mean was lower than the control group. During the semester, the students took five identical tests and a departmental multiple choice final exam. The experimental group's mean score was as well, if not better, than the control group every time, but the findings were not significant at a .05 level. A survey administered at the end of the semester indicated that 86% of the students used a calculator for homework and 91% of the students protested that in-class use of a calculator was not allowed. The students in the control group were generally negative in their attitude toward the course, in direct contrast to the generally positive attitude of the experimental class.

Davidson, Donaldson, Hodge-Hardin and McGill (1996) examined the effects of calculators on developmental algebra students at East Tennessee State University. Eight introductory algebra classes were selected at random. The 192 students were aware of their participation in the study and were allowed to choose the class that fit their scheduling needs. Four classes were allowed to use calculators. The calculator and non-calculator group had the same text, homework and exams. A post-test was administered the last week of the semester as a final exam. The data showed no significant difference in post-test scores or final grades. The non-calculator group had a higher post-test score. The calculator group had a higher final grade mean score.

Vasquez & McCabe (2002) evaluate the effect of calculator usage with four established sections of basic mathematics students at a central Texas four-year university. The sections were randomly assigned to one of four treatments: graphing calculator, four-function calculator, optional use of calculator or no calculator. The students were presented with lessons on integer addition and subtraction, equivalent fractions and scientific notation. Students were not allowed to use a calculator on the pretest or the post-test. Data was collected from homework, course examinations and journals of the instructors.

The means for all four groups increased from the pretest to the post-test but there was no significant difference among any group. Most of the students did not submit their homework; however, the students did better than expected on the course examination. The journals of the instructors showed that students did not want to use the calculator, as it would not be allowed on the test. Even with instruction on how to use the calculators, students felt that the calculator was not “keeping it simple” (Vasquez, p. 40). Students that used the calculators mostly used them for basic arithmetic. Students in the no calculator group did not even comment about calculator usage at all. The students seemed to expect to not be able to use a calculator.

The results of these research studies seem to show that calculators do not hinder basic skill development but can not show that calculators improve student achievement. These studies are spread out over a 27 year period. When the first study was published in 1976, graphing calculators did not exist and handheld calculators basically performed 4 operations (Leitzel & Waits, 1976). As time went by, the calculator became more complex but seldom was calculator instruction for students included in the study (Boyd & Carson, 1991). Calculator instruction for the instructors was never provided and researchers also did not provide the instructors with pedagogical instruction for using calculators in their classroom. Possibly if the instructors had been provided with the skills required to integrate the calculator into the classroom as a teaching tool, the results of the studies would have aligned with the K-12 and graphing calculator research.

Students' attitudes toward mathematics seemed to increase with both the graphing and non-graphing calculators. This increase could be caused by many variables not controlled for in these studies. Students have access to calculators outside of the classroom. Possibly their prior knowledge of calculators and the ability to use them in the classroom positively increased their attitude towards mathematics.

None of these studies questioned students about why they use a calculator nor did they question students as to when using a calculator was useful to them. If students are just using calculators to do computation instead of tools to help them understand the mathematics, that may significantly change the impact of the study.

Questions Raised by the Research

The research at the K-12 level is plentiful and shows that calculators can impact student achievement and attitude. Research at the developmental level is more limited. Examining some of the graphing calculator research at the developmental level shows that graphing calculators also can increase student achievement and positive attitudes towards mathematics.

The research at the basic mathematics and prealgebra level is extremely limited. Most of the research shows that calculators neither harm nor increase student achievement. The small amount of research on students' attitudes shows that they can positively increase with the use of calculators in the course.

What is missing from the research is information on why instructors use or do not use calculators in basic mathematics and prealgebra courses. This information is important to understand if we want to encourage the use of technology per the standards. Of interest is to understand how instructors perceive their students' use of calculators at this level and how that is the same or different from students' actual use. Also of interest is the perceived impact of calculators on students' grades by instructors and students at this level.

Research at other levels shows calculators are a positive influence on basic skills, conceptual learning and attitude toward mathematics. Studies show this probably is true as well for basic mathematics and prealgebra students based on the small amount of data available. What is missing is data on student and instructor calculator usage at this level. This information will help provide a base for further research by providing information on the fundamental usages of calculators in the developmental classrooms. If instructors only see calculators as a tool for computation and not a teaching tool, research could be developed to address this issue. This study gathered more information to help researchers understand the current state of calculator usage in the developmental classroom.

CHAPTER 3

METHODOLOGY

This chapter provides information about the methodology used in this study of student and instructor calculator usage in developmental mathematics at the community college level. It provides information about the research context as well as the methods used to collect and analyze the data.

Research Questions

This study investigated the following research questions relative to basic mathematics and prealgebra community college courses:

1) Why do instructors choose to use or not use calculators?

2) What are instructors' perceived reasons for student calculator use?

3) How often do students use a calculator, and what are their reasons for calculator usage?

4) Do students and instructors believe that calculator usage affect grades?

Research Context

The study was conducted at XYZ college, a multi-campus community college in the southwestern US. At the time of this study, the college was the fifth largest community college in the nation with six campuses in a large metropolitan area. There were also classes offered at non-campus locations throughout the city. The college had

351 full-time instructional and educational support faculty. The college had approximately 30,000 students per semester in both credit and non-credit courses.

The students at the college were very diverse. Women made up 57% of the college population. The overall student population was 59% white with Hispanic students at 29% comprising the majority of the remaining population. The mean student's age was 27 with a median of 22. About 70% of the students attended part-time. The college had over 160 programs ranging from certificate programs for trades to transfer programs.

The campuses were diverse as well as shown in Table 1. The percentage of female students ranged from 53% to 63%. The number of Native American, African American and Asian American students was fairly stable at all campuses, ranging from 1% to 5%. The White and Hispanic population varied much more dramatically based on campus. The White population ranged from 21% to 65%. The Hispanic population ranged from 21% to 64%.

The student's ages varied greatly as well. In the thirteen to nineteen year old age group, the amount of students ranged from 17% to 37% of the campus population. The other age groups had less dramatic differences with only a ten percent range of difference between campuses. Students who were non-high school graduates and at least 16 years of age with the ability to benefit from instruction were admitted through the regular admissions process. Students who attended high school were required to have permission from the high school and their parents or legal guardians. Students under 16 had additional registration requirements.

The majority of the students were part-time students. Full-time students carried at least 12 credits in a semester. Students with less than 12 credits were considered part-time students. The college did not have any dormitory facilities so all students lived off campus.

An examination of the demographics reveals that Campuses E and C had more white students and younger students. Campus A had the most students and the highest percent of fulltime students. Campus B had the highest male population. Campus D had the highest percent of Hispanic students. Campus F had the highest amount of part-time students. This diversity among the campuses provided a variety of populations to study.

Table 1

Student Demographics by Campus

Campus	A	B	C	D	E	F	Total
# of Students [a]	11,659	9,023	6,764	3,671	4,349	4,484	30,901
Male	44%	45%	40%	36%	40%	36%	42%
Female	54%	53%	58%	63%	58%	62%	57%
Native American	3%	3%	2%	4%	1%	2%	2%
African American	4%	4%	5%	3%	2%	5%	4%
Asian American	4%	4%	4%	2%	3%	3%	4%
Hispanic	32%	30%	21%	64%	21%	22%	29%
White	47%	50%	59%	21%	65%	59%	54%
Other	3%	4%	3%	3%	3%	3%	3%
13-19	25%	22%	28%	33%	37%	17%	26%
20-29	51%	50%	46%	40%	42%	46%	45%
30-39	11%	13%	13%	13%	9%	18%	13%
40-49	6%	9%	8%	9%	7%	11%	9%
50-59	4%	5%	3%	4%	3%	8%	5%
60-100	2%	2%	1%	1%	1%	1%	2%
Full-time	40%	32%	35%	32%	36%	23%	28%
Part-time	60%	68%	65%	68%	64%	77%	72%

[a] Note: Campus totals do not add to college total because students may be enrolled at multiple campuses

The college had an open admission policy in which no students were denied admission to the college. Students who attended college for the first time, were currently in high school, or were enrolled in a mathematics, writing, reading or general education course for the first time were required to take assessment tests in reading, writing and mathematics. The students took the computerized Compass test (Compass, 2008) or the paper and pen Asset test (Asset, 2008). The Compass and Asset tests are placement tests created by ACT to help colleges place students in the correct Math, Reading, or Writing course. Students who scored below 54 on the Compass prealgebra mathematics test or below 43 on the Asset test numerical skills were required to take basic mathematics or prealgebra.

The college had 43 fulltime mathematics instructors and one fulltime administrative appointment in the spring semester when the data was collected as shown in Table 2. Faculty who taught fulltime were required to be certifiable to teach academic transfer as well as developmental courses in the college. Academic transfer courses are courses that will transfer to a University. Faculty teaching academic transfer courses were required to have a masters degree in mathematics or in any teaching field with 18 graduate semesters credit hours or 24 upper division semester credit hours in mathematics. Developmental courses could be taught by faculty with a Bachelors degree in mathematics or in any teaching field with 24 lower/upper division semester credit hours in mathematics.

Table 2

Breakdown of Campuses by Full-time and Adjunct Instructors

Campus	A	B	C	D	E	F	Total
Full-time	11	13	9	5	5	1[a]	44
adjunct	10	12	13	8	6	5	54

[a] This position was an administrative appointment.

The mathematics department relied on adjunct faculty to teach over 70% of its three credit basic mathematics (Math 82) or prealgebra (Math 86) courses as shown in Table 3. The adjunct faculty came from a variety of places. Some taught at local high schools or the local university, while others were in higher degree programs at the local university. Some worked at large engineering and research firms in the city. Some have retired from other jobs and taught part-time because they enjoy teaching.

Table 3

Breakdown by Campus of Sections Taught by Fulltime or Adjunct

Campus		A	B	C	D	E	F	Total
Math 82	Full-time	0	1	1	2	0	0	4
	Adjunct	6	5	5	2	3	2	23
Math 86	Full-time	3	6	1	3	2	2	17
	Adjunct	9	8	12	8	4	5	46

The developmental courses were usually offered in three credit classes taught once or twice a week using a traditional format with an instructor in a classroom. Each campus chose their own textbook and the individual faculty could decide if it they wanted to use additional resources such as computerized homework systems. One campus offered the developmental courses in a self-paced learning lab where the courses were broken into one credit modules. These courses were overseen by an instructor with the help of lab staff.

This multi-campus community college provided a large diverse faculty and student audience to survey. The college also agreed to provide access for information gathering with student and instructors in individual classes. The Human Subjects paperwork is on file with the researcher.

Method of Data Collection

This study was a descriptive study. Data to answer the research questions was gathered using survey instruments. The instructors and students were given separate surveys to gather information to answer the research questions. The data collected was analyzed to provide information to answer the research questions.

The instructor survey was created by the researcher to answer research questions one, two and four (see appendix A & B). The survey was interoffice mailed the second week of the spring 2007 semester to all 43 fulltime instructors at the college as well as all 54 adjunct faculty who were currently teaching basic mathematics (Math 82) and/or prealgebra courses (Math 86). Each instructor received a letter explaining the survey (see appendix A) and the survey along with a return envelope that only had the researcher's name and mail code for interoffice mail on it to ensure confidentiality. All surveys that were returned by April 1, 2007 were used in the data analysis process.

The instructor survey collected information on whether the instructor was full-time or adjunct, as well as the number of semesters that an instructor had taught basic college mathematics and prealgebra in a traditional classroom, online or using some other methodology. Instructors were asked if they allow students to use calculators for homework, in class and for tests in basic college mathematics and prealgebra. They were asked open and closed-ended questions to gain insight on why they allow or do not allow calculator usage at each level; how often they think their students use calculators for homework, class work, tests, math in other classes and outside of school; why instructors think that students use calculators; what kinds of math problems cause students to use a calculator; and if they changed their calculator usage policy would it have an effect on students' grades.

The student survey was a researcher-created survey designed to gather data to answer research questions three and four (see appendix C & D). The students were asked if they were allowed to use a calculator for homework, in class work or tests. They were asked open and closed-ended question to gain insight on how often they use calculators to do homework, to complete work in class, to take math tests, to do math in other classes and to do math outside of school; what kind of calculator that they use; why they use their calculator; what kinds of problems either make them want to use or cause them to use their calculators; if students were changing classes over calculator policies; and the perceived effect of calculator usage on their grades.

In the spring of 2007, there were 90 basic mathematics and prealgebra sections using a three credit courses format and 10 sections of one credit self paced courses being offered. Table 4 shows the breakdown of Basic Mathematics and Prealgebra courses by type offered in the spring of 2007. Traditional three credit courses were offered in a classroom with an instructor. Online courses were totally online while web enhanced courses used some online resources usually to facilitate homework and quizzing. Self paced courses were offered in either a classroom or lab setting and could be taken at one campus in modules where students only have to complete 1/3 of the semesters work at a time.

Table 4

Breakdown of Sections Offered by Type

	Traditional	Online	Web enhanced	Self paced
Basic Math	26	0	0	7
Prealgebra	49	3	6	9

The researcher interoffice mailed letters the third week of the semester to all full-time and adjunct faculty who were currently teaching in the spring 2007 semester (see appendix E). The letter asked for permission to give the survey to students in their courses at a time convenient to the instructor. By the fifth week of the semester, 10 instructors teaching 15 sections had responded to the request. The researcher had set a maximum of 12 sections for distribution of the survey which required that three sections be eliminated. One instructor's two sections of students were not included in the survey due to the courses having only three and five students. Another instructor's section was chosen for elimination because the researcher had collected data at that campus at the same time on a different day of the week. The twelve remaining sections were surveyed by the researcher during the sixth through eight week of the semester at various campuses during morning, afternoon and evening courses as shown in Table 5.

Table 5

Number and Type of Sections Surveyed by Campus

Campus	A	C	D	E	Total
Morning		Basic Math Prealgebra	2-Prealgebra	2-Prealgebra	6
Afternoon	2- Prealgebra		Prealgebra		3
Evening		Prealgebra	Basic Math Prealgebra		3

The student surveys were administered by the researcher to all students who attended the class on the day the researcher was present. A total of 198 students were surveyed; student counts are shown in Table 6. The researcher provided the students with verbal instructions that explained the Human Subjects consent form and how the students needed to fill out different sections depending on whether or not their instructor allowed calculators. Students were shown the three different types of calculators- four function, scientific and graphing. This was to be sure that the students understood the different types of calculators. The surveys were given during the sixth thru eighth week of the semester so that students had enough time to become familiar with all aspects of the instructors calculator policy but prior to the withdrawal date so that students who were not doing well in the course would be surveyed as well.

Table 6

Number of Students Per Section Surveyed

Section	1	2	3	4	5	6	7	8	9	10	11	12
Morning		16			27		10	20			21	17
Afternoon			9						15	12		
Evening	19			19		13						

Analysis Process

An open coding process (Corbin & Strauss, 1998) was used to analyze the data gathered from the open-ended questions. The first step of this process was to transfer all answers from the individual surveys to an Excel spreadsheet. The next step was to create labels for the answers to the open-ended questions. These labels were then used to derive categories that explained what was happening in the data. For example, labels such as add, subtract, multiply and divide were combined to form the category basic computation. The researcher attempted to summarize the ideas presented by the instructors and students as they answered the open-ended questions. Data collected from all surveys was used in this process.

Descriptive statistics were used to analyze the closed-ended questions. Means, median, modes, ranges and standard deviations were found for all Likert-type scale questions. The Likert-type scale on the survey was from 1 “always” to 5 “never”. For ease of interpreting the data, this scale reverse scored to 1 “never” and 5 “always” in all tables. Percentages were found for the “yes” or “no” questions.

The instructor and student data was analyzed by individual question and then the information gathered from the individual questions was used to answer the research questions. The analysis of the data is found in chapter 4.

CHAPTER 4

FINDINGS

This chapter provides an analysis of the data that were collected from the instructor and student surveys. First, the instructors who were surveyed are described. Next, the findings of the survey questions are analyzed using the following categories: calculator policy, calculator usage, calculator effect on grades and calculator effect on instructor selection. Finally, the findings are summarized.

Description of Instructors Surveyed

The instructor survey was given to 97 instructors in the spring 2007 semester. By April 1, 2007, 54 instructors returned their surveys. This was a 56% overall return rate. The instructor survey asked if the instructor was fulltime or adjunct faculty. Fulltime faculty were required to teach 15 credit hours a semester and could also teach two overload classes if they desired. Adjunct faculty could only teach a maximum of 10.5 credit hours for the college per semester. Exactly half of the instructors who responded to the survey taught fulltime, and the other half taught as adjunct faculty.

With an overall return rate of fifty-five percent, it was important to see if the individual campus return rates varied (see table 7). The campuses had fairly similar rates of return with the range being from 38% to 77%, except for campus F which had 16% rate. Campus F classes were not held at a traditional campus but were scattered throughout the city, and many of the classes were taught online. Campus F also had the fewest basic mathematics and prealgebra classes as well as only one fulltime faculty member. These issues might be the reason for the low rate of return from this campus. Since campus F students were not surveyed, the low rate of return on the instructor survey should not impact results.

Table 7

Return Rates by Campus

Campus	Fulltime Surveyed	Fulltime Returned	Adjunct Surveyed	Adjunct Returned	Total Returned	Return Rate
A	11	5	10	3	8	38%
B	13	10	12	3	13	52%
C	9	5	13	10	15	68%
D	4	3	8	7	10	77%
E	5	4	6	3	7	64%
F	1	0	5	1	1	16%
Total	43	27	54	27	54	56%

Table 8 shows the length of time faculty who responded to the survey taught basic mathematics or prealgebra as well as the methodology used when they taught. The majority of the instructors taught in a traditional classroom with adjunct faculty having taught as many or more semesters than many of the fulltime faculty. In basic mathematic, the highest number of semesters taught was 30 semesters by an adjunct faculty member and 20 semesters by a fulltime faculty member. In prealgebra, an adjunct had taught 32 semesters while a fulltime faculty member taught 25 semesters.

Table 8

Number of Instructors by Type (fulltime or adjunct), Semesters Taught and Methodology Used

Course	Semesters Taught	Traditional		Online		Computers in Traditional class		Self Paced Lab	
		Full	Adj.	Full	Adj.	Full	Adj.	Full	Adj.
Basic Mathematics	0-4	10	11			1	2		
	5-10	4	6		1			2	
	10+	2	4						
PreAlgebra	0-4	10	9		1	4	2		
	5-10	5	10						
	10+	4	6		1			1	

In both basic mathematics and prealgebra, the computer instruction in a traditional classroom involved two programs, Hawkes (Hawkes Learning, 2008) and Enable Math (Enable Math, 2008). These programs provided online lessons and homework in a traditional classroom setting with paper and pencil testing. One instructor did not specify the program name but taught using online materials, except for the tests, similarly to the Hawkes and Enable math programs.

The fulltime faculty were asked when they last taught basic mathematics or prealgebra because many were not teaching either course this semester. This question was not asked of adjunct faculty as all adjuncts surveyed were currently teaching one of these courses. The majority of full-time faculty had taught basic Mathematics or prealgebra in the last five years. Of the full-time faculty who had not taught in the last five years, one instructor had not taught these courses for 8 to 10 years. The other three instructors had not taught these courses in over 20 years. All full-time faculty regardless of how long it had been since they taught were included in the survey as they are part of creating the policies surrounding calculators in the departments at the campuses.

Calculator Policies

Calculator policies were examined at the department level and at the classroom level. As the college did not have a calculator policy for all developmental classes, the mathematics departments at each campus developed their own policy or not based on what the department chairs in conjunction with the full-time faculty at the campus decided to do. Four out of the six campuses had a calculator policy but overall about 50% of the adjunct and fulltime faculty answering the survey did not know the correct policy. This confusion surrounding the calculator policy extended into the classroom as well. Students were unclear as to the calculator policy of their instructor. The following analysis of the survey questions describes the confusion around calculator policy at both the instructor and student levels.

Department Policies

The instructor survey asked the instructors if their campus had a calculator policy for basic mathematics or prealgebra. The follow-up question asked what the policy was if they had one. Table 9 shows the result by campus. Some instructors who said the campus did not have a policy answered the question that asked what the policy was. These answers tended to show that the instructors did not feel the campus had a formal policy but seemed to have an informal policy which they wrote in response to the question about what the policy was. One instructor who said there was no policy and then noted “I think it [calculator usage] is unofficially discouraged” which shows an example of this informal policy information.

Table 9

Instructor Knowledge of Calculator Policy

Campus	Does campus have policy?	Campus has policy	Campus does not have policy	Did not know if had policy	Did not answer	Wrote correct policy	Wrote wrong policy
A	Yes	6		2		4	2
B	Yes	6	6	1		6	3
C	Yes	6	7	2		2	8
D	Yes	5	3	1	1	4	1
E	No		5	2			1
F	No	1					1
Total		24	21	8	1	16	16
% of instructors surveyed		44%	39%	15%	2%	50%	50%

As the college did not have a cross campus policy, the researcher asked the department chairs of the campuses about their department policy after the surveys were returned. Every campus had a different policy with only campuses E and F not having a calculator policy. The lack of consistency among campus policies might have contributed to the confusion surrounding calculator policies. Another issue that might have contributed to the confusion was that some adjunct faculty teach at multiple campuses. In the semester that the instructors were surveyed, no adjunct was teaching at more than one campus, however, some have taught at other campuses in the past. The following individual campus data shows the differing policies and how well the faculty understood their campus policy.

The A campus department chair said that calculators were not allowed in basic mathematics on exams but in prealgebra calculators were used at the instructors' discretion. Seventy-five percent of the instructors at this campus knew there was a policy, and 66% that wrote there was a policy had it correct.

The B campus department chair said that the fulltime faculty disagree on what the policy should be so the adjuncts were told what the department chair believed the policy should be. At the time of the survey, adjuncts were told that calculators are not allowed in basic math and prealgebra. Fulltime faculty should have been aware of the policy so that if they were asked by an adjunct faculty member they could provide them with the correct information even if they did not abide by the policy themselves. The adjunct faculty at this campus knew there was a policy and two of the three adjuncts had the correct policy. Three of the ten fulltime faculty knew there was a policy and two of the three had the correct policy. Overall, 46% of the instructors at this campus knew there was a policy, and 66% that wrote a policy had it correct.

The C Campus Department chair said the policy was that calculators are optional and at the instructors discretion in basic math and prealgebra. Forty percent of the instructors at this campus knew there was a policy, but only 20% that wrote there was a policy had it correct.

The D campus department chair encouraged faculty to use calculators but left the decision to the individual faculty. The campus policy was that calculators were optional. Fifty-five percent of the instructors at this campus knew there was a policy, and 80% that wrote a policy had it correct.

The E campus department chair said that they did not have a policy about calculator usage in either course. Seventy-one percent of the instructors knew there was not a policy. The only instructor who wrote what the policy was said that instructors just agreed that calculators should not be used.

The F campus department chair said that they had no written policy and it would be hard to enforce a policy with online classes which was the majority of the courses at that campus. The one instructor who worked at F campus said that they did have a policy and that the policy was that the calculator was an opportunity to learn skills.

These findings show that many instructors did not have an accurate understanding of the calculator policies of the campuses. Fifty percent of the instructors that wrote that there was a policy had the policy wrong. Fifteen percent of the instructors did not even know if there was a policy on their campus. These findings are important because the confusion surrounding calculator policies shows that instructors are not certain when it is allowed or appropriate to use calculators.

Student View of Classroom Policies

To examine calculator policies in the classroom, students were surveyed. The student survey had an introductory part consisting of four questions, and then the remainder of the survey was divided into two parts. Questions 5 to 10 were to be answered by students whose instructor allowed calculator usage and questions 11 thru 14 were to be answered by students whose instructor did not let them use a calculator in class. Students were told how to fill out the survey by the researcher immediately before they began the survey. Table 10 shows how many students answered which sections by each of the 12 classes surveyed.

Table 10

Number of students that answered questions by class

Class	Students should have answered	Questions that were answered: 5 to 10	11 to 14	5 to 14	1 to 4 only
1	5 to 10	18		1	
2	5 to 10	13		3	
3	5 to 10	7		2	
4	5 to 10	12	4	2	1
5	5 to 10	27			
6	5 to 10	12		1	
7	5 to 10	8		2	
8	5 to 10	20			
9	11 to 14		10	5	
10	11 to 14	1	10	1	
11	5 to 10	12	5	4	
12	5 to 10	16		1	
Total		146	29	22	1

These findings show that students generally knew if the instructor allowed them to use calculators in class or not. Only classes 9 and 10 were not allowed to use calculators according to their instructor. The instructors were asked if they allowed calculators when the researcher set up the classroom visit. Only two classes had all of the students complete the surveys according to the instructions that were given prior to the beginning of the survey. This presents a question as to whether the students did not know the instructor's calculator policy or if the students just did not understand how to fill out the survey. As the surveys were given anonymously, there was no way to go back and ask the students who filled the survey out differently from their fellow students. However, the researcher observed that some students did not listen well when given the survey. As the survey was not part of their grade, some students seemed unconcerned about how well they answered the questions. The researcher also observed that some students were bilingual. One student who answered all of the questions wrote “English is my second language, so some classes I don't now about the values the instructor use.” Comments like this showed that some students’ language skills might have caused some of the confusion as to which questions they should answer.

Classes 4 and 11 had a larger number of students unsure about how to fill out the survey. Both of these instructors allowed calculators in class, but from the answers provided by the students, these instructors were not seen using calculators frequently in class. These instructors told students that they could use them, but the instructors did all of the work long hand or in their head, according to the students. This might be what was confusing the students as they assumed since the instructor did not use one that they should not either. However, other classes had higher percentages of students reporting that their teachers did not use calculators and their students answered the surveys with better accuracy. It might be that these students were just uncertain about how to fill out the survey or were unaware that they could use calculators in class.

These results show that both instructors and students had confusion around calculator policies. The instructors seem to be unclear about what the department policy was, and some students seem to be unclear about the instructors' classroom calculator policies. As the instructor surveys were anonymous, there was no way to see if the instructors' confusion relates to the student confusion in the classrooms that were surveyed. However, three instructors had two separate classes surveyed. In Class 1, 5% of the students completed the survey differently from what was expected while Class 4 taught by the same instructor had 37% of the students complete the survey differently. Students that completed the survey incorrectly might reflect confusion surrounding the instructors' calculator policy. In classes 7 and 8 (taught by the same instructor), the rates were 20% and 0%. In classes 9 and 10 (taught by the same instructor), the rates were 33% and 16%. This variation among classes with the same instructor indicated that instructors were not the only source of confusion surrounding calculator policies.

Classroom Policies Regarding Homework, In Class Work, and Tests

To examine calculator policies more in depth, the instructors were asked if they allowed their students to use calculators for homework, in class and for tests in basic mathematics and prealgebra courses. This question was answered using a Likert-type Scale with responses ranging from 1 "never" and 5 "always". The results are in Table 11. In all categories, the range was from 1 to 5 with most categories having a fairly even distribution. Some responses, such as "For tests", had a high distribution of 1's (never) compared to 5's (always), which is reflected in the median.

Table 11

Instructors' Calculator Policy

	Homework			In class			For Test		
	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Basic Math									
Adjunct	3.12	3.00	1.62	2.61	2.00	1.54	2.33	2.00	1.61
Fulltime	2.69	2.50	1.45	2.19	2.00	1.38	1.80	1.00	1.52
Combined	2.91	3.00	1.53	2.41	2.00	1.46	2.09	1.00	1.57
Prealgebra									
Adjunct	3.52	4.00	1.66	3.19	3.00	1.67	3.00	3.00	1.68
Fulltime	3.50	3.50	1.59	3.33	3.00	1.50	2.83	2.50	1.62
Combined	3.51	4.00	1.61	3.25	3.00	1.59	2.93	3.00	1.64

This table shows that instructors allowed their students to use calculators more for homework than in class or for tests in both basic mathematics and prealgebra courses. Usage on tests was always the lowest average of the three. The only category where fulltime faculty allowed usage more than adjunct faculty was in class during prealgebra classes. In all other categories, adjunct faculty were more likely to have allowed calculator usage than fulltime faculty.

This table also shows that basic mathematics instructors tended to allow calculators use less frequently (Means for Homework 2.91, In class 2.41, Tests 2.09) than prealgebra instructors (Means for Homework 3.51, In class 3.25, Tests 2.93). This is supported by responses to other survey questions that indicated basic mathematics instructors might use the calculators for some things like problem solving but did not use calculators for chapters where they were teaching basic operations. One instructor said "do not allow for chapter 1-3 specifically basic operation with whole #, fraction, decimals" which exemplified how basic mathematics instructors' typical use of calculators.

This table also shows that instructors in prealgebra tended to use calculators more in every category than basic mathematics instructors. Responses from open ended questions showed that instructors seemed to think that the students should have learned how to do basic computation in the basic math class and now they can use a calculator to make the process easier, faster and more accurate. As one instructor put it "math 86 [prealgebra] students should be proficient in manual math operations."

In order to examine calculator usage from the students' point of view, students were asked if their instructor allowed them to use a calculator for homework, in class and for tests using the same Likert-type scale where responses ranged from 1 "never" to 5 "always." The means of the responses by class are in Table 12.

Table 12

Means of student responses by class surveyed to the question "Does your instructor allow you to use a calculator?"

Class	Calculator Allowed (according to instructor)	For Homework	In Class	For Tests
1	Yes	4.79	4.68	4.53
2	Yes	5.00	4.73	4.27
3	Yes	4.33	3.89	4.00
4	Yes	3.71	3.33	2.50
5	Yes	4.63	4.69	4.58
6	Yes	4.08	4.08	3.62
7	Yes	4.20	4.20	4.20
8	Yes	4.30	3.95	3.72
9	No	2.50	1.14	1.00
10	No	2.50	1.36	1.00
11	Yes	3.10	2.56	2.44
12	Yes	4.88	4.88	4.82
Total		4.07	3.75	3.51

The responses clearly show that students believed that their instructors allowed them to use calculators on homework. Classes 9 and 10 were not allowed by the instructor to use calculators for anything. Both classes have an average of 2.50 which is a high amount of students saying the instructor allowed calculator use for homework when it was not allowed. Classes 9 and 10 did say that a calculator was not allowed on the test which shows that the students only understood part of the calculator policy. The students understood that they could not use their calculators for the test but some students thought it was okay to use the calculators for homework and in class.

This data also shows that even when students were told that they could use calculators by the instructor, some students did not get that message. Class 11 was told that they could use calculators, but the mean for homework was 3.10, the mean for in class was 2.56 and the mean for tests was 2.44. These means are a fairly low for a class that was allowed to use a calculator. Class 4, another class that was allowed to use calculators, also had fairly low means with a homework mean of 3.71, in class of 3.33, and test of 2.50. Students in both of these classes had difficulties filling out the correct survey questions. This lack of understanding might have contributed to the low means. Also, students in both of these classes indicated that they did not see their instructor use a calculator in class. This lack of use by the instructor might be a reason why the students believed that they should not be using a calculator.

The responses for in class use were slightly less than for homework. Class 11, a class where students had difficulty filling out the survey, had a 2.56 which was one of the lowest averages. Class 9, a class where the instructor did not allow calculators, had the lowest with a 1.14 average which relates well to the teachers policy.

The responses for tests were usually the lowest of the three responses. Students seem to feel that the instructors did not allow calculator usage on tests more than with homework or in class use. Class 9 and 10 were classes where the instructor did not allow calculator use and the students understood that. Once again, classes 4 and 11 exhibited the most confusion about the instructors' calculator policy with the lowest means for calculator use on tests among classes that were allowed to use a calculator. In class 4, 28%, and in class 11, 29% of the students thought calculators were never (answered survey question with a 1) allowed for the test when the instructor allowed them.

The students' confusion surrounding the calculator policy could result from many factors. Instructors may not have had a clear calculator policy on their syllabus to provide students with information about when calculators are appropriate to use or not use. Students may also have reported how they have used a calculator in previous mathematics courses. Students may have received conflicting messages regarding appropriate use of calculators. Many people including instructors feel that calculators are not necessary to learn mathematics. It is impossible from the information that was collected during this survey to discover the reason for the confusion surrounding calculator policies.

The survey does support the idea that students' own calculator usage may reflect how they see their instructor use a calculator in class. The classes with the lowest average usage on tests (except for classes 9 and 10 which were not allowed to use calculators) had a high percentage of students who said their instructors did not use a calculator in class. Class 11 (mean of 2.44) had 24% of the students report that their instructor did not use a calculator in class while class 4 (mean of 2.50) had 39% and class 6 (mean of 3.62) had 69%.

The instructors' averages in every category were always at least one Likert-type scale level lower than the students' averages. This showed that students were more likely to think that they could use a calculator when compared to what instructors stated was happening in their classrooms. This possibly resulted from the high number of students who were surveyed in classrooms where instructors allowed calculators. Basic mathematics instructors means for allowing calculators use were 2.91 for homework, 2.41 for in class and 2.09 for tests. Prealgebra instructors' means were 3.51 for homework, 3.25 for in class and 2.93 for tests. These means showed that approximately half of the instructors allowed calculator usage. As only two classes were not allowed to use calculators for any reason, it is reasonable that student averages would be higher as the sample was not representative of the population. However, the data clearly showed that students were confused about when instructors allow them to use calculators and when they were not allowed to use them. If the students had a good understanding of their instructor's calculator policy, the differences should have been even higher as the instructors surveyed were fairly evenly divided between allowing and not allowing calculator usage.

Encouragements for Policy Change

As calculator usage is encouraged by national standards at the community college level (Blair, 2006), it was important to find out what it would take to get instructors who currently do not allow calculators to change their policy. An open-ended question asked instructors what might cause them to change their policy. The results of this question are in Table 13. All instructors provided only one answer to the question.

Table 13

Reasons to Change From Not Allowing to Allowing Calculator Usage

Reason	Basic Math			Prealgebra		
	Fulltime	Adjunct	Percent	Fulltime	Adjunct	Percent
Nothing	4	1	29%	3	3	30%
Department Policy	2	3	29%	1	2	15%
Complicated Problems	1	3	24%	2	1	15%
Pedagogical Instruction	1	1	12%	3	3	30%
Compelling Argument	1	0	6%	1	1	10%

Both basic mathematics and prealgebra instructors indicated that information about how to teach using calculators would encourage a change in their policy with prealgebra instructors reporting this response three times as much. One basic mathematics instructor who did not allow calculators wrote “if I had some good lesson plans that used calculators for discovery” as something that would cause the instructor to change their calculator policy.

Both basic mathematics and prealgebra instructors indicated that if the textbook had more complex problems that needed calculators as a tool they would consider changing their policy. One basic mathematics instructor said “If I had a textbook with some really complicated homework problems then I might consider the calculator as a tool.”

Only 15% of prealgebra instructors indicated that a department policy would cause them to change their calculator policy. This is down from basic mathematics where 29% answered with that response. The instructors that indicated a department policy would cause them to change their policy all used a calculator infrequently or never in class, for homework and for tests. The instructors taught at campus B where calculators were not allowed and campus C where calculators were optional. Campus B instructors might not use calculators to comply with the department policy but campus C instructors are allowed to use calculators if they so desire. The campus C instructors might be indicating that they would only allow calculators if the department policy required them to use calculators. The decrease from basic mathematics to prealgebra among instructors indicating that a department policy would cause them to change their calculator policy is possibly due to the fact that more faculty seem to feel that calculators should not be used in basic mathematics. The data showed that instructors think calculators are more acceptable in prealgebra because students should have already learned the basic skills. Basic mathematics instructors might feel that it would have to be a department policy to force them to use calculators.

Instructors who indicated that nothing would get them to change their calculator policy seldom allowed calculator usage. The majority never allowed them on tests and occasionally allowed them for homework or in class work. Only one prealgebra instructor allowed calculators on the test but specified that the calculator was not allowed when testing basic operations. The instructors came from Campuses A, B, C and E.

These campuses had a large variety of policies ranging from never allowing (campus B) to no policy at all (campus E). The policy of the campus did not seem to affect the view of the instructors. As no campus had a policy that required instructors to use calculators, it is unknown if instructors would use them against their beliefs if the department policy required them to use a calculator. As 58% of the basic mathematics instructors and 45% of the prealgebra instructors answering this question indicated that only a department policy or nothing at all could get them to change their calculator policy, the data showed that many instructors were still resistant to using calculator in class.

The data showed that calculator policies at the campus level and the classroom level seem to be a source of confusion. Approximately 1/2 of the instructors who thought they knew their campus calculator policy had it incorrect. Fifteen percent of the instructors did not even know if their campus had a calculator policy. In regards to their classroom policies, the majority of the instructors (67% in Basic Mathematics, 60% in Prealgebra) indicated that they used calculators some of the time. Prealgebra instructors always allowed calculators more than Basic Mathematics Instructors (27% compared to 15%). Basic mathematics instructors (15%) and Prealgebra (13%) instructors had similar percentages of not allowing calculators at all. Among the instructors who do not allow calculators, approximately 2/3 would be willing to change their policy if department policy was different or they had more training in how to integrate calculators into the classroom. However, approximately 20% of all the instructors surveyed indicated that nothing or only a department policy requiring them to use calculators would cause them to use calculators in their basic mathematics and prealgebra courses. This showed that there was still a fairly strong resistance to calculator use at this level.

Many students do not clearly understand their instructor's calculator policy. Only 2 of 12 classes surveyed completed the student survey following the instructions and based on the calculator usage reported by their instructor. Even students taught by the same instructor in different classes showed confusion about the calculator policy of their instructor. This data showed that the instructor might not be the only influence that causes students to be confused about calculator policies however the survey did not produce data that can provide reasons for the confusion.

The confusion surrounding calculator policies at both the department level and the classroom level was evident from the data. Instructors need a clear understanding of the department calculator policy so that they can provide students with consistent instruction at the campuses. Students need a clear understanding of their instructor's calculator policy so that they will know when it is appropriate to use their calculator for homework, in class and on tests.

Calculator Usage

Understanding what causes instructors and students to use calculators is important for understanding the current state of calculators in the developmental classroom. The data showed that instructors and students mainly used calculators for computation at this level. It also showed that instructors understood that students wanted to use a calculator to make computation easier and that they used a calculator more outside of class than in class.

Instructor Usage

To examine the usage of calculators in the classroom, an open-ended question asked instructors why they either allowed or did not allow calculator usage for homework, in class or on tests for basic mathematics and prealgebra. Table 14 shows the specific reasons instructors list both for allowing and prohibiting calculator usage.

Table 14

Why Instructors Allow or Do Not Allow Calculators

Reason	Basic Math			Prealgebra		
	Allow	Not	% of responses	Allow	Not	% of responses
Basic Skills	2	14	47%	8	19	62%
Ease/Accuracy/Faster	3		9%	4		9%
Real Life	2		6%	3		7%
Problem solving	2		6%	1		2%
Confidence	2		6%	1		2%
Need to use Brains		2	6%			
Memorization of Basic Facts	1	1	6%			
Skills for Algebra		2	6%			
Dept Policy/Book requires		1	3%	1		2%
Increases Learning	1		3%	1		2%
Refuse to allow		1	3%			
Increase Concept Development				1	2	7%
Consist with real world				2		5%

Basic mathematics instructors usually said that students need to develop basic skills before they would let them use a calculator. One basic mathematics instructor who did not allow calculators said "problems are basic and students should learn how to do the work with paper and pencil in order to understand the problems." Another basic mathematics instructor who allowed calculators only after students showed proficiency in basic skills said “towards end of the class problems become more laborious and students have demonstrated basic manual math calculations.”

As in basic mathematics, prealgebra instructors believed that “they should learn how to add, sub, mult [multiply] and divide all real #'s without the help of calculators.” However, prealgebra instructors were more likely to allow calculators because the students should have already learned the basic skills and now “use of the calculator is primarily to aid computation after the prerequisite skills have been mastered.”

Other answers were highly varied. One basic mathematics instructor who allowed calculators said “mental skills are either rusty, poorly learned or non-existent. In order to get any advancement in the syllabus, I allow calculators. More calculators mean more problems and more drill and more learning of concepts.” Another basic mathematics instructor said that calculators were allowed “so calculations are done easily, correctly without time spend doing them or worrying about them.” These same ideas were also present in the prealgebra responses.

Two basic mathematics instructors discussed basic fact memorization but came at it from opposite ends of the calculator usage spectrum. One instructor said “students need basic drill on memorizing addition and multiplication tables. They can get some of this through routine calculations done by hand- not with calculator” while another instructor that allowed calculators said “by college should have their addition, mult facts. If not, they should learn them on their own.”

Basic mathematics instructors who did not allow calculators gave many reasons as well. One said students need to "learn how to do operations by hand in order be successful in algebra." Another said "they do not learn to use their brains."

Prealgebra instructors had a few answers that did not show up in the basic mathematics answers. One prealgebra instructor who allowed calculators said "students need to become as skilled as possible with their math tools." Another prealgebra instructor who allowed calculators said that it was "more important to understand concept than to make [a] simple math error a calculator can eliminate." One prealgebra instructor said that students "will always use them for homework, so I think to be consistent they should be able to use them in class." Another prealgebra instructor who gives homework on the computer said that allowing calculators provided consistency from homework to the test.

The differences between the basic mathematics instructors and the prealgebra instructors seemed to center on when students should be allowed to use a calculator. Only 13% of the basic mathematics instructors indicated basic skills as a reason to allowed students to use calculators while 30% of the prealgebra instructors indicated this same reason. The prealgebra instructors seem to believe that it is the job of the basic mathematics instructors to teach the student basic operations without a calculator and since the students have already learned their basic skills; the prealgebra instructors can now use calculators for computation. This assumption makes sense as many times in mathematics students learn how to do a difficult task and then are shown a simpler method once the more difficult method was mastered. This also fits well with the idea of the calculator as a tool since students have first mastered computation by hand and now are allowed to use a tool to make computation simpler.

Instructors were also asked an open-ended question about how they had students use calculators given the examples of computation, problem solving and discovery learning. The results broken out by basic mathematics and prealgebra are in Table 15.

Table 15

How Instructors Have Students Use Calculators

Reason	Basic Math		Prealgebra	
	Number	Percent	Number	Percent
Basic computation	8	35%	16	44%
Basic computation/problem solving /discovery learning	7	30%	7	19%
Problem Solving	1	4%	3	8%
Discovery learning	1	4%	1	3%
Problem Solving/Discovery Learning			3	8%
Accuracy	4	17%	2	6%
Everything	2	8%	2	6%
Calculator Instruction			2	6%
Total of responses	23		36	

The data showed that basic computation was the most common reason why instructors had students use calculators with basic mathematics instructors at 35% and prealgebra instructors at 44%. This is interesting as instructors previous reported basic computation as the primary reason that they did not allow students to use calculators. All three examples (basic computation, problem solving and discovery learning) were also a common choice with basic mathematics instructors at 30% and prealgebra instructors at 19%. These results indicate that instructors report using calculators for more than computation if only occasionally in their classrooms.

Only three answers did not come from the examples provided in the question. They are “accuracy”, “calculator instruction” and “everything”. Instructors, however, did elaborate on the examples provided which shows that the examples did not overly influence responses. One basic mathematics instructor said calculators were allowed for “all but mostly problem solving after the first 3 chapters I want the students to concentrate on comprehending the concepts of the applications and not worry as much or take too much time on long division, etc.” Another basic mathematics instructor said “if not studying whole numbers, decimals or percents I allow for long division or large multiplication problems, I especially like to let them use them on application problems.” As one prealgebra instructor said at “some point they need to not focus on computation- like we can do longer problems bigger numbers harder problem solving if they use a calculator.” These responses show that the examples in this question just provided instructors with examples and did not limit the instructors thinking.

In prealgebra and basic mathematics, accuracy and everything were indicated by instructors as reasons that they have their students use calculators that were not listed in the question examples. One prealgebra instructor whose answer indicated accuracy said "student[s] use to verify their work, I want to see student's thinking process on quizzes and tests, check work with calculator." Unlike basic mathematics, prealgebra instructors also brought up calculator instruction as a topic that was not listed in the examples. One of those instructors said "to do more real life exercises, teach features on calculator." This purpose of teaching how to use the calculator was not considered at all in basic mathematics.

Student Usage

To compare the instructors' answers with student answers, the students who were allowed to use calculators were asked how they used a calculator in class. The results are show in Table 16. The question provided the following examples: "to check answers, to do multiplication problems, etc." As the first example was to check answers and 81% of the students answered with this response, the students might have been biased by the examples listed in the question. The second example was "to do multiplication" and 3% of the students answered with that response. Another 4% included division with their multiplication answer which makes sense as multiplication and division are closely related. Another 2% percent answered all of the above. These answers that so closely replicate the examples show that the examples might have limited the students thinking in response to this question. However, anecdotal evidence from the Fox (1998) study also indicated that students mainly used their calculators to check answers. In this survey, a few students did respond with answers not in the examples including one student who said that the calculator was used "to help me when I get stuck" but the majority of the students only considered the examples listed in the question.

Table 16

Results of How Students Use Calculators

Reason	Number	Percent
Accuracy	128	81%
Multiplication	4	3%
Multiplication and Division	7	4%
Division	4	3%
Large Numbers	5	3%
Do not use	5	3%
All of the above	3	2%
Help	1	1%
Total responses	157	

In comparing what the instructors said they had students use calculators for to what the students said they actually used calculators for in class, a differing picture emerged. Students said that they mainly used calculators for computation and checking answers while instructors agreed but instructors said they also had students use calculators for many other things like discovery learning, problem solving and calculator instruction. These results may have been biased by the way the question was asked but, they could also reflect a lack of understanding on the part of the students. Students might not understand that using a calculator to help them solve a story problem is problem solving. They also might not understand that doing computation to figure out a pattern could be considered discovery learning. The students might just see this all as computation and believe that they are just using the calculator to check the answer to problems that they should be figuring out without the calculator. Another reason for this difference could be that the instructors inflated their actual use of calculators for things other than computation in the survey.

To investigate calculator usage in the classroom from a different perspective, students were asked how their instructor used calculators in class. The examples that followed the question were "to do multiplication or division problems, to help you understand how something works, to help you find a rule or pattern." These examples did not seem to influence the students who answered this question unlike the examples in the previous question. The 6% that listed basic computation (multiplication and division) was a much lower amount than the 81% that answered using the first example in previous question received. The examples provided in the question accounted for 35% of the answers that students gave which shows that students did think about their answers and did not just use the examples given as the only possible responses. All students that responded gave only one answer. The results to this question are in Table 17.

Table 17

Results of How Students See Instructor Use Calculators

Reason	Number	Percent
Accuracy	32	22%
Help understanding	28	19%
Pattern/Rule	13	9%
Calculator Usage	10	7%
Computation	9	6%
All of the above	2	1.3%
Proof	2	1.3%
Yes	2	1.3%
Instructor does not use	49	33%
Total responses	147	

Answers that were not listed in the examples included instructors taught them how to use their calculator and instructors used a calculator to prove things. One student said the instructor used the calculator "to help prove the rules that apply" while a student in a different class said to "prove that the method or formula really works."

The surprising result from this question was that 33% said that their instructor did not use a calculator in class. Many students echoed the thoughts of the student who said "he doesn't really use a calculator in class." One student said that "she just says we can use them if we would like." One student seemed to think that the reason the instructor did not use a calculator was because they were learning algebra first as the students said “no[t] yet with [we] are learning algebra” while another said “no, he doesn't he asks the students to check.” Most of the students did not give a reason why the instructor did not use one.

These findings showed that instructors said they mainly used calculators in class for computation with some problem solving and discovery learning activities. Students said that they mainly used calculators to check their answers and do computation. The students’ lack of reporting other methods might be because the student did not understand how the instructor was using the calculator to teach. They only saw the instructor using the calculator to check answers or perform a computation. When we examine what students saw instructors doing with calculators, students reported that instructors used calculators for computation, problem solving and discovery activities. However, quite a few students reported that they seldom saw their instructor use a calculator even when the instructor allowed calculators in class. This lack of instructor modeling the use of a calculator might be a cause for confusion among students as to the instructors’ calculator policy as well as a reason why students usually limit their usage to computation. If instructors modeled more calculator usage, students might use calculators for more than computation.

Frequency of Usage

To look at calculator usage from another angle, the instructor survey asked the instructors how often they thought their students used a calculator to do homework, to complete work in class, to take math tests, to do math in other classes and to do math outside of school using a Likert-type scale with responses ranging from 1 “never” to5 “always”. The results are in Table 18.

Table 18

Means and Standard Deviations of Instructors’ Responses to the Questions "Do You Think Your Students Use a Calculator for:"

	Homework		In Class		Tests		Other Classes		Outside School	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Adjunct	3.44	1.05	2.85	1.13	2.78	1.55	3.62	.88	3.62	1.02
Fulltime	3.64	.95	2.73	1.20	2.68	1.36	3.67	1.11	3.64	1.18
Overall	3.54	.99	2.82	1.16	2.76	1.45	3.65	.97	3.63	1.07

The results seemed to indicate that instructors believed that students used their calculators for math in other classes and math outside of school more than doing homework, in math class or taking math tests. When students were asked the same question, students indicated that they used calculators more to do homework and to do work outside of school. The students indicated that they used a calculator to take a math test more often than they used a calculator in other classes or than to complete work in class. This makes sense as 10 out of 12 classes were able to use a calculator on the test. As the instructors overall were more evenly divided as to allowing or not allowing calculators on tests, it makes sense that they would rate other classes and outside of school higher than in class, tests and homework. The means and standard deviations are in Table 19.

Table 19

Means and Standard Deviations of Student Responses by Class to the Questions "Do You Use a Calculator:"

Class	Calc	Homework		Work in class		Tests		Other Classes		Outside School	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	Yes	3.84	1.17	4.06	1.11	4.11	.99	3.88	1.22	3.79	1.36
2	Yes	4.06	1.18	3.47	1.41	3.87	1.46	3.07	1.33	3.27	1.39
3	Yes	3.88	1.36	3.38	1.60	3.50	1.31	2.88	1.37	3.63	1.30
4	Yes	2.94	1.43	2.40	1.35	2.21	1.31	2.27	1.39	3.31	1.35
5	Yes	3.63	1.11	3.19	1.30	3.48	1.31	2.93	1.54	3.19	1.49
6	Yes	3.00	1.08	2.77	1.30	2.92	1.44	2.50	1.31	3.31	1.49
7	Yes	3.70	.95	3.11	1.05	3.33	.87	3.33	1.32	3.22	1.20
8	Yes	4.00	.92	3.55	1.10	3.80	1.20	3.70	1.30	3.45	1.15
9	No	2.60	1.30	1.40	.83	1.33	.72	2.00	1.25	3.00	1.51
10	No	3.17	1.27	1.55	1.29	1.36	.81	2.82	1.33	3.58	1.31
11	Yes	2.60	1.23	2.32	1.34	2.11	1.35	2.37	1.50	3.11	1.02
12	Yes	4.29	.85	3.94	1.09	4.71	.69	4.24	1.25	4.35	.93
Total		3.48	1.26	2.98	1.45	3.14	1.52	3.03	1.50	3.43	1.32

This data showed that most students clearly seemed to use their calculator at least occasionally as they do their homework. The classes that were not allowed to use calculators had averages of 2.60 and 3.17, which showed that even these students thought they could use calculators for homework at least sometimes. Class 11, a class allowed to use calculators, also had a 2.60 while class 4 had 2.94 and class 6 had 3.00. These averages seemed low for students who were told they could use a calculator.

The data showed that some students will use calculators to do homework even if the instructor tells them not to. The surprising result was that many students that are allowed to use calculators in class do not use them to do their homework. This may result from the fact that students are not seeing their instructors use calculators in class as noted previously and so they believe that they should not be using them. It also could be because the students are not seeing calculators modeled by the teacher and so the students are uncertain as to how to use the calculator.

The data also showed that some students are not using their calculators in class. Classes 11 (average 2.32), 4 (average 2.40) and 6 (average 2.77) had low averages for use in class. These were the classes that had a high number of students report they did not see their instructor use a calculator in class (class 11-24%, class 4- 39%, class 6- 69%). The responses from open ended questions showed that students used their calculators in class mainly to check the instructors work. Sometimes instructors used the calculator to show a pattern or a rule as well as to instruct students on how to use their calculator but many students had never seen their teacher use a calculator. Only class 1 (average 4.06) had a high average for calculator use in class.

These responses also showed that students do use a calculator when taking a math test, with the total average being 3.14. Even the classes that are not allowed to use a calculator indicated that they use their calculators to take math tests occasionally with averages of 1.33 and 1.36. It is unclear if the students who are not allowed to use a calculator were considering previous courses as they answered this question, if they were including quizzes where a teacher might have allowed calculator usage occasionally or if they are using a calculator to take the test without the instructors' knowledge. Once again, among classes that allowed calculators, class 11 (average 2.11), class 4 (average 2.21) and class 6 (average 2.92) reported the lowest calculator usage for tests. This supports the idea that students were not using calculators because their instructor did not use them in class.

The responses indicated that students used their calculators in other classes to do math. The instructors' average of 3.65 was higher than the students' average of 3.03. The instructors' average could be higher as they probably considered classes with a high math component such as science courses that the students at this level might not have taken yet. This data showed that calculators are not just for math but affect classes outside of mathematics as well. Students might be learning calculator skills in other classes which they want to use in math class or they could be taking things they learn in math class to use in other courses.

The responses indicated that students often used calculators when they were doing math outside of school. The instructors' average of 3.63 was slightly higher than the students' average of 3.43. The responses that the students gave on open-ended questions showed that students used calculators as tools at work and at home. The students indicated that they used calculators for bills, finances, medication dosage amounts as well as for carpentry and other real life applications.

Instructors thought that students used calculators more for classes other than math and outside of school more than in math class. Students said that they used calculators more to do homework than to do work in other classes but used a calculator more outside of school than for school work. Overall, both instructors and students felt that students used calculator more outside of math class than in class.

Reasons for Usage

To see why instructors thought students used calculators, an open-ended question that asked instructors why they think their students use a calculator in or out of class was included in the instructor survey. The responses are in Table 20.

Table 20

Why Instructors Think Students Use Calculators

Reason	Number	Percent
Ease/Faster/Accuracy	20	42%
Lack confidence/skills	11	23%
Computation	7	15%
Habit/Real World	6	13%
Lazy	2	4%
Problem Solving	1	2%
Homework	1	2%
Total of responses	48	

These results showed that most instructors think students used calculators because it is easier, faster and more accurate. One instructor said "they do not want to spend time actually doing all mathematical operations by hand" while another said "faster and easier and more accurate." Lack of confidence and lack of skills was another popular answer. One instructor said that students "may not be real confident in their computation skills, forget the meaning of square root and raising numbers to powers so the calculator keys and operations remind them." Another instructor said "because they question their own abilities and believe the numerical answers is all that matters." One instructor said "most student seem to grab out a simple 4 operation calc or their cell phone when they are trying to figure stuff out."

The real world usage was an answer given multiple times. This real world usage was evident in an instructor's response of "balance checkbook or debit accounts, math homework, quicker computations, to find percents." Another instructor said "it's a tool." One instructor said "they are encouraged to use them from an early stage of math (elem school), many used to getting x and / facts from calculator" which showed that instructors perceived that students used them from habit as well.

Students were also asked why they used their calculator in class or outside of class. The majority of the students that answered the question fell into two categories: accuracy or faster/easier. All students' responded in only one category. The responses are in table 21.

Table 21

Why Students Use Calculators

Reason	Number	Percent
Faster/Easier	68	37%
Accuracy	54	29%
Large numbers/hard problems	18	10%
Computation	12	6%
Work	12	6%
Understanding	8	4%
Homework	4	2%
No calculator	4	2%
Lazy	3	2%
Lack of confidence	2	1%
Total of responses	185	

The instructors had a fairly accurate picture of why students used calculators. Accuracy, ease and faster were the highest responses for instructors (42%) and students (68%) as to why students used calculators. Computation and real world use showed up in both as well with the instructor reporting this at almost double the rate of the students. The surprising answer was that both instructors and students said that students used calculators because they were lazy. One student wrote " I use my calculator both inside and outside of class because either the equations to big or honestly I'm just to lazy to even add or multiply in my own head how sad Huh? Welcome to the 21st century."

These responses show that instructors had a fairly accurate picture of why students used calculators.

Problems That Prompt Usage

Instructors were also surveyed to find out what kinds of problems instructors thought prompted students to use a calculator. The results are in Table 22.

Table 22

What Problems Instructors Think Prompt Student to Use Calculators

Type	Number	Percent
Everything	23	47%
Basic computation	11	23%
Computation with large number	4	8%
Fractions, percents, decimals, exponents	5	10%
Problem Solving	3	6%
Accuracy	2	4%
Don't know	1	2%
Total of responses	49	

One instructor's response of "all kinds of manipulations regardless of the simplicity of the problem" seemed to be the common theme of the answers. Instructors thought that students' first response when they were given a problem was always to use their calculator even when they did not need to. One instructor just did not know what kinds of problems would prompt students to use their calculator which seems unusual as you would think instructors would have some knowledge about why students' used calculators.

Students who were allowed to use a calculator were also asked about what kind of math problems caused them to use a calculator either in class or outside of class. The results are in Table 23.

Table 23

Problems That Prompt Students to Use a Calculator

Type	Number	Percent
Basic Computation	50	34%
Large Numbers	33	22%
Fractions/Decimals	22	15%
Algebra	12	8%
Everything	11	7%
Exponents	6	4%
Accuracy	5	3%
Integers	4	3%
Homework/Test	2	1%
No calculator	4	3%
Total of responses	149	

Although instructors had students using calculators for any kind of problem on the top of their list, students overwhelming reported that they used their calculators for basic computation. When you include the large number category, computation was at 57%. It seemed appropriate to include large numbers in with basic computation as most students' responses were similar to this student's response of "two or three digits #'s multiplying or dividing that are too large for me to do in my head." Overall, students reported that basic computation with both large and small numbers caused them to use their calculators the most with other skills such as fractions, decimals, exponents, and integers being done with a calculator to a lesser degree.

Students who were not allowed to use a calculator were asked what kind of problem would prompt them to want to use a calculator. The responses are in Table 24.

Table 24

Problems That Would Prompt Student to Use Calculator

Type	Number	Percent
Basic Computation	11	26%
Large Numbers	10	23%
Fractions/Decimals	3	7%
Algebra	7	16%
Everything	1	2%
Exponents	4	9%
Accuracy	1	2%
Real life	1	2%
No calculator	1	2%
Problems unable to do	1	2%
Unsure	3	7%
Total of responses	43	

The students who were not allowed to use calculators answered very similarly to students who could use calculators. Basic computation was what caused them to want to use a calculator. The answers that were different included using a calculator in real life and for problems that the student was unable to do.

These questions showed that students in basic math and prealgebra courses usually looked to calculators to help them with basic computation especially with large numbers. They also wanted calculators to help them with fractions, decimals, integers and exponents. Students who wanted the calculator to help with fractions seldom said what they used the calculator for but one student did specify the following "fractions, find lowest common denominators." It is unclear if the students realize that scientific calculators can usually do fraction problems or if they just used the calculator to help them with the basic computations needed to complete a fraction problem.

The students who wanted the calculators to do algebra usually indicated graphing, linear equations, polynomials but never said what they wanted to do with the calculator. It seemed like algebra was used as a way to say problems that are harder than basic math and prealgebra. One algebra answering student said in response to the question about why they use a calculator "to check my answers and do to big multiplication problems" which implies that the student thought algebra problems were the harder problems where the student needed to use the calculator instead of the computation problems where the student currently used the calculator.

Instructors seemed to have a fairly accurate understanding of why students used a calculator as both instructors and students indicated that students used calculators more in other classes and outside of school than in math class. Instructors indicated that students wanted to use calculators for all problems while students indicated that they wanted to use calculators for computation more than anything else.

Calculator Influence on Grades

Instructors and students both believed that calculators had an effect on students' grades. Because calculators were believed to be more efficient and faster, instructors and students usually believed that using a calculator caused a students grade to increase.

However, most instructors and some students did not think that using a calculator increased learning.

Instructor Beliefs About Calculator Influence on Grades

Instructors were asked if they changed their calculator policy would it affect students' grades in their math class. The question specifically did not say increase or decrease in an attempt to allow for either affect. Of the 44 instructors who answered this question, 61% (27 instructors) thought that changing their calculator policy would affect students' grades. Thirty percent (13 instructors) thought changing their policy would not affect students' grades. The remaining four instructors were unsure as they answered both yes and no, don't know or maybe. The instructors were also asked why they believed that calculators affected students' grades; the results are in Table 25, showing their responses to the yes/no part of the question. The other response category indicates instructors who either did not answer the yes/no part or answered both yes and no, don't know or maybe.

Table 25

Why Instructors Think Calculators Affect Grades

Reason	Yes affect	No affect	Other response	Total Number	Percent
Accuracy	13	2	3	18	42%
Confidence	4		1	5	12%
Concept Development	2	3		5	12%
Computation	2	1		3	7%
Would change teaching method		1	1	2	5%
Lack of learning	1		3	4	9%
Less practice	1			1	2%
Inflated Grades/Future failure	3		1	4	9%
Number sense			1	1	2%
Total of responses				43	

One instructor who indicated a change would affect grades said "Grades would increase because calculators would eliminate errors in x, /,+,- /82 [Math 82 Basic Mathematics] grades would be partially based on how well they can use calculator opposed to skill." Another instructor who believed a change would affect grades said "calculators would do the work of their brains and in most cases this would yield better scores." Not all instructors believed that it would be better to allow calculators. Another instructor who believed a change would affect grades said "it would eliminate some mistakes they make but I don't think it will enhance their learning as much."

An instructor who believed calculators gave students more confidence as well as affecting their grade said “transitional students need confidence that they can problem solve. Calculators offer some sense of security for many.” Another instructor who believed calculators helped in concept development but a change in policy would not affect grades said “in classes where calculators are allowed, usually I don't ask "arithmetic" questions. There are several steps to be done and some thinking and reasoning before the calculator is any help at all.” Another instructor who did not believe a change would affect grades said “they still have to get concepts and the ones that do not know how to add, sub, mult, divide are the ones that also do not get concepts.”

One instructor who thought a change in policy would affect grades by causing grade inflation wrote “in the short term for the immediate class, I think their grade may improve but once they get into a higher math course, the calculation they should be able to do mentally will not be able to be done with they [without their] use of a calculator and they will quickly fall behind and become frustrated.”

Two instructors said they would change their teaching if they changed their calculator policy so it would not have that great of an effect. One instructor said “My teaching plans would also change. I would be adding more skills to the course and would change my assessment plans accordingly.”

Many instructors believed that changing their current calculator policy would affect the grades of the students. Most instructors believed that students would get better grades because they would be more accurate and have more confidence but they did not believe that learning would be enhanced. Instructors did not see calculators as increasing concept development and some would specifically change their course if they allowed calculators so that calculators would not affect the students' grades.

Student Beliefs About Calculator Influence on Grades

In order to get the student view, students who could use a calculator were also asked if being able to use a calculator changed their grade in their math class with no indication of increase or decrease to allow for either affect. Of the 157 students who answered, 59% (93 students) indicated that being able to use a calculator changed their grade. The answers to the why section of this question seemed to indicate that when students answered yes, they meant that their grade would increase. Thirty-six percent (57 students) did not think that the calculator changed their grade. One student said "my grade is reflected on me, not my calculators." The remaining seven students indicated that it might change their grade but they were unsure if it did or not. A student that was unsure stated "because if you don't use it and get it wrong & then use it & get it right your [you are] more confident with a calculator." The responses to the explain portion are listed in Table 26 with their response to the yes/no part of the question. The other response category indicates students who either did not answer the yes/no part or answered both yes and no, don't know or maybe.

Table 26

Why Students Who Can Use Calculators Think Calculators Affect Grades

Reason	Yes affect	No affect	Other response	Total Number	Percent
Accuracy	54	2	1	57	44%
Faster/Easier	10	13		23	18%
Can do math without calculator		9		9	7%
Concept understanding	7	9	1	17	13%
Confidence	3	2	3	8	6%
Self satisfaction	1	2		3	2%
Helped them	3	1	2	6	5%
lazy	2			2	2%
Inability to do work	1			1	1%
Calculators give incorrect answers		3		3	2%
Like Instructor		1		1	1%
Privilege		1		1	1%
Total of responses				131	

Accuracy, faster and ease were the most frequent answers. One student said "I think so, [because] I am very careless." Being able to check their answers made many students want to be able to use a calculator. Many students commented on how a little mistake could change the answer. Some students also believed that the calculator helped them to understand concepts better. One student put it like this "I believe when you do the work by hand the[n] check it on the calculator, it makes you understand the problems better." A few students said that they could do the work and the calculator "it just helps me with time." One student who thought a calculator would change her grade thought so "because it's a little easier and simple." One student who thought that calculators help students said "because it helps me do the classwork and the homework." One of the two students who said being lazy was why they needed a calculator said "so that my answers are correct[.] w/out a calculator I would be too lazy to do it myself." One student said that a calculator would change his grade because he "can't do numbers in my head."

Students who said the calculator would not change their grade explained that you do not need a calculator for this class. Students also noted that calculators are not always correct. Three students said that they get more self-satisfaction from doing the work themselves. One of these students said "because I feel I'd be earning my grade for my hard work that was put in to it." One student said that s/he did not think the calculator changed the grade because the instructor knew how to teach.

Students who were not allowed to use a calculator were asked if being able to use a calculator would change their grade. As in the question asked of calculator using students, the number of student who answered yes was larger, 64% (25 students) answered yes as compared to only 33% (13 students) who answered no. Also, the students who answered yes seemed to be indicating that their grade would increase. The results of the explain section are in Table 27 with their response to the yes/no part of the question. The other response category indicates students who either did not answer the yes/no part or answered both yes and no, don't know or maybe.

Table 27

Why Students Who Can Not Use Calculator Think Calculators Affect Grades

Reason	Yes affect	No affect	Other response	Total number	Percent
Accuracy	14		1	15	48%
Faster/Easier	2			2	6%
Can do math without calculator		5		5	16%
Concept understanding	3	2		5	16%
Helped them	1			1	3%
lazy	1			1	3%
Inability to do work	1			1	3%
Just improve grade not learning	1			1	3%
Total of responses				31	

Students who could not use a calculator still thought that accuracy was the reason that using a calculator would affect their grade. They also included understanding the work as a reason. One student said "because with or without [a calculator] the work to the problem needs to be shown." Another of these student thought that "I would understand the steps better because I have to punch the right signs for the answers." The remaining answers were similar to students who could use a calculator except for the student who said "I would not learn as well [but] might get better grade."

Learning With a Calculator

Because better grades do not equate perfectly with learning, the students were also asked if being able to use a calculator helps you learn more than if you could not use a calculator. One hundred thirty-three students who were allowed to use a calculator answered the yes/no portion of this question. Forty-nine percent (65 students) answered yes while 47% (62 students) answered no. This question was split fairly close to half with five students not being able to decide which to choose. The fairly even split seemed to come about because students either viewed the calculator either as a tool that helped them learn or a tool that did computation but did not help them learn. This is evident from the explain section where large variety of answers approached the same concept from opposite directions. The responses to the explain section are in Table 28 with their response to the yes/no part of the question. The other response category indicates students who either did not answer the yes/no part or answered with a response other than yes or no.

Table 28

Why Students Who Can Use Calculators Think Calculators Help or Do Not Help You Learn

Reason	Yes affect	No affect	Other response	Total Number	Percent
Understand concept	17	17	1	35	31%
Accuracy	13	3	1	17	15%
Faster/Ease	5	8		13	11%
Calculator usage	5	7		12	11%
Lazy/think less		8		8	7%
Confidence/Encourage	5	1	1	7	6%
Large numbers	3	1	1	5	4%
Error Awareness	4			4	4%
No calculator/Don't need calculator	1	3		4	4%
No Effect		3		3	3%
Help	1	1		2	2%
Real Life	1		1	2	2%
Instructors teach		2		2	2%
Total of responses				114	

The largest response which related to using the calculator to help you understand the concept had 17 students who thought it affected learning and 17 who did not. One student who said the calculator helped him learn said "it helps me understand some of the concepts we learn." Another student who thought the calculator did not help said "because leaving the steps helps you understand the material on the test better."

Accuracy had 13 students for and 3 students against calculators helping them learn. One student who did not think the calculator helped learning said “you should be able to do the work[.] using a calculator helps w/checking and difficult problems.” Another student who thought calculators helped learning said “helps me check my answers like hands on learning.”

Students who discussed calculator usage came from opposite directions as well with 5 affecting and 7 not affecting learning. A student who said the calculator helped to learn said “because for one thing we learn how to use a calculator.” Another student who did not think the calculator helped said “I don't think it helps you learn more in class, it will make you learn more calculator skills but not math skills.”

Even the students who indicated that the calculator was faster approached this question from different directions with 5 stating that the calculator affected learning and 8 that it did not affect learning. One student who thought calculators helped learning said “Since I finish problems quickly I can learn more math.” Another student who thought calculators did not help learning said “it only speeds up the process.”

Some students believed that calculators make you lazy and cause you to use your brain less. One student who responded this way simply said “calculators stop brain waves.”

The remaining students reported a variety of reasons why calculators either helped or hurt learning. Some of the reasons that the calculator helped learning were that they encouraged students, they helped with confidence, they made mathematics easier, they helped with large numbers and they made students aware of their errors. Some of the reasons that the calculator did not help students learn were that they did not need a calculator, did not use a calculator and that instructors teach, not calculators. Two students said that calculators helped with learning because calculators are in real life and they need to learn how to use them. One student said “because in real life you would always use a calculator [rather] then pen and paper its easier ex. Construction workers, carpenters, people who lay tile, etc.” This real life usage was in other students answers as well. One student who expressed this real life practical use of calculators said “I go over my work more completely. My calculator is my math dictionary or my ABC check to check my spelling before turning in a term paper.”

When comparing the responses to the questions about calculators affecting grades and learning, students who were allowed to use calculators had some interesting results. Fourteen students thought that calculators did not affect their grades but did help them learn. Most of these students believed that they could do the work without a calculator so it would not affect their grades but the calculator helped them to learn by increasing their awareness of errors, helping them work faster which allowed them to do more problems, and reassuring them that they are doing the work correctly. Twenty-five students thought that calculators affected their grades but did not help them learn. Most of these students thought that the calculator affected grades because it made them more accurate and faster but did not think that it affected learning because they still needed to understand the concept. Once again, this data shows how students view the calculator either as a tool for learning or just a tool that does computation.

Students who said that their instructor does not allow them to use a calculator were asked if they thought they would learn more if they could use a calculator in class. The yes/no answers for students that could use calculators were split almost in half. With the students who could not use a calculator, the 39 students who answered this question overwhelming said that the calculator would not help them learn more. Seventy-two percent (28 students) answered no while only 23% (9 students) said yes, calculators would help them learn. The responses to the explain question are in Table 29 with their response to the yes/no part of the question. The other response category indicates students who either did not answer the yes/no part or answered with a response other than yes or no.

Table 29

Why Students Who Can Not Use Calculators Think Calculators Help or Do Not Help You Learn

Reason	Yes affect	No affect	Other Response	Number	Percent
Concept Understanding	2	6	1	9	28%
Do not need		6		6	19%
Accuracy	3			3	9%
Lazy		3		3	9%
Learn From Teacher		2	1	3	9%
Calculator usage	1		1	2	6%
confidence			1	1	3%
Difficult Subject		1		1	3%
Error Awareness	1			1	3%
Faster	1			1	3%
Rely		1		1	3%
Tool		1		1	3%
Total of responses				32	

Students who answered using the concept of understanding as their major theme generally did not think the calculator would help them learn more. One student summed up most of the responses with “I think is better not to use one because by working out the problem I have a better understanding where the answer came from.” Responses that did not occur with the students who could use calculators involved relying to much on a calculator and using calculators as tools to do work. One student who answered that using a calculator would not increase learning said it was “because you would always be counting on the calculator” while another student said that “calculators are only tools to help with large scale problems” when he said that calculator would not increase learning.

Students unable to use a calculator who believed a calculator would increase their learning implied that the accuracy of the calculator would help them learn better. They also said students should be learning how to use a calculator in class. One student went so far as to say “It's very important to learn how to use one [a calculator].” The remaining students said that calculators were faster, gave them more confidence, and help them to be more aware of errors in their work.

When comparing the responses to the questions about calculators affecting grades and learning, students who were not allowed to use calculators had similar responses to students who could use calculators. One student said calculators would not affect the grade because you need to understand how to do the problem and then said that the calculator affected learning because it helped the student to be more accurate. Fourteen students said it would affect their grades but not affect learning. These students indicated that the calculator would affect their grades because the calculator would increase their accuracy and make them faster but would not affect learning in a positive way because the calculator would make them lazy, would take away their ability to think, and would not help them learn concepts.

When comparing students who could use calculators to those who could not, similar findings emerged. Some students believed that a calculator was just a tool to do computation. It did not teach concepts. It only made you faster and more accurate. Other students believed that the calculator was a learning tool that could help you understand concepts as well as give you confidence. Even students who had different opinions on whether calculators affect grades and learning still generally went back and forth between these two positions.

Instructors and students both thought that being able to use calculators would change students' grades usually due to the accuracy and ease of calculators in computation. However, this did not mean that instructors or students thought calculators would increase learning. Students who could use calculators were fairly evenly divided while students who could not use calculators overwhelming believed that calculators did not increase learning. The students seemed to view the calculator either as a tool that does computation but does not teach concepts or as a tool to help them learn concepts as well as make them more accurate and faster. Instructors seemed to see the calculator mainly as a tool to help with computation not as a learning tool. Instructors generally believed that using calculators did not necessarily increase learning.

Calculator Effect on Instructor Selection

The students who were surveyed generally had no way of knowing the instructors' calculator policy prior to the first day of class when they received their syllabus. The students usually were not willing to change classes just because of the calculator policy as most students believed that they could learn the material without a calculator. Most students saw the calculator as a tool to help them but not the only thing that would help them pass a mathematics course. The data below supports this conclusion.

The student survey asked students whose instructors allowed calculators if they would change to another instructor if the calculator policy had been to not allow calculators. Of the 155 students who answered the yes/no part of this question, 77% (120 students) said that they would not change to another instructor. Twenty-one percent (33 students) said they would change to another instructor and two students said maybe. The responses to the explain portion of the question are in Table 30.

Table 30

Reasons Students Who Can Use Calculators Would or Would Not Change Instructors if the Calculator Policy Changed

Reason	Number	Percent
Can learn without a calculator	68	52%
Need a calculator	13	10%
Concept Understanding	12	9%
Like Instructor	9	7%
Calculator instruction	6	5%
Teacher in charge	5	4%
Accuracy	4	3%
Instructors don't allow	4	3%
Faster	2	2%
Difficulty learning	2	2%
Outside Influences	2	2%
No calculator	2	2%
Real life	1	1%
Total of responses	130	

The majority of the students who answered the explain part of the question indicated that they could learn the material without a calculator. One student said "I can use my mind and a piece of paper to solve problems. It isn't brain surgery." Only 13 students indicated that they needed a calculator to pass the course while two students said that they would not change because they don't use a calculator anyway.

Some of the reasons why the students would not change showed the authority of the instructor in a classroom. Five students said that the instructor was in charge of the classroom as revealed in the comment of one student "I would adjust to his teaching style." Other students said that they would not change because most teachers don't allow calculators at this level or because they liked their instructor.

The students who would change indicated that calculators helped them to understand the mathematics better. One student said "I think that sometimes u [you] need to use a calculator to help [.] college is [about] using all of your resources." Six students indicated that they wanted instruction on how to use the calculator as part of the class. Other students indicated that calculators were faster and more accurate. For two students, the difficulty of the course was the deciding factor as they said it "depends if is the course is very difficult." One student gave the following as a reason to change instructors "as a working adult, in the work force mental math is conducted to a limit. Calculator usage is more common practice." Two other students said that they would not change instructors based on calculators alone but did not give the other factors that would contribute to them changing instructors.

Students who said their instructor does not allow them to use a calculator were also asked if they would have changed instructors if they knew about the no calculator policy prior to class starting. Of the 44 students who answered the yes/no section of the question, 75% (33 students) said that they would not change instructors. Twenty-two percent (10 students) said that they would change and one student responded with both yes and no. The responses to the explain section are in Table 31.

Table 31

Reasons Students Who Can Not Use a Calculator Would Have Chosen Another Instructor if They Knew the Policy Before Class Began

Reason	Number	Percent
Can learn without a calculator	23	59%
Faster/Ease	3	8%
Teacher in charge	2	5%
Instructors don't allow	2	5%
Like calculators	2	5%
Try	1	3%
Concept Understanding	1	3%
Tool	1	3%
Help	1	3%
Don't know	1	3%
Hard to change teachers	1	3%
Confidence	1	3%
Total of responses	39	

The majority of the students said that you do not need a calculator to pass the course. One student indicated this with the following comment "it is best to learn math on your own w/out the calculator crutch." One student said "I would just try at" and another student who would not change said it was just "more work to change instructors." One student said "It's a helpful tool for test" but would not change instructors.

Students answering this question also indicated the authority of the instructor. One student showed that with the comment "because if I felt the teacher needed us to learn this I would accept that." Two students also echoed the comments of the previous question when they indicated that instructors don't allow calculators at this level.

Students who indicated that they would change gave reasons like the calculator gave them more confidence, the calculator was faster or easier, the calculator helped the student understand the material better and that they just liked calculators.

The responses to these questions showed that students were usually not willing to change instructors based on calculator policy alone. Students who could use calculators would have stayed in the class even if they were not allowed to use calculators mainly because they knew they could learn the material without a calculator. The students saw calculators as tools to help them and not as vital to learning. Students who could not use calculators had the same reasoning.

Miscellaneous Information

One of the student survey questions asked students what kind of calculator they used. Fifty-three percent of the students used a scientific calculator. Only 29% used a four function and 10% used a graphing calculator. The remaining 8% either did not answer the question (7%) or did not use a calculator (1%).

Summary of Findings

Prior research has shown that calculators do not impede or increase student learning in basic mathematics or prealgebra courses (Vasquez & McCabe, 2002,Hector & Frandsen, 1981,Boyd & Carson, 1991). The research has mainly focused on providing the students with calculators and not providing much calculator instruction for the students or the instructors, then looking for an effect. The research has also shown that basic mathematics students seem to like calculators (Leitzel & Waits, 1976) but has not examined teachers or students use calculators in the classroom or out of the classroom. The findings of the present study fill in this missing piece in the research, examining how teachers and students use calculators as well as calculator policies and teacher and student perceptions of the effects of calculator usage on grades and learning.

In the present study, many instructors did not have an accurate understanding of the calculator policies of their campuses. The students seemed to be unclear about the instructors' classroom calculator policies as well. The confusion for the students might be related to the amount of time that instructors spent using a calculator in the classroom. Classes where the instructor allowed calculator usage but did not use a calculator in class seemed to have more confusion surrounding the calculator policy.

Some instructors who do not allow calculators would be willing to change their policy if the department policy was different. Instructors also would be willing to allow calculators in class if the instructors had more training in how to integrate calculators into the classroom and sound reasons why calculators should be used in the classroom.

Instructors said they mainly used calculators in class for computation with a limited amount of use for problem solving and discovery learning activities. Students whose instructors used calculators in class generally agreed that instructors used calculator for computation, but approximately one-third of the students allowed to use calculators reported that they did not see their instructor use a calculator in class.

Instructors thought that students used calculators more for classes other than math and outside of school than in math class. Students said that they used calculators more to do homework than to do work in other classes but used a calculator more outside of school than for school work. Overall both instructors and students felt that students used calculators more outside of math class than in class.

Instructors had a fairly accurate picture of why students use calculators. Accuracy, ease and speed were the measures given by both instructors and students. Computation and real world use showed up in both as well. When asked what kinds of problems prompt students to use calculators, instructors seemed to think that students used calculators for everything as well as computation, while students usually looked to calculators to help them with basic computation, especially with large numbers.

Instructors and students both thought that being able to use calculators would change students' grades, usually due to the accuracy and ease of calculators in computation. However, this did not mean that instructors or students thought calculators would increase learning. Students who were allowed to use calculators were fairly evenly divided, while students who were not allowed to use calculators overwhelming believed that calculators did not increase learning. Instructors also believed that using calculators did not necessarily increase learning.

Students were usually not willing to change instructors based on calculator policy alone. Students who were allowed to use calculators would have stayed in the class even if they were not allowed to use calculators mainly because they knew they could learn the material without a calculator. The students saw calculators as tools to help them and not as vital to learning. Students who could not use calculators had the same reasoning.

These finding from the instructor and student surveys will be used to answer the research questions in chapter 5.

CHAPTER 5

CONCLUSIONS

The first part of this chapter summarizes the study and uses the findings of the instructor and student surveys to answer the research questions. The second part of this chapter discusses the findings and limitations of the study and makes recommendations for further study.

Summary of Study

This study examined instructor and student calculator usage in basic mathematics and prealgebra classrooms. An anonymous survey instrument was used to examine if instructors allowed calculator usage, why instructors allowed calculator usage, how instructors thought students used calculators and if instructors believed that calculator usage would affect students' grades. A separate survey was given to students to examine why they used calculators, how often they used calculators and if they thought calculator usage affected their grades and their ability to learn.

This study was conducted in a large multi-campus community college in the southwestern United States during the spring semester of 2007. Fifty-four of the 97 surveys sent to fulltime and adjunct faculty were returned for a return rate of 56%. Twelve classes totaling 198 students were surveyed from four different campuses. Two of the twelve classes had instructors who did not allow calculators to be used in the class.

The data from the surveys was analyzed using an open-coding procedure and descriptive statistics. All open-ended questions were analyzed to determine categories that were used to find similarities and differences in the data. The descriptive statistics used for the Likert-type scale questions included averages, medians, modes and standard deviations.

Research Question Analysis

This study's purpose was to use the information gathered from the instructor and student surveys to answer four research questions. Some of the questions in the surveys asked the specific research questions while other questions were asked to gather information about the instructors and students and to examine the research questions from multiple points of view.

Research Question One

Why do instructors choose to use or not use calculators?

In basic math, instructors reported less use of calculators than in prealgebra. However, both basic math and prealgebra instructors indicated that the major reason they did not allow calculator usage was to develop basic math computation skills in students. The instructors understood that calculators can do all of the computation but felt that the students needed to know how to do the computations by hand instead of using their calculator. For many instructors, especially prealgebra instructors, once students had shown that they had mastered the basic skills of performing addition, subtraction, multiplication and division by hand, the students were allowed to use the calculator as a tool, allowing them to concentrate on learning other skills without being required to do large or tedious computation problems. Furthermore, two instructors indicated that the reason students need to understand how to do these basic computations by hand was to be successful in algebra.

Instructors who allowed calculator usage usually indicated that good computation skills were not as important as learning concepts. These instructors wanted students to concentrate on problem solving and not spend time on repetitive computation, especially with large numbers. The instructors indicated that since calculators were a tool available everywhere, the students should be able to use them to perform basic computation and concentrate on learning more difficult concepts. These instructors indicated that it was important to teach students the limitations and uses of a calculator. These instructors did not see teaching math as teaching basic computation skills but as teaching higher order mathematics skills like problem solving. These instructors felt that the ease of calculator use and the accurate answers usually provided by a calculator allowed for coverage of more material without being held back by the students' poor computation skills. They also felt that calculators provided the students with confidence and encouraged students to connect the mathematics that they are doing in class with the mathematics that they do in the real world.

Research Question Two

What are instructors' perceived reasons for student calculator use?

Generally, instructors (42%) believed that students used calculators because it was easier, faster and more accurate than doing computation by hand. Students seemed to agree with the instructors. The majority (66%) of students said they wanted to use calculators because they were easier, faster and more accurate. Some instructors blamed the students' perceived desire to use calculators on a lack of confidence and skills (23%) as well as laziness (4%). The student surveys showed that some students agreed with this assessment. Survey responses indicated that some students believed they were not good in basic skill computation (6%) and a few even admitted to being lazy (2%).

Instructors believed that students used calculators mostly for computation. Very few instructors indicated that students did anything other than addition, subtraction, multiplication and division with their calculators. Some instructors included exponents and square roots in the list, but usually instructors felt that students only used their calculators for basic computation. Interestingly, this also was reflected in how instructors used calculators in the classroom. Most instructors (basic math 35% and prealgebra 44%) indicated that they had students use calculators only for computation. Very few (approximately 10%) indicated that they used calculators to help students understand concepts or to have students discover mathematical ideas on their own. This was also reflected in the student survey. Mainly, students reported that instructors had used the calculator for accuracy (22%), computation (6%) and calculator usage (7%).

Most instructors believed that students used calculators outside of class and in the real world more than they used them in their mathematics classes. The student survey verified the instructor perceptions, indicating that students used their calculators more to do homework and to do work outside of school. Many students (33%) who indicated on the student survey that their instructor allowed calculator usage had not seen their instructor use a calculator in class. This lack of calculator usage in the classroom reported by students was very high. The data seems to indicate that over 60% of the instructors are either not using calculators or only using calculators for computation in their classrooms. This limited use by instructors might be the reason students are not using calculators for things other than computation. If instructors limit their use of calculators in the classroom, students would be less likely to use them as well.

Approximately 12% of the basic math and 30% of the prealgebra instructors indicated that if they had better teaching methods for using calculators in class, it might change their calculator policy towards allowing calculators in class. A lack of pedagogical training might also be a factor in why instructors don't use or limit the use of calculators in class to computation. The overwhelming use of the calculator as a computation machine instead of a learning tool permeated both the instructor and student survey.

Research Question Three

How often do students use a calculator and what are their reasons for calculator usage?

Students in this study reported that they use their calculator more outside of class then in class. Students reported that they use a calculator more often to do homework (mean=3.48 on a scale of 1 to 5) and to do math outside of school (m=3.43) than any other purpose. To take math tests was next (m=3.14) followed by math in other classes (mean=3.03), and completing work in class (m=2.98). This data indicates that students use calculators more to do homework and to do math outside of school than they use calculators in class or in school.

The lack of calculator use in class was verified by students. While 10 out of 12 instructors whose classes were surveyed said that they allowed calculator usage, 33% of the students indicated that their instructor never used a calculator in class. Twenty-two percent of the students indicated that their instructor used a calculator to check the accuracy of their work with many of these students saying that the instructor had the students use the calculator to do the actual checking. The lack of calculator use by instructors and students during actual instruction was repeatedly indicated by multiple student responses.

Students stated that they used calculators for two major reasons: accuracy and ease. Students repeatedly reported that they used calculators to check their answers. They also indicated that calculators were faster and easier, especially when they were doing basic computation such as addition, subtraction, multiplication and division. Students reported that they could do basic computation by hand if they had to but that the calculator was more accurate and provided them with an answer faster. If the numbers were large, the calculator was even better because it was faster and less likely to make the small mistakes that cause students difficulty with these basic computations. One student said, “because it's faster than writing it out on paper if I know how to do the problem on paper why take the time to write it out when you can type it in.”

Three students also admitted that they were not good at doing basic computation but stated that a calculator helped them make up for this inability. These students admitted that they had difficulty remembering their multiplication tables and indicated that the calculator helped them to overcome this problem. When it came to large numbers, eleven students indicated that they did not want to do the math in “their head.” Even doing it on paper was not something that they thought productive. In our instant everything society, the students did not see value in doing the mathematics by hand when the calculator could get them a more accurate answer faster. One student said “b/c [because] since we have the tech why not put these millions of dollars into making calculators.”

Students realized that calculators were a tool that was good for basic computation but felt it could not provide more than that. Many students indicated through various responses that the calculator could not do the problems for them; it only helped them to get the answers right. They seemed to understand that mathematics was more than computation and calculators only were effective if you knew what to put in them, or as one student said, “because I still need to understand how to do the math problems in order to get a good grade.”

The majority (53%) of the students had scientific calculators but very few said that they used calculators to do computations other than adding, subtracting, multiplying or dividing. When students were asked about what kinds of problems they used their calculators for, fractions and decimals were only listed by about 15% of the students.

Most of the students did not say how they used a calculator to do fraction problems, but one student did comment that it was to help with common denominators. As students said that their instructors seldom taught them how to use a calculator, it makes one wonder how many students realize that their calculator can do the fraction problems for them. Classroom experience of the researcher has shown that the majority of the students are unaware of the features of a scientific calculator that perform fraction operations. This might be a reason why using a calculator to do fractions was not expressed more often. Some students (3%) did give exponents as a reason to use their calculator, and one student specifically said, "problems that are more complicated then basic math and things such as 6 ^7 where it would just be easier to use a calculator."

Another group of students stated that algebra was the reason that they used their calculator. These students listed things like polynomials, graphing, and linear equations as problems for which they wanted to use a calculator. The students did not elaborate on what skills in completing the algebra problems required them to use a calculator. One student who said, "problems like graphing and linear equations" also had a graphing calculator and said, "I only use it when problems start getting difficult or when I start getting tired." It seems that these students used algebra as a way to say problems that were harder than what they were doing in basic math and prealgebra courses. Many students who are enrolled in basic mathematics and prealgebra have had previous experience with mathematics at a higher level, usually in high school. These students are enrolled to refresh and review basic skills, not to learn an entirely new skill. It seems that these students believe that algebra is harder and that is when they need a calculator. Scientific calculators can perform intricate basic computations but do not have algebraic computation abilities. Graphing calculators have varying degrees of algebraic computation abilities but still require students to have a basic understanding of algebra in order to operate them. For example, graphing calculators can show students the graph, but students must get graph in y intercept form prior to entering it into the calculator. Neither type of calculator can perform the majority of the algebra skills required in algebra courses. This also supports the interpretation that students used the word "algebra" just to mean that problems are harder than what they are currently doing in basic mathematics and prealgebra.

Students often expressed that they used a calculator outside of the mathematics classroom either in the real world or other courses that they are taking. Students said that they used calculators to do real world tasks that require basic computation. One student said, "Im's [I am] a bartender at like end of the night I have lots of cash to count." Another student said "in class it is sometimes faster to use it outside of class, I use it at work to do payroll, billing and adding footages." A couple of students said that they used calculators to do bills and finances. One student said, "well probably when I'm doing multiple equations- like in chemistry." Students reported to use calculators outside of the mathematics classroom more than in class. Students seem to understand that calculators are an important part of their real life. One student, when asked if calculators help you learn, said, "not really, just makes it easier on us, teaches us how to use them so [it is like] what we are in the real world." The students saw calculators as part of life outside of the classroom and realized that once they left the classroom they would be using calculators to accomplish mathematical tasks in their real life. In the classroom, the students seldom if ever used calculators for more than basic computation. Students recognized calculators as useful tools but were not being taught in class how to use the calculator as a tool for more than computation.

Research Question Four

Do students and instructors believe that calculator usage affects grades?

Instructors and students both believed that calculator usage affected grades. The majority (54%) of the instructors believed that students would get better grades in class because they were less likely to make computational errors and that calculators gave the students more confidence in their mathematical ability. Instructors, however, did not usually think that calculators would increase learning. Some instructors believed grades would go up in basic mathematics and prealgebra but students that used calculators would have more difficulties in algebra courses as their basic skills would not be as developed as those of students that did not use calculators.

The majority (44%) of the students also agreed that being able to use a calculator kept them from making computational mistakes. Some students however believed that using calculators changed their grade because the calculator helped them to learn. Students indicated that calculators helped them understand the concepts better, provided them with more confidence in their answers, and allowed them to complete more problems in a timely manner so that they learned more.

Instructors who did not think calculators would change students' grades indicated that students still needed the conceptual skills. Just because the student had a tool to do computation did not mean that the students would understand how to apply the mathematical concepts. Students who said their instructors did not allow calculators seemed to agree with this assessment by instructors. These students said that they still needed to show their work and understand how to do the steps. For them, the calculators could perform the computation but unless the student understood how to do the problem, having a calculator to do the computation did not help.

When students were asked if calculators helped them to learn, students who used calculators were fairly evenly divided on the subject. Some students thought calculators helped them learn the concepts while others thought that doing problems by hand taught them the concepts better. Some students thought that calculators helped them to learn more because they could be more accurate while others thought that you should be able to be accurate without the calculator. Some students thought that using calculators helped them learn because they could do problems faster while other students thought that calculators just made them faster but did not help them learn. Students whose instructors did not allow them to use a calculator overwhelmingly thought that the calculator did not help them learn. These students believed that calculators could not help one learn the concepts and that was the important part of learning mathematics.

Summary of the Findings

The analysis of the data and research questions reveals many findings. Some of these findings have never been examined in previous research and others were just discussed anecdotally and never examined thoroughly. Most previous calculator research at the developmental college mathematics level attempted to show the effectiveness of using calculators in a classroom by comparing calculator users to non-calculator users and did not look at usage on a broad scale. As research on the use of calculators in developmental mathematics courses is very limited, it was important to look at how and why instructors and students at this level use calculators. The K-12 research has shown that calculators can make a positive difference in both students' skills and attitude (Hembree & Dessart , 1986; Ellington, 2003). Calculator research at the developmental college mathematics level has not shown a statistically significant positive effect in either skills or attitude (Weitzle & Waits, 1976; Davidson, Donaldson, Hodge-Hardin, & McGill, 1996) but has shown that calculator usage does not hamper basic skills development. The findings of the present study provide insight into instructor and student usage of calculators. These findings document what is happening in real classrooms.

This study indicates that the major reason that instructors did not allow calculator usage in their classrooms was because instructors felt that students needed to be able to do basic computation by hand instead of using a calculator. Once students have shown their ability to master basic computation by hand, instructors were more likely to allow calculator usage which was evident in the fact that more prealgebra instructors allowed calculator usage than basic mathematics instructors. This finding is important because it shows that many instructors still do not consider calculators as a way to improve computational skills. The literature on elementary school mathematics shows that using calculators improves the computational skills of most low and average ability students (Hembree & Dessart , 1986). It is possible that using calculators could also improve the computational skills of developmental college students. A research study at the developmental college level showed that using a calculator to learn fraction skills produced no significant increase when compared to not using a calculator (Hector & Frandsen, 1981), however, no one has studied the effects of a calculator on the acquisition of basic computational skills. This is the reason most students use a calculator at this level.

The findings indicate that instructors who allow calculators seemed to feel that learning concepts was more important than computation. These instructors felt that using calculators allowed the students to spend more time problem solving instead of concentrating on computation. They felt the accuracy and speed as well as availability of calculators increased students' ability to perform mathematically even if they had poor computation skills. This finding shows a shift in philosophy of some instructors towards the goals of standards set by AMATYC (Don Cohen, 1995; Blair, 2006). These instructors are using calculators because they increase students' mathematical thinking and problem solving ability.

This study also revealed that both instructors and students seemed to be confused about calculator policies. Over 50% of the instructors surveyed that wrote their department policy on calculators had an incorrect policy, and 15% of the instructors surveyed did not even know if their campus had a calculator policy. The confusion was also evident in the student surveys. The student data showed that students were also unsure of when they were allowed to use calculators. Some students who were told they can use calculators all of the time believed that they could not use calculators to do things like tests. Other students who were not allowed to use calculators believed that they could calculators on tests or homework. The confusion surrounding calculator usage shows that communication about calculator policies is lacking for both instructors and students. This is an important finding because it emphasizes the importance of having clear policies about what is appropriate calculator usage for both instructors and students. Calculators have gone from rare, expensive machines in the 1970's to common, everyday items that are on most cell phones today. This change has caused confusion in education as instructors are uncertain as to the value of calculators as a learning tool. Instructors do not want to damage students' future mathematical skills by allowing calculators and not teaching important basic skills, but they also want to encourage students that have poor computational skills. The research for basic mathematics and prealgebra is very sparse and inconclusive as to the effects of calculator use so it seems reasonable to accept the national standards recommendation of integrating calculators into the classroom at all levels as a teaching tool. Institutional policies aligned to the national standards can provide instructors with guidance as to the use of calculators in their classrooms. Instructors then can clarify calculator policies for their students.

This study showed that instructors believed that students used calculators because they were faster and easier than doing computation by hand. Students agreed. Basic computation was the major reason given by both instructors and students for student calculator use. Students at this level seldom indicated that they used calculators for any other reason. Also, students indicated that they seldom saw their mathematics instructors use a calculator in class, and if the instructor did use a calculator, it was mainly to check answers or do large computation problems. This finding shows that instructors may be contributing to the students' use of calculators as only computation machines. Many instructors limited the use calculators in the classroom to computation if they used them at all. It is possible that if instructors modeled the use of calculators as more than computation machines, students would start using calculators in ways that would help them gain more mathematical knowledge. A study by Doerr and Zangor (2000) showed this exact effect with graphing calculators. They found that the role, knowledge and beliefs of the teacher influenced the emergence of a rich usage of graphing calculators in a high school precalculus course.

Some instructors who did not allow calculators indicated that they would be willing to change their policy if the problems were more complicated and if they had pedagogical instruction to help them use calculators effectively in the classroom. Around 30% of the instructors that would not allow calculators said that nothing would get them to change their policy to allow calculators. Considering that the national standards encourage calculator usage (Blair, 2006), this is a large percentage of people who seem unwilling to change. This possibly could be due to the lack of research on the effectiveness of using calculators at this level as well as the lack of pedagogical instruction on how to integrate calculators into the classroom. The lack of pedagogical instruction could also be a factor in why instructors who allow calculators do not use them in class for anything other than computation. The K-12 literature also shows that some teachers were reluctant to integrate calculators into the curriculum; however, this resistance is decreasing as more research is showing the positive effects of using calculators in the classroom (Burke, 2001).

Students reported to use calculators in other classes and outside of school more than they used them in mathematics courses. Students indicated that they used calculators because it was easier and the calculator was more accurate. Students realized that mathematics involves more than computation and believed that calculators could only help them get the answers. The students believed that calculators would be part of doing mathematics in the real world but did not indicate that they used them for much more than computation.

Instructors and students both agreed that using calculators would increase students' grades as the students would make fewer computational errors using a calculator. Instructors however generally believed that calculators would hurt students as they advanced to higher level courses because they would not have learned the computational skills necessary for algebra success. Students seemed to be divided on the issue of calculators increasing learning. Some students felt that calculators helped them to learn the material better while others felt that calculators just helped them to do the problems faster and did not help them learn concepts better.

These findings show that basic computation was the major reason for calculator usage at this level. The current research has examined the effectiveness of calculators when students used them to do fraction problems (Hector & Frandsen, 1981; Vasquez, 2002) or just allowed students to use calculators without providing instructors methodology for instructing students in effective methods for using calculators (Leitzle & Waits, 1976; Boyd & Carson, 1991Davidson, Donaldson, Hodge-Hardin, & McGill, 1996). As the findings of this study show that students seldom use calculators for fractions and instructors seldom provide students with calculator instruction in class or model calculator usage in class, it is possible that some of the reasons that college level developmental mathematics research does not show the same effectiveness as K-12 research is that researchers are not looking at areas where students use calculators in the curriculum and that instructors are not getting the methodology instruction to effectively integrate calculators into the classroom.

Implications of the Study

There are multiple implications as a result of this study. The following implications show that by asking students and instructors about what happens in class, we can better understand the activity of the classroom and use that knowledge to improve instruction.

This study showed that instructors were confused about calculator policies. About 50% of the instructors did not know the correct calculator policy for their department. This is not surprising when you consider the variety of policies at the different campuses. It is interesting to note that none of the campus policies reflected the national standards for two year colleges. These standards clearly state that developmental students should have experience using calculators in all developmental courses (Blair, 2006). The problem with the national standards is that they do not define what kind of experiences students should have.

The lack of guidance as to proper use of calculators in developmental classes was also evident in this study's review of the college's department policies. When calculators were allowed, no direction for use in the classroom was provided for the instructors by the department policy. The confusion surrounding department policies shows that it is important for department chairs to develop clear policies that provide instructors with guidance on how to integrate calculators into the classroom. Even departments that do not want to allow students to use calculators for computation can create policies that provide calculator experiences for students by providing instructors with ways of integrating calculators for specific uses that encourage mathematical thinking. For example, a department policy could state that students should have experience using calculators as a way of finding the pattern in multiplication by 10 or 100. Clear department policies that provide instructors with guidance on how to integrate calculators into the classroom are an important step to elimination of calculator policy confusion.

Just as important as eliminating instructor confusion, is the elimination of student confusion surrounding calculator policies. Students were unclear as to the calculator policy of their instructors. Students whose instructors allowed calculators did not always think they were allowed to use them and students who were not allowed to use them thought they could. This shows the importance of instructors providing students with a calculator policy that tells the student specifically when to use or not use calculators. Instructors that do not allow calculators need to tell students if they are allowed on homework as students tended to assume that even if they could not use calculators for tests, using calculators on homework was acceptable. Instructors that allow calculators need to tell students what they want them to use the calculator for and when the want them to use their calculators. Students generally believed that calculators were good for computation but little else. If instructors want students to use calculators for more than computation, they need to model this in the classroom. Instructors need to show students techniques for using calculators to help with problem solving as well as understanding mathematical thinking. By providing students with calculator policies that clarify when and how to use calculators to increase their mathematical skills, students will have less confusion surrounding the use of calculators in these courses.

As seen in this study, students mainly used calculators for basic computation in class. Many students had never seen their instructor use a calculator at all, or if the instructor did use a calculator, it was only to check basic computation answers. This lack of instruction with calculators seriously deviates from the national standards that say instructors should be using calculators in instruction in the classroom. The instructors themselves said that a lack of materials that would guide them on how to instruct using a calculator was one reason that they were not likely to allow calculators in class. Students believed that calculators are what they are going to be using in the real world and a few stated specifically that they want instruction on how to use a calculator effectively. This use of calculators only for computation shows the need for more integration of technology into the classroom in a way that uses the technology to instruct and not just perform basic computation.

In order to accomplish the integration of more technology into the classroom, instructors need pedagogical training. One way to provide this training is for national associations, such as AMATYC, to create training opportunities for instructors. Currently, AMATYC provides a traveling workshop that will come and provide information on how to integrate graphing calculators into developmental classes. It would be very beneficial to have a similar workshop for using scientific calculators in developmental classrooms. This training should include ways to help students use calculators to discover relationships in mathematics such multiplying by fractions makes things smaller. Calculators could also be used to develop different kinds of problem solving skills just as guess and check, a method more easily accomplished if they do not have to do computation.

However, one workshop is not enough to effect change in classroom practice. It is important that colleges provide ongoing professional development experiences for developmental instructors. K-12 research has shown the difficulty in making changes in classroom practice. Burill (1995) found that teachers believe that they know what students should learn and are reluctant to abandon what they have done successfully for years. Schmidt (1997) surveyed elementary teachers two years after the teachers participated in a six month professional development project to integrate fraction calculators as a teaching tool in elementary classrooms. During the project, the teachers were exposed to constructivist teaching and learning theory and were provided with fraction calculators to keep for use in their classroom. Two years after the completion of the project, the teachers were surveyed and they had rarely continued their professional growth beyond where they were at the end of the project. This study concluded that to influence teachers' beliefs, ongoing support is needed.

Seese (1994), in a summary of the changes effecting a community college mathematics department, reported that one of the major issues in effecting change toward a more current view was the faculty. Aging faculty were difficult to involve in professional development activities and did not want to adjust to the new technology and new instructional methodologies. Seese indicated that change required ongoing professional development as well as discussions, planning and assessment of alternative methods that included all faculty, adjunct and fulltime. In order to effectively change developmental classroom practice, colleges need to provide ongoing professional development. The professional development must include ways to try out new ideas and methods of using calculators in developmental classrooms and evaluate their effectiveness. It also needs to include time for all faculty to reflect on their current calculator practices and examine the current practices of other faculty in their discipline. Finally, the professional development needs to include all faculty in planning the pathway to change that will lead to an effective integration of calculators into the developmental classroom.

Finally, this study showed that it is important to examine the feeling and thoughts of developmental students to create an effective atmosphere for instruction. Instructors who did allow calculators in class seemed to believe that when students use a calculator the students spend more time on understanding concepts and less time with computation. Approximately half of the students who were allowed to use calculators agreed with this idea and reported that calculators helped them learn. As teaching is slowing moving from an instructor centered classroom where instructors transmit knowledge to students to a student centered classroom where students construct their own knowledge, it is important to take students' feeling and thoughts into account. This belief by students that calculators are important in their learning could be utilized by instructors to help overcome students' deficiencies in their mathematical skills. A meta-analysis of 27 studies at the k-16 level showed that students who use calculators report more positive attitudes toward mathematics (Ellington, 2004). By allowing a student access to a calculator, instructors might be providing that student with a psychological benefit that will help them learn mathematics.

Limitations of the Study

This study does have limitations. The study was done using instructors and students from one college in the southwestern United States. This college has a diverse faculty and student population and all of the five campuses that make up the college were represented in the study. However, results might be different in other regions of the county or in colleges with a smaller or less diverse population.

Another limitation is that this was a voluntary response survey. With a return rate of 55% percent among the faculty, it would seem that the instructor sample is likely representative, but it is possible that instructors who did not respond could have changed the findings if they had. The instructors who responded might have had strong opinions about calculator usage as it is a controversial topic in math education. These strong opinions that caused the instructors to take the time to respond might have caused the instructors also to inflate their actual calculator usage because they believe that they should be doing more with calculators in their classes. These strong feeling also might have biased the answers of the instructors who were against calculator usage. They might have caused instructors to be defensive and to response more negatively because they believed that the survey had a pro calculator agenda. The instructors who did not respond might have provided a more moderate view, however, they might just have been to busy too answer the survey.

Students also could choose not to answer the survey. It is impossible to know if the non-responding students just did not want to answer the survey or if they were underage and unable to complete the survey. Students were told that they did not have to answer the survey and were also told that if they were under 18 that they could not answer the survey. Students were told just to put the survey back into the envelope as to not embarrass any students or provide other students information about a fellow student's age. No class had more than 1 or 2 blank surveys returned. The overall student response rate was 97%.

Another limitation is students who were surveyed were overwhelmingly in classes where the instructor allowed calculators. Only 2 of the 12 classes did not allow calculators. The results may have been different if more classes that did not allow calculators were represented, but instructors who did not allow calculators did not respond to the request to survey their students. Maybe the instructors who did not allow students to use calculators were afraid that their students would respond negatively about the class or about the instructor themselves.

Another limitation comes about because all of the surveys were anonymous. This makes it is impossible to match the instructor survey results with the results of the student surveys. The only connection between the instructors and the students was a question that asked the instructors who allowed their students to be survey if they allowed calculators or not. It is impossible to see if the information that the instructor filled out in the original survey matched the information that was gathered from the student surveys.

Another limitation of the survey is the exploratory nature of the study. Because the surveys were created by the researcher, it is possible that if the questions had been different or if another methodology had been used the results would have been different. The survey instruments overall seemed to provide a variety of responses that were different from examples given in the questions. Only one of the questions had an unusually high number of responses match the examples given in the question. Question six of the student survey asked students that could use a calculator how they used a calculator in class and provided two examples: to check answers and to do multiplication problems. The students responded to this question using the examples 84% of the time. The examples seemed to bias the responses of the students. However, the study attempted to gain information about calculator usage by using multiple questions which helped to validate the data. Even if question six provided an unusually large percentage, other responses by students supported the findings that students mainly use calculators for accuracy and computation. The validity of the survey answers is supported by using multiple questions to explore the topic which helps to reduce the limitations of the instrument.

Even though the study does have limitations, the study is still valuable. It provides a picture of calculator usage in basic mathematics and prealgebra courses that had not been examined in the literature to date.

Recommendations for Further Study

Due to the limited number of studies in basic mathematics and prealgebra relating to calculators, it is obvious that there is much more to look at in this area. Hiebert (1999) says that research can not be expected to determine standards, prove what the "best" curricular or pedagogical decisions are, or imagine new ideas. Research can influence the nature of standards, document the current situation, document the effectiveness of new ideas, and suggest explanations for successes and failures.

Using these expectations of research, this study has noted that there are already national standards which encourage calculator use in developmental classrooms as tools to increase student's understanding of mathematics. This study has also documented the current situation in Basic Mathematics and Prealgebra at one community college which shows instructors and students using calculators as computation machines not as tools to increase mathematical knowledge. What we need in future studies is research that documents the effectiveness of new ways of integrating the calculator into the developmental classroom as well as more explanations on what makes students succeed or fail when they use calculators.

Most of the current research with graphing calculators, as well as other kinds of calculators, has been experimental studies that compare success with or without calculators on specific mathematics topics (Reznichenko, 2007). The issue with this type of study is that they do not look at curricular and pedagogical changes that need to happen to use calculators effectively. Just allowing calculator usage in the classroom is not sufficient. Research needs to be done on how to effectively integrate calculators into basic mathematics and prealgebra so that the calculator becomes a learning tool instead of a computation machine. This integration will require examining the curriculum as well as making pedagogical changes. Instructors need new ideas on how to integrate calculators into their classroom to help students create conceptual knowledge and research needs to be done to document the effectiveness of the integration.

Along with the integration of calculators for acquiring conceptual knowledge, instructors also need to learn how to use calculators to connect other subjects and the real world to the mathematics that they are teaching in the classroom at this level. This study reported that students believe that calculators are part of their lives and will be used as tools in the real world. Instructors need to learn how to tap into that belief to encourage and develop the mathematical skills needed for these students to have success in college and in life.

Another area that needs more examination is how beliefs surrounding the calculator affect students and their success in mathematics. This study reported that approximately half of the students that could use calculators thought that calculators helped them learn. Anecdotal evidence showed that students who were using graphing calculators were more likely to keep trying because the graphing calculator made them think they still had a chance to figure out the solution (Fox, 1998). Research has shown that students that have access to graphing calculators were more likely to engage in problem solving and were more flexible in their solution strategies (Burill et al, 2002).

Burill et al in their 2002 review noted that more research is needed about how students' attitudes and beliefs surrounding the use of graphing technology affect how they use the technology. This is also true about scientific calculators in developmental courses. No one has researched the effect of student's attitudes and beliefs surrounding calculators in a comprehensive manner.

Research is also needed on how teacher's beliefs surrounding calculator technology affect the classroom. The first community college national standards encouraging the use of calculators at all levels were written in 1995 (Cohen, 1995). These standards had a fairly even balance between new and old methods. The revised standards, which were released in 2006, embraced change in instructional practices towards innovation (Foley, 2007) calling for "inquiry, problem solving, modeling and collaborative learning, using appropriate technology" (Blair, 2006, p. 10). This study shows that instructors are still not using technology as a teaching tool to change the instructional practices in their classrooms. Research at the K-12 level has shown that professional development programs that introduce teachers to an innovation but do not provide long term support are not successful in changing the teachers practice (Schmidt, 1997). The importance of long term professional development to change instructional practice has also been reported at the community college level (Seese, 1994). Long term research is needed to evaluate professional development programs that encourage change in classroom practice. This research needs to examine how teacher's beliefs in the value of calculators affect implementation of the national standards into classroom practice.

Research is also needed to examine the effects of calculator usage in developmental courses on subsequent mathematics acquisition. This study reported that 41% of basic mathematics and 44% of prealgebra instructors did not allow calculator usage because they believe that students do not gain the basic computation skills necessary to succeed in the higher level courses when calculators are allowed in class. It would be useful to study students who are both successful and unsuccessful in algebra courses to see how well they perform basic computations to validate or invalidate this assumption. If basic computation skills do not influence a student's success in algebra, many instructors would be more likely to allow calculator usage.

Finally, we need to examine the effects of the calculator on student success or failure in basic mathematics and prealgebra courses. This study has shown that even though most students use calculators only for computation, calculators can provide confidence and encouragement to students as well as opportunities to concentrate on problem solving instead of computation. What is needed is research that examines how calculator usage affects student confidence, problem solving skills, and mathematical ability. Entry level courses such as basic mathematics and prealgebra can be major roadblocks to the completion of a college degree. Research is needed to provide instructors with information on how to help students at this level succeed in their coursework which in turn with help the student to succeed in life.

APPENDIX A

CONSENT FORM FOR INSTRUCTORS

Dear Developmental Educator,

My name is Darla Aguilar and I am the Department Chair for Mathematics at the Desert Vista Campus. As Pima Community College encourages faculty to do classroom research and complete doctoral degrees, I am currently working on my EdD in Teaching and Teacher Education at the University of Arizona. As part of my dissertation, I am doing a research project on calculator usage in developmental classrooms.

I am hoping that you will be willing to participate in my project. Enclosed you will find a survey. If you are willing to participate, please fill out the survey and return it in the enclosed envelope. The survey should only take approximately 5 to 10 minutes of your time.

It is anticipated that the information we gain from this study will improve developmental mathematics courses in the future. Thank you for your time and cooperation in this matter.

Sincerely,

Darla Aguilar

Mathematics Department Chair

Desert Vista Campus

Pima Community College

Title of Project: Developmental Mathematics Calculator Usage Survey

You are being invited to voluntarily participate in the above-titled research study. The purpose of this project is to gather information from teachers and students about calculator usage in developmental classrooms. You are eligible to participate because you are a teacher in a developmental mathematics course.

If you agree to participate, your participation will involve taking a survey. You may choose not to answer some or all of the questions. Any questions you have will be answered and you may withdraw from the study at any time. There are no known risks from your participation and no direct benefit from your participation is expected. There is no cost to you except for your time.

In order to maintain your confidentiality, no personal information will be collected in the survey. You can obtain further information from the Darla Aguilar, EdD candidate at (520) 206-5160. If you have questions concerning your rights as a research subject, you may call the University of Arizona Human Subjects Protection Program office at (520) 626-6721.

By participating in the survey, you are giving permission for the investigator to use your information for research purposes.

APPENDIX B

DEVELOPMENTAL MATHEMATICS CALCULATOR USAGE SURVEY FOR ISNTRUCTORS

<u>Developmental Mathematics Calculator Usage Teacher Survey</u>

1. Do you teach: ______ fulltime or ______ adjunct?

2. How many semesters have you been teaching (including this semester):

Math 82 Basic College Mathematics

In a traditional classroom ________ Online___________ Other ________

Please explain types of courses in other category: _____________________

Math 86 Prealgebra

In a traditional classroom ________ Online___________ Other _________

Please explain types of courses in other category: ______________________

3. If you are not currently teaching Math 82 or Math 86, when was the last time that you taught either of these courses? ____

4. For which campus do you teach the majority of your classes?

Community _______ Desert Vista _______ Downtown ______

East _____ West _____

5. Does the campus that you choose in question #4 have a policy about calculators for

Math 82 or Math 86? Yes No Don't Know

If yes, what is the policy? ____

____

The following questions are for Math 82 instructors.

If you have never taught Math 82 please skip down to question 10.

Please circle the appropriate response. Please feel free to attach additional pages if more room is required.

6. Do you allow your students to use calculators:

	Always		Sometimes		Never
For homework	1	2	3	4	5
In class	1	2	3	4	5
For tests	1	2	3	4	5

Other (please list):____

7. Please explain why you allow or do not allow for calculator usage in the above categories. ____

____

____

____

____

____

8. If you allow students to use calculators in class, how do you have students use the calculator? Please be as specific as possible. (For example, computation, problem solving, discovery learning, etc.) ____

____

____

____

____

____

9. If you do not allow students to use calculators in class, what would cause you to change this policy? ____

____

____

____

The following questions are for Math 86 instructors.

If you have never taught Math 86 please skip down to question 14.

Please circle the appropriate response. Please feel free to attach additional pages if more room is required.

10. Do you allow your students to use calculators:

	Always		Sometimes		Never
For homework	1	2	3	4	5
In class	1	2	3	4	5
For tests	1	2	3	4	5

Other (please list):____

11. Please explain why you allow or do not allow for calculator usage in the above categories. ____

____

____

____

____

____

12. If you allow students to use calculators in class, what are your pedagogical purposes for using the calculator? Please be as specific as possible. (For example, computation, problem solving, discovery learning, etc.) ____

____

____

____

____

____

13. If you do not allow students to use calculators in class, what would cause you to change this policy? ____

____

____

____

14. Do you think your students use a calculator:

	Always		Sometimes		Never
To do homework	1	2	3	4	5
To complete work in class	1	2	3	4	5
To take math tests	1	2	3	4	5
To do math in other classes	1	2	3	4	5
To do math outside of school	1	2	3	4	5

15. Why do think your students use a calculator in or out of class (Please give specific examples)?____

____

____

____

____

16. What kinds of math problems might prompt your students to use a calculator? (For example: multiplication, fractions, percents, story problems, etc.) ________________

____

____

____

____

17. Do you think if you changed your policy on calculator usage that it would have an effect on students' grades in your math class? YES NO Explain.

____

____

____

____

____

Thank you for your time and cooperation.

APPENDIX C

CONSENT FORM FOR STUDENTS

Developmental Mathematics Calculator Usage Survey

You are being invited to voluntarily participate in this survey. The purpose of survey is to gather information from students about calculator usage in developmental classrooms. You are eligible to participate because you are a student in a developmental mathematics course.

If you agree to participate, your participation will involve taking a survey. You may choose not to answer some or all of the questions. Any questions you have will be answered and you may withdraw from the study at any time. There are no known risks from your participation and no direct benefit from your participation is expected. There is no cost to you except for your time.

In order to maintain your confidentiality, no personal information will be collected in the survey. You can obtain further information from the Darla Aguilar, EdD candidate at (520)-206-5160. If you have questions concerning your rights as a research subject, you may call the University of Arizona Human Subjects Protection Program office at (520) 626-6721.

By participating in the survey, you are giving permission for the investigator to use your information for research purposes.

APPENDIX D

DEVELOPMENTAL MATHEMATICS CALCULATOR SURVEY FOR STUDENTS

<u>Developmental Mathematics Calculator Usage Student Survey</u>

When you answer the questions below, please consider the math course you are currently enrolled in. Circle the appropriate response.

1. Does your instructor allow you to use a calculator:

	Always		Sometimes		Never
For homework	1	2	3	4	5
In class	1	2	3	4	5
For tests	1	2	3	4	5

2. Do you use a calculator:

	Always		Sometimes		Never
To do homework	1	2	3	4	5
To complete work in class	1	2	3	4	5
To take math tests	1	2	3	4	5
To do math in other classes	1	2	3	4	5
To do math outside of school	1	2	3	4	5

3. What kind of calculator do you use: four function scientific graphing

4. Why do you use your calculator in class or outside of class? ________________

____

____

____

____

____

____

If your instructor lets you use a calculator in class, please answer question numbers 5 thru 10 and stop. If not, please skip to question number 10.

5. What kind of math problems cause you to use your calculator either in class or outside of class?____

____

____

____

6. How do you use a calculator in class? (For example: to check answers, to do multiplication problems, etc.)____

____

____

____

7. How does your instructor use calculators in class? (For example: to do multiplication or division problems, to help you understand how something works, to help you find a rule or pattern, etc.) ____

____

____

8. If your instructor did not allow you to use a calculator in class, would you change to another instructor? YES NO Explain: _______________________________________

____

____

9. Do you think being able to use your calculator in class changes your grade in this math class? YES NO Explain: ____
____
____

10. Does being able to use a calculator in class help you to learn more than if you could not use a calculator? YES NO Explain: ____
____
____

If you instructor does <u>not</u> let you use a calculator in class, please answer the questions 11 thru 14.

11. What kind of math problems would prompt you to want to use a calculator either in class or outside of class?____
____
____
____

12. If you knew before classes started that your instructor did not allow you to use a calculator in class, would you have chosen an instructor that let you use a calculator? YES NO Explain: ____
____
____

13. Do you think being able to use your calculator in class would change your grade in this math class? YES NO Explain: ____
____
____

14. Do you think that if you could use a calculator in class you would learn more?

YES NO Explain: ____

____

____

APPENDIX E

LETTER TO RECRUIT TEACHERS TO LET STUDENTS IN THEIR CLASS TO BE SURVEYED

Dear Developmental Educator,

My name is Darla Aguilar and I am the Department Chair for Mathematics at the Desert Vista Campus. As Pima Community College encourages faculty to do classroom research and complete doctoral degrees, I am currently working on my EdD in Teaching and Teacher Education at the University of Arizona. As part of my dissertation, I am doing a research project on calculator usage in developmental classrooms.

As part of my research, I need to survey Math 82 or Math 86 students on their calculator usage. If you would be willing to allow me to survey your students, I would appreciate it. It will only take about 15 minutes of your class time. If this is something that you are willing to do, please contact me at 206-5160 or email me at Darla.Aguilar@pima.edu. We can discuss how this would work at that time. By contacting me, you are in no way obligating yourself to allowing me into your classroom.

It is anticipated that the information we gain from this study will improve developmental mathematics courses in the future. Thank you for your time and cooperation in this matter.

Sincerely,

Darla Aguilar

Mathematics Department Chair

Desert Vista Campus

Pima Community College

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