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A study of calculator usage on the mathematics achievement of seventh- and eighth-grade students and on attitudes of students and teachers

Tracie Bidwell Ellerman
Louisiana Tech University

A STUDY OF CALCULATOR USAGE ON THE MATHEMATICS ACHIEVEMENT OF SEVENTH AND EIGHTH GRADE STUDENTS AND ON ATTITUDES OF STUDENTS AND TEACHERS

by

Tracie Bidwell Ellerman, B.A., M.M.E.

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UMI
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ABSTRACT

The purpose of this study was to examine the effects of calculator usage on the mathematics achievement of seventh and eighth grade students as measured by the Mathematics Concepts and Applications sections of the California Achievement Test. The study also investigated the attitudes of students and teachers toward calculator usage. Student attitudes were measured through responses to the Student Calculator Survey. Teacher attitudes were measured through responses to the Attitude Instrument for Mathematics and Applied Technology-Version II.

Intact classes from two north central Louisiana school systems were assigned randomly to treatment and control groups. The sample consisted of 1070 students and 33 teachers from nine schools.

Data analyses were conducted through t-tests and ANOVA routines of the SPSS-X program. Significant differences ($p < .05$) were found which favored the calculator group for both the number of correct responses and number of problems attempted. Significant differences for the variables of gender, race, grade, and level were reported for both the number correct and number attempted. Mean scores favored the calculator group for the variables of gender, race, grade, and level.

Responses on the student survey indicated a positive attitude toward calculator usage for both instructional and assessment purposes. Students reported calculator availability during class time in the categories of "some of the time" at 49.5% and "rarely or never" at 36.1%.

Classroom calculator availability was reported by 84.8% of the sample teachers. Usage was reported in the category "some of the time" at 81.8%. Survey responses differed significantly for the variables of conceptual mastery and teacher training. Findings from this study suggested that teacher training may result in more positive attitudes toward calculator usage.

Results of this study indicated that calculator usage during assessment appeared to have a positive influence on student mathematics achievement. Student and teacher survey responses appeared to support calculator usage for both instructional and assessment purposes. Teacher training and calculator availability should be considered as integral parts of calculator usage policies. School systems should consider the effects of calculator usage on student mathematics achievement as well as the attitudes of students and teachers in the development of calculator usage policies.

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CHAPTER I

INTRODUCTION

The calculator has caused notable changes in the availability and use of calculating power outside the realm of schools (Bell, 1976). There exists considerable agreement that calculators should be included in mathematical curriculum development and applications in school mathematics instruction. However, Bell claimed that this role cannot be established until solutions have been found to numerous problems: problems of philosophy, problems of curriculum and methodology, problems of design, and problems with the management of the calculators themselves.

For a number of years, groups such as the National Council of Teachers of Mathematics (NCTM) have urged increased use of calculators in the schools, particularly in problem solving work. In 1974, NCTM issued a statement that recommended the use of calculators in the classroom. This position stated:

> Mathematics teachers should recognize the potential contributions of this calculator as a valuable instructional aid. In the classroom, the minicalculator should be used in imaginative ways to reinforce learning and to motivate the learner as he becomes proficient in mathematics. (p. 468)

In its An Agenda for Action: Recommendations for School Mathematics of the 1980s, NCTM (1980) emphasized that the use of calculators helped students develop and use problem solving skills. One of the recommendations for the development of mathematics programs was that mathematics programs "take full advantage of the power of calculators and computers at all grade level" (p. 1) and that "most students must obtain a working knowledge of how to use them, including ways in which one . . . commands their services in problem solving" (p. 8).

In a position statement on calculator use in the classroom, NCTM (1986) recommended the "integration of the calculator into the school mathematics program at all grade levels in classwork, homework, and evaluation" (pp. 2-3). NCTM further recommended that all students should be allowed to use calculators in order to: concentrate on the problem solving process rather than on the calculations associated with problems, gain access to mathematics beyond the students' level of computational skill, and perform tedious computations that arise when working with real data in problem solving situations.

In recent years, educational reform efforts at the state level have addressed the issue of calculator usage for instructional and assessment purposes. A National Science Foundation grant was awarded in 1991 to the state of Louisiana. This grant led to the development of the Louisiana Systemic Initiatives Program (LaSIP) for improvement in the teaching and learning of mathematics and science. LaSIP's five-year mission focused on eight areas related to effective teaching in the areas of mathematics and science: educational technology, curriculum development, teacher certification, business partnerships, inservice training, preservice training, information dissemination, and assessment and evaluation. Emphasis for the mathematics component was placed on the use of technology, including calculators, for instructional and assessment purposes. LaSIP initiatives also focused on promoting change in teacher attitudes as a means of educational reform (LaSIP, 1997). The effectiveness of the LaSIP reform efforts with respect to calculator usage have yet to be fully researched or reported.

Statement of the Problem

The purpose of this study was to investigate whether the use of calculators on a selected standardized test of mathematics concepts and applications influenced the mathematics achievement of seventh and eighth grade students. The state of Louisiana recently adopted a standardized test which allows for calculator usage on portions of the mathematics battery. This study provided empirical data to support school system decisions in regard to calculator use on standardized tests. The study also examined the relationship of student and teacher attitudes toward calculator usage and perceptions with regard to calculator use. Although availability of technology does not ensure use, research suggests that the predominant impediment to employment is lack of access (Dick, 1990; Schultz, 1989; Wiske, Zodhiates, Wilson, Gordan, Harvey, Krenskey, Lord, Watt, & Williams, 1988). This study examined the availability and usage of calculators in order to form recommendations for appropriate access and use of calculators. Student and teacher attitudes toward calculator usage were examined in order to determine possible relationships between attitude and usage. Rogers (1983) found that an individual's attitude about an innovation, such as calculator use, could intervene in the decision to accept or reject the innovation. Teacher attitudes were examined to determine the effects of philosophical orientation and LaSIP training on attitudes toward calculator use. Following the research of Pryor, Fors, Hicken, and Sanchez (1990), this study sought to investigate the factors that motivated teachers to integrate calculator usage as well as the factors that created resistance to the integration of calculators. This study provided a research basis for recommendations with regard to calculator usage for both instructional and assessment purposes at the local school system level. The study provided findings which were factors in the development of calculator use policies for the participating school systems, which did not exist at the time of the study.

Significance of the Problem

Research has shown calculators to be effective tools in the problem solving process. Students who use calculators emerge from school with "better problem solving skills and much better attitudes about mathematics" (National Research Council, 1989, p. 48). If assessment practices are to be aligned with instructional strategies, then the use of calculators on standardized assessments of mathematical achievement should be examined. Despite the recommendations of groups such as NCTM, many teachers have been reluctant to use calculators in their classrooms, particularly during assessments of student achievement. This reluctance may be due in part to teacher attitudes toward calculators and restricted use of calculators on standardized tests. As commonly designed, many standardized tests at the elementary and middle school grade levels are constructed as paper-and-pencil measures of achievement (NCTM, 1989). With the increased usage of calculators not only during classwork, but also during non-standardized assessment measures, it follows that standardized assessment policies should reflect instructional practices with regard to calculator usage. Findings from this study may encourage revision and modification of calculator use policies to reflect the recommendations of NCTM.

In a statement reported by The Associated Press (Greene, 1997), Education Secretary Riley stated that proposed national tests for mathematics should permit only limited use of calculators. He also ordered a temporary halt in the development of the national tests. Riley's statement regarding calculator usage appeared to represent an effort toward appeasing critics who felt the test design favored a less than vigorous approach to teaching mathematics. The National Test Panel, which wrote the specifications for the proposed national tests, recommended that students should be allowed to use their own calculators during the 90-minute tests. Riley, however, said the tests should allow for only limited use of calculators for advanced problem solving in algebra and geometry. "In my view, a test of eighth-grade students should measure, as NAEP (National Assessment of Educational Progress) does, whether students have learned to do arithmetic accurately without a calculator," commented Riley. "But a visit to any good eighth-grade classroom will show students who have moved beyond arithmetic to more advanced topics" (Greene, 1997). The statements and comments presented by the Education Secretary point to the significance of the calculator use controversy.

The Louisiana State Department of Education recently approved the use of the Iowa Tests of Basic Skills as the norm-referenced mathematics achievement measure. This test has provisions for calculator usage on the Mathematics Problem Solving and Data Interpretation sections, but school systems need empirical evidence prior to approving calculator usage in standardized assessment situations. Findings from this study provided information relative to the adoption of a format which allows for calculator usage on appropriate sections. The study identified areas where calculator use was beneficial on the California Achievement Test (CAT) with implications for appropriate calculator usage on other standardized tests.

In a statement by the Research Advisory Committee of NCTM (1990), the significance of research related to the effects of calculator usage was supported: "It is important to be mindful of the difficulties associated with the expectations of practitioners, the public, and policy makers relative to research" (p. 289). Shavelson

(1988) identified two faulty assumptions about educational research. The first assumption was that "education research should directly and immediately apply to a particular issue, problem, or decision" (p. 5). The second assumption was that education research findings led directly to rational action, followed by good education, to the mutual benefit of society. The contribution of educational research most often lies in constructing, challenging, and changing how policy makers and practitioners think (Research Advisory Council, 1990, p. 290). The presence of technology has changed the discipline of mathematics; unsolved problems have become trivial, and underemphasized themes have achieved central importance (Hoffman, 1989). "Technology allows us to emphasize different parts of the traditional school mathematics curriculum and to de-emphasize others, to include mathematical topics new to the traditional curriculum and to reorganize instruction" (Research Advisory Council, 1990, p. 291). The significance of this study can be summarized in a statement from the Research Action Council of NCTM (1995): "In general, NCTM considers mathematics education research to be disciplined inquiry into matters related to mathematics learning, teaching, curriculum, or policy" (p. 301). The rationale for this study is based on a similar statement from the council: "The point of doing research is more often to gain insights into problems, their sources, and their definitions, or to open new ways of seeing what is currently taken as simple and obvious" (p. 302).

Theoretical Framework

In 1989, NCTM published the Curriculum and Evaluation Standards for School Mathematics. Support for technology, including calculators and computers, was reflected in statements such as "appropriate calculators should be available to all students at all times" (p. 8), that "students need to experience genuine problems regularly" (p. 10), and that "computers and calculators are powerful problem-solving tools" (p. 75). The evaluation standards proposed that tests should be changed because they were designed based on different views of what knowing and learning mathematics mean. "Knowing mathematics by doing mathematics in a technological world differs from developing a sequence of skills or objectives when calculators and computers did not exist and when mathematical applications were primarily confined to the physical sciences and commerce" (p. 193). The first evaluation standard addressed alignment of evaluation with the curriculum:

> This alignment can be determined by examining the extent to which the instruments measure the content of the curriculum; are consistent with its instructional approaches, particularly the use of calculators, computers, and manipulatives; and cover the range of topics weighted according to the emphases of the curriculum. (p. 193)

Consideration should be given to the extent to which assessment practices reflect the use of calculators. When calculators are used during instruction, they should be available during assessment as long as their use is consistent with the purposes of the assessment. NCTM further stated that ". . . until tests provide for the appropriate use of calculators, many teachers will continue to prohibit their use in the classroom" (p. 252).

According to a study by Reys and Reys (1987), standardized mathematics tests assessed students' abilities in several areas, such as computation, concepts, applications, and problem solving. When skills in pure computation were measured, Reys and Reys concluded that calculator use should not have been permitted. The remaining portions of such tests claimed to measure other important components of a mathematics program that were not purely computational in nature. Findings suggested that the availability of calculators on noncomputational portions of standardized tests ensured that students were not penalized twice for weak computational skills.

Standardized tests exert considerable influence over the curriculum. The question was raised, "Yes, but who will change the tests?" (NCTM, 1989, p. 189). Clarkson (1992) questioned whether standardized tests could be changed to reflect more accurately the mathematics curriculum proposed by NCTM. It appears that as the Standards have become more widely implemented in the schools, standardized tests will require change in order to reflect more accurately the vision of the mathematics curriculum as outlined in the Standards (Romberg, Wilson, Khaketla, & Chavarria, 1992).

Despite empirical support for the application of calculators to classroom instruction, many teachers reported they remained hesitant about using calculators with their students, except in the most elementary ways (Jaji, 1986). Gilchrist (1993) stated that while many teachers believed it was vital for mathematics education to follow social trends in technological development, there was at the same time resistance to employment of new technologies, such as calculators, into the classroom. Teacher attitudes toward calculator usage have had a profound influence on the incorporation of calculators into instructional and assessment practices. Dick (1988) reported that the effect of calculator use on the acquisition of basic skills has been one of the major points of disagreement between teachers. Rogers (1983) stated that an individual's attitudes or beliefs about an innovation, such as calculator use, could intervene in the innovation-decision process. There was a tendency for favorable attitudes toward an innovation to lead one toward adoption and for unfavorable attitudes to lead to rejection of the innovation.

An important issue related to calculator implementation is the equity of opportunity for utilization of the technology (Huang & Waxman, 1996). Equity issues have strongly influenced the attitudes of students toward calculator usage. Collis, Kass, and Kieren (1989) found that female students reported the use of technology significantly less often than males in mathematics classes. Koontz (1991) reported gender differences that favored males during classroom instruction related to technology. There were similar concerns raised that affected students of minority groups. The Office of Technology Assessment (1988) reported that minorities had less access to technology than did non-minority students. Gilchrist (1993) noted the area of socio-economic status as a possible source of inequity related to calculator usage. One such problem resulted from the varying degree of sophistication among calculators. Because the sophistication level of the calculator was directly related to cost, the equity issued was raised once again. Although the availability of technology did not ensure use, the predominant obstacle cited for the impediment of employment was the lack of access (Dick, 1990; Schultz, 1989; Wiske, Zodhiates, Wilson, Gordan, Harvey, Krensky, Lord, Watt, & Williams, 1988).

The theoretical framework to support the effects of calculator usage on mathematics achievement was based on findings from a number of significant studies. Suydam (1982) found positive effects for the use of calculators in problem solving. These findings were supported by Wheatley (1980), Szetela (1982), and Wheatley and Wheatley (1982). Further substantiation was provided by Hembree and Dessart's (1986) meta-analysis of the effects of calculator usage on problem solving. From 13 studies which focused on the development of concepts or problem solving strategies, Hembree and Dessart concluded that calculator usage increased the problem solving performance of students as a result of improved computation and strategy selection. Roberts (1980) examined 34 studies related to the effects of calculator use on mathematics achievement. Doubts concerning the effectiveness of calculator use for problem solving were reported through nonsignificant findings. Based on the conflicting findings of these studies, further research concerning the effects of calculator usage on mathematics achievement was warranted.

Student attitudes toward mathematics were examined in a meta-analysis conducted by Ma and Kishor (1997). Findings from the 113 studies examined indicated that the factors of gender, race, and grade level contributed significantly to the relationship between attitude and achievement. Aiken (1976) concluded that "it is clear that in prediction studies involving a measure of attitude toward mathematics, separate analyses by sex should always be conducted" (p. 302). In a study of the correlation between attitude toward mathematics and mathematics achievement, Behr (1973) and Callahan (1971) noted that not only did the correlation vary by gender, but by grade level. Secada (1992) found that differences in achievement varied among ethnic groups and the differences increased as students grew older. Bitter and Hatfield (1993) studied changes in attitudes and perceptions toward calculator use. Although many of the differences in attitude were small, girls' beliefs changed over the course of the study toward more positive feelings concerning calculator use. These studies formed the basis for examination of student attitudes toward mathematics and calculator usage.

Fine and Fleener (1994) reported response categories concerned with teacher beliefs and attitudes in a study which involved the use of calculators as instructional tools. The response categories, namely the influence of personal characteristics, experience, and social factors which affected potential use of calculators in the classroom, had significant bearing on pedagogical beliefs about calculator use. Fleener (1995b) analyzed the responses of 94 middle school and secondary mathematics teachers on the Attitude Instrument for Mathematics and Applied Technology (AIM-AT) to determine the relationship among philosophy, experience, and attitudes toward calculator use. Interactions between mastery orientation and experience were suggested. Fleener (1995a) further identified contextual frameworks related to calculator use as expressed through Habermasian interest categories. Findings indicated that philosophical orientation pertaining to calculator use was a function of both experience and attitudes. The existence of a developmental continuum involving experience and philosophical orientation implied that change efforts should address both experience and philosophical orientation toward calculator use. The role of teacher training was the focus of a study by Bitter and Hatfield (1993). Findings from the study indicated that teacher training must meet two needs. First, teachers must be trained in appropriate methods of integrating calculator usage. Second, teachers must be sufficiently convinced of the calculator's utility in order to integrate it into instruction. Knowing how to integrate and deciding to integrate are not equivalent. Findings from studies concerning teacher attitudes toward calculator usage supported the framework for the teacher attitude portion of the study.

The research studies presented above formed the theoretical framework for the mathematics achievement section and the attitude sections of this study. It was posited that calculator usage has a significant effect on the mathematics achievement of seventh and eighth grade students. This effect may be influenced by the factors of group, gender, race, grade, and level. The use of a control group-treatment group design has been substantiated as an appropriate model for this portion of the study. The relationship of student and teacher attitudes toward calculator use was examined for perceptions regarding calculator usage. Survey research has been shown to be an effective method for examination of attitudes and perceptions.

Hypotheses and Research Questions

Data from this study were used to test four null hypotheses and to answer the six research questions. The hypotheses address the effects of calculator usage on mathematics achievement and are as follows:

1. H_0: There is no statistically significant difference between the mean number of correct responses of the treatment group and the control group as measured by the Mathematics Concepts and Applications sections of the California Achievement Test (CAT).

2. H_0: There is no statistically significant difference between the mean number of correct responses for the variables of gender, race, grade, and level as measured by the Mathematics Concepts and Applications sections of the CAT.

3. H_0: There is no statistically significant difference between the mean number of problems attempted by the treatment group and the control group as measured by the Mathematics Concepts and Applications sections of the CAT.

4. H_0: There is no statistically significant difference between the mean number of problems attempted for the variables of gender, race, grade, and level as measured by the Mathematics Concepts and Applications sections of the CAT.

This study addressed student and teacher attitudes toward calculator usage through six research questions. Data from the survey responses were used to support the following research questions:

1. What perceptions do students have regarding calculator availability as measured by self-report responses on the Student Calculator Survey?

2. What attitudes do students have regarding calculator usage as measured by mean responses to the Student Calculator Survey?

3. Are there statistically significant differences between the attitude toward calculator usage responses of the treatment group and the control group as measured by the Student Calculator Survey?

4. What perceptions do teachers have regarding calculator availability as measured by survey self-report responses?

5. What attitudes do teachers have regarding calculator usage as measured by mean responses to the Attitude Instrument for Mathematics and Applied Technology-Version II (AIM-AT-II)?

6. Are there statistically significant differences between the teacher attitude responses as measured by the AIM-AT-II with respect to the variables of philosophical orientation and teacher training?

Assumptions

1. The Mathematics Concepts and Applications sections of the CAT are appropriate instruments for the measurement of mathematics achievement.

2. The attitude instruments used in this study are appropriate for the purposes of this research. The Student Calculator Survey was designed specifically for use with seventh and eighth grade students. The AIM-AT-II was designed to measure the responses of teachers with respect to the variables of philosophical orientation and training.

Limitations

1. Determination of ability levels was made on the basis of criteria developed for the purposes of this study.

2. The assignment of classes to ability levels was self-reported by teachers and principals and may not have accurately reflected the criteria established for this study.

Definition of Terms

1. Achievement test refers to a test that is designed to identify the knowledge and skills that students have acquired in specific content areas at a certain time (CTB Macmillan/McGraw-Hill, 1993, p. 71).

2. Mathematics achievement refers to performance on the Mathematics Concepts and Applications sections of the California Achievement Tests, Fifth Edition, Form A, Levels 17 and 18.

3. Problem solving is defined by Polya (1945) in terms of using a strategy to obtain a goal: "To have a problem means: To search consciously for some action appropriate to obtain a clearly conceived but not immediately attainable aim" (p. 117).

4. Attitude is defined by Aiken (1970) as "a learned predisposition or tendency on the part of an individual to respond positively or negatively to some object, situation, concept, or another person" (p. 551).

5. Student attitude toward calculator use refers to responses on the Student Calculator Survey developed by Bitter (1993). The instrument measures agreement with statements regarding calculator use through responses on a 4-point Likert scale.

6. Teacher attitude toward calculator use refers to responses on the Attitude Instrument for Mathematics and Applied Technology-Version II (AIM-AT-II) developed by Fleener (1995). As expressed through fundamental human interests (Habermas, 1971), contextual frameworks reveal elemental philosophical orientations which may have implications for the success of reform or change efforts (Fleener, 1994b).

7. Teacher training refers to participation in the Louisiana Systemic Initiative Program (LaSIP) mathematics section. LaSIP training includes a calculator instruction component and workshops specifically designed to deliver calculator instruction.

8. Mastery refers to teachers' philosophical orientation as defined by their responses on specific items of the AIM-AT-II survey. Item 7 (Students should not be allowed to use calculators until they have mastered the concept) and item 17 (Students should be allowed to use calculators even before they understand the underlying concepts) were used to determine MASTERY = YES and MASTERY = NO categories. Teachers who agreed with item 7 and disagreed with item 17 formed the MASTERY = YES group. Teachers who answered inconsistently (agreeing or disagreeing with both items) or who consistently answered against the mastery requirement (disagreeing with item 7 and agreeing with item 17) formed the MASTERY = NO group.

9. Ability level refers to classification on the basis of criteria established for this study by the researcher (see definitions 10-12).

10. Low level refers to a class in which 25% or more of the students met one or more of the following criteria: scored below the 35th percentile on the total mathematics battery of the CAT; failed mathematics the previous year; or currently received documented modifications in mathematics instruction.

11. High/honor level refers to a class which was classified by the school as honors, advanced, algebra, or gifted and talented.

12. Regular level refers to a class which was not classified as either low level or high/honor level.

CHAPTER II

REVIEW OF THE LITERATURE

This chapter summarizes findings from a review of the literature on the effects of calculator usage on mathematics achievement and student attitudes toward calculator usage. The review includes studies and research regarding the use of calculators on standardized tests. Research and studies on teacher attitudes toward calculator usage are also reported. The review has been organized into four areas related to this study:

1. Calculator Usage at the Elementary Level
2. Calculator Usage at the Secondary Level
3. Calculator Usage on Standardized Tests
4. Teacher Attitudes Toward Calculator Usage

Calculator Usage at the Elementary Level

Hohlfeld (1974) examined the effect of a calculator programmed to provide immediate feedback on working simple multiplication problems with students in the fifth grade. Within each of seven classes, four students (total N = 84) were assigned to one of three groups: the experimental group used the calculators as a feedback device; control group one used paper and pencil to work by hand the same problems as the experimental group; and control group two followed the normal classroom routine without any particular attention being given to multiplication drill. The Mathematics

Computation section of the Metropolitan Achievement Tests (MAT) and a 100-item multiplication test developed by the researcher were given as pretests and used as covariates. Alternate forms of the multiplication tests were readministered as a posttest after one month of treatment, as a short-term retention test after one additional month, and as a long-term retention test after an additional three months. An analysis of variance (ANOVA) revealed the experimental group scored higher than both the control group one and the control group two on the posttest and the first retention test, but all groups had the same score on the long-term retention test. It was noted, however, that on the average the experimental group worked nearly twice the number of problems as did control group one. Additional practice may have accounted for the improved performance for the experimental group.

Spencer (1975) used fifth and sixth grade students to observe the impact of calculators on computational skills and arithmetic reasoning abilities. The 84 students consisted of 42 males and 42 females. The Iowa Tests of Basic Skills (ITBS) subsets on arithmetic concepts and problem solving were given both before and after the eight-week treatment. Students in the experimental group (N = 42) were allowed to use calculators on all class work and the actual posttest. Students in the control group (N = 42) had no access to calculators. ANOVA was used to compare the gain scores between the groups; separate analyses were made for each grade. For the fifth grade, the mean score of the experimental group was greater than that of the control group on the problem solving test whereas in the sixth grade, the mean score of the experimental group was greater than the control group on the arithmetic computations section.

Miller (1977) examined whether calculators would be effective instructional aids in the development of the concept and skill of long division with fifth grade students. Two intact classes were each assigned randomly to the experimental (N = 24) or control (N = 23) conditions. Pretests, used for covariates, included an arithmetic readiness test, an investigator-developed division test, and the mathematics section of the Comprehensive Test of Basic Skills (CTBS). The investigator-developed test consisted of two difficulty levels and was used as a posttest measure. All students received instruction emphasizing the subtractive approach to long division, with the experimental group students allowed calculator usage on the posttest. Analysis of covariance (ANCOVA) was conducted, with separate analyses for low- and high-ability groups. Results indicated the score of the experimental (low) group was greater than the control (low) group. The experimental (high) group score was equivalent to the score of the control (high) group.

In two studies which utilized the same sixth grade students, Jones (1976) and Allen (1976) investigated the effects of calculator usage on mathematics achievement, attitudes, and self-concept. Six intact classes were assigned randomly: four to the experimental condition (N = 113), and two to the control condition (N = 62). Pretests included the SRA Assessment Survey for mathematics, the Criterion Referenced Test in Metric Measurements, and a researcher-developed test on decimals. Treatment consisted of calculator usage by the experimental group students during their mathematics classes to solve problems and check work. Students in the control condition had no access to calculators during classroom sessions. After one month, the Criterion Referenced Test in Metrics Measurement and the decimal test were readministered. After an additional month, the SRA was readministered along with the Dutton's Attitude Toward Arithmetic Scale and the Piers-Harris Children's Self-Concept Scale. Students in the experimental condition were not allowed to use calculators on the posttest. In Jones's work, SRA gain scores along with posttest attitude and self-concept data were analyzed, whereas in Allen's work, metric measurement and decimal test gains were examined. ANCOVA was the statistical procedure, with SRA pretest scores used as the covariate. For the SRA, the experimental group score was greater than the control group score on the posttest; however, the experimental and control groups were equivalent on scores for attitudes and self-concept. On the individual metric measurement and decimal tests, the experimental and control group scores were equal; however, with a linear combination of both measures, the control group scored higher than the experimental group. A problem encountered in the study was the admission by six percent of the control group students of having used calculators outside the classroom during study.

With fourth- through seventh-grade summer school students, Nelson (1976) investigated the impact of calculator use on computational skills and attitudes. Sixteen classes were assigned randomly to one of four conditions: experimental group one (N = 45) used a commercial program that included calculator work; experimental group two (N = 47) utilized a locally developed, remedial program which included calculator work; experimental group three (N = 55) used the regular program with calculators available, but not part of the regular instructional emphasis; and the control group (N = 49) utilized the regular program with no calculators available. Students were pretested and posttested on the Shaw-Hiehle Computation Test and the SMSG attitude inventory, PX 0101 Scale Incentive Code, "Arithmetic Fun vs. Dull." Students were not allowed to use calculators on the posttest. The treatment lasted four weeks with daily 50-minute sessions. For both computations and attitudes, experimental group two had the highest score, followed by the score of experimental group one equivalent to the score of experimental group three, and all experimental groups were superior to the control group. No mean scores for any of the groups or any of the tests were reported in this study.

Schnur and Lang (1976) utilized 48 summer elementary school students to determine if calculator use improved their computational skills. The treatment lasted one month and consisted of work with basic arithmetic operations. The experimental group students (N = 26) used calculators to check and work problems whereas the control group students (N = 22) used paper-and-pencil techniques. All students were pretested and posttested with alternate forms of the Individualized Computational Skills Program Computational Test 3-4. Students in the experimental groups were not allowed to use calculators on the posttest. Data analysis though ANOVA for the gain scores indicated that the experimental group score was greater than the control group score for computational performance.

Kasnic (1978) studied the effect of calculator usage on mathematical problem solving in relation to three levels of ability of the sixth-grade students tested. Four schools were each assigned randomly to one of four treatments: experimental group one (N = 30) used calculators to practice problems but did not use calculators on the posttest; experimental group two (N = 30) used calculators for both practice problems and on the posttest; control group one (N = 30) used paper-and-pencil methods to practice the problems and were not allowed to use calculators on the posttest; and control group two (N = 30) had no particular treatment. The treatment lasted nine days with 50-minute sessions each day. The posttests involved a problem solving measure. A two-way ANOVA, with pretest ability as a blocking variable, detected no significant differences between the experimental and control groups, nor were any differences found for the different ability levels between experimental and control groups.

Roberts (1980) summarized the findings of several studies at the elementary level which involved the use of calculators. The majority of the studies completed at the elementary level showed computational advantages from the introduction of calculator usage into mathematics instruction, even though the use of calculators was not allowed on the posttest. However, in one study of the five which investigated concepts there were conceptual benefits due to calculator usage, and in one study of the four which investigated attitudes there were attitudinal benefits.

Bitter and Hatfield (1993) reported findings from their study of the integration of the Math Explorer calculator into the mathematics curriculum. The two-year study involved 580 seventh and eighth grade students and their teachers from a middle school in Arizona. The study was in collaboration with mathematics educators from Arizona State University and investigated the effects of the calculator's role in mathematics instruction. Although perceptions reported by students and parents appeared to have been quite positive, participating teachers differed widely in the degree to which they integrated calculator usage as suggested by NCTM. The central recommendation from the study was that integration of the calculator in the middle school mathematics curriculum positively influenced student performance and attitudes.

Calculator Usage at the Secondary Level

Quinn (1976) used honors eighth and regular ninth grade students to observe whether the use of a programmable calculator facilitated algebra achievement and positive attitudes toward mathematics. Classes in one school which had the calculators served as the experimental condition (N = 105), whereas students from the other school served as the control condition (N = 79). The Cooperative Mathematics Tests (Algebra I and the Mathematics Attitude Inventory) were given as pretests and posttests. Selected data from the Comprehensive Test of Basic Skills and the Short Form Test of Academic Aptitude were used as covariates. For the experimental classes, treatment consisted of incorporation of a programmable calculator into routine instruction throughout the year; however, the calculator was used only after students proved that they could work the problems by hand. The experimental group students were not allowed to use the calculator on the posttest. Data analysis through ANOVA revealed no achievement differences between the experimental and control groups, but the experimental group score was greater than the control group on the attitude test.

Zepp (1976) examined whether there was an interaction between the use of a calculator and ability level in ninth-grade and college students' solutions to proportion problems. Based on a pretest, students were assigned to high, medium, and low levels depending on performance on the proportion problems. Half of each level was then assigned to the experimental (N = 184) condition and the other half to the control (N = 184) condition. The experimental group used calculators throughout the two-week programmed instructional sequence on proportions. Students in the experimental group were allowed to use calculators on the posttest, which was again a proportions problems test. A two-factor ANOVA with separate analyses for ninth grade and college levels revealed no differences between the experimental and control groups, although there were differences for the ninth grade due to ability level.

Gaslin (1975) compared the achievement and attitudes of ninth grade students who used either conventional or calculator-based algorithms for operations on positive rational numbers. The sample consisted of six classes, two from each of three schools.

The three treatments involved a conventional algorithm set (CAS; N = 38) where operations were performed by the usual textbook approach; an alternative algorithm set (AAS; N = 32) where fractions were converted to decimals on a calculator first, then the various operations were performed with the decimals using the calculator; and the control condition (N = 31) with no calculator usage. CAS served as the experimental group one; AAS served as the experimental group two. Treatments lasted ten weeks followed by a retention test after two weeks. Students in both the experimental groups were allowed to use calculators on posttests and retention tests. Criterion measures included an operations with fractions test, a transfer test, a fractions retention test, and semantic differential attitudinal test about mathematics. Analyses through ANOVA and ANCOVA used achievement and intelligence test scores as covariates. Significant treatment effects were found for both posttest achievement measures, with the experimental group two mean greater than both the experimental one group mean and the control group mean. For the retention test, the experimental group two mean was greater than the experimental group one and equal to the control group; however, no differences on attitude measures were found between any of the groups.

Fischman (1976) examined high school students' attitudes and concept learning in business arithmetic courses where some classes used calculators to complete their work and others did not. All students were tested on the New York Computation Test and the Aiken Revised Math Attitude Scale at the beginning and end of the school year. In the three experimental group classes (N = 48), students were allowed to use calculators in their daily class work, whereas students in the three control group classes (N = 52) were not. No treatment effect was found on the attitude measure, but there was an overall positive change for both experimental and control groups from the beginning to the end of the school year. The experimental group was posttested twice, once when calculators were used on one form of the posttest and a second time without calculator use on an alternate form of the posttest. The mean score was higher than the control group score when calculator use was allowed on the test. When calculator use was not allowed, no differences were found in comparison to control groups.

Wajeeh (1976) examined the effects of a program of meaningful and relevant mathematics on student achievement and attitude. For the experimental group one, students (N = 75) used the developed program with calculators. The experimental group two (N = 75) used the program, but without the benefit of calculators. The control group one (N = 75) was not exposed to the new program, but was taught by the same teachers who taught the experimental groups. The control group two (N = 75) was taught by different teachers. The treatment lasted 15 weeks and was preceded and followed by mathematics subtests of the California Achievement Tests and Dutton's Attitude Toward Arithmetic Scale. It was not reported whether the students in the experimental group one were allowed to use calculators on the posttests. ANOVA and ANCOVA results showed superiority of both experimental groups over the control groups on both achievement and attitudes, but no significant difference was found between the scores of the experimental groups.

Hutton (1977) examined the effects of calculator use on the achievement and attitudes of ninth grade algebra students. Pretests and posttests were the SMSG Mathematics Inventory Form 122A for achievement and SMSG PY-408 Pro-Math Composite Scale and PY-408 Math Fun vs. Dull Scales for attitudes. For treatments, both the experimental group one (N = 53) and the experimental group two (N = 45) received calculators for use. The teachers in the first experimental group incorporated calculator use into mathematics instruction, whereas teachers in the second experimental group did not. In the control classes, students (N = 72) were not allowed to use calculators. Treatment lasted for four weeks, and the unit of study was a chapter on real number powers, roots, and radicals. Students in both experimental groups were not allowed to use calculators on the posttest. Analysis through t-tests revealed no differences between any of the experimental and control groups on any of the achievement or attitudinal variables.

Jamski (1977) investigated the impact of calculator usage on seventh graders' learning of decimal/percent conversion algorithms. Classes were assigned randomly to experimental and control conditions. For both groups, the treatment period lasted four weeks; experimental group students (N = 66) were allowed to use calculators during mathematics instruction, whereas control group students (N = 70) did not use calculators. The pretest measure used to compare experimental and control groups for equivalency was Form 7S-3, Test D from the SMSG series. The criterion test was developed by the researcher and was used both as a posttest and as a retention test five weeks later. The experimental group students were allowed to use calculators on the posttest, but not on the retention test. ANOVA results showed the score of the experimental group was greater than the control group for achievement on the posttest, but no differences were noted for the retention test.

In a study conducted with seventh grade students, Andersen (1977) was interested in the effects of restricted versus unrestricted use of calculators on mathematics achievement and attitudes. Three classes were selected at random from each of four schools; one was assigned to each of two experimental conditions and one to a control condition. In the experimental group one (N = 106), students were allowed restricted use of calculators only to check hand computations; in the experimental group two (N = 105), students were allowed unrestricted use of calculators; and in the control group (N = 114), no students had access to calculators. The study lasted for 20 weeks and students were both pretested and posttested on achievement for computations and problem solving and on attitudes. For the posttests, both experimental groups were allowed to use calculators on the computational tests, but not on the problem solving tests. ANCOVA was the principal analysis procedure and the reported score of experimental group two was equivalent to experimental group one. Both experimental group scores were greater than the control group for attitudes.

Rudnick and Krulik (1976) investigated whether the availability of calculators, but not integrated use in the curriculum, affected seventh grade students' mathematics achievement and attitudes. Half of the seventh grade classes in the two schools in the study were assigned randomly to either experimental or control conditions. After all students received instruction in the use of calculators, the experimental group students (N = 258) were allowed unrestricted use of the calculators. No special changes in the mathematics program were made to accommodate calculator usage. Students in the control condition (N = 209) were not allowed to use calculators. Students were pretested with the Cooperative Mathematics Test and an attitude measure at the beginning of the school year, retested with the achievement test in January, and then retested again with both the achievement and attitude measures at the end of the year. Participants in the experimental condition were not allowed to use calculators on the first retest. However, two forms of the achievement test were administered at the second retest, at which time students in the experimental condition were allowed to use calculators on one of the tests. Data were reported for only the pretest and the first retest. ANCOVA showed no achievement differences between experimental and control group scores on the retest. Significant differences favored the control group on the pretest of achievement.

Calculator Usage on Standardized Tests

Ansley, Spratt, and Forsyth (1989) conducted research to determine the effects of calculator usage to reduce the computational burden on a standardized test of mathematics problem solving. The Quantitative Thinking subtest (Test Q) of the Iowa Tests of Educational Development was utilized to determine the importance of computational skill for answering items involving problem solving ability. The subjects for the study were 190 students in grades 10 through 12 in one Iowa high school. Data analysis included a 3-way ANCOVA with treatment group, gender, and grade level as the factors. The covariate was mathematics ability as defined by the students' scores on Test Q from Form X-8 of the ITED administered at the school the previous October. The study also investigated the amount of time required to complete the test. The absence of a significant treatment effect and significant treatment interactions indicated that for this particular test, which required some computation, the use of calculators did not appear to be advantageous. Generally, it appeared that students who used calculators spent longer completing the test. The possibility that students spent more time exploring possible solutions was offered as a viable explanation for the increased completion time.

Long, Reys, and Osterlind (1989) reported results of the administration of the Missouri Mastery and Achievement Tests (MMAT), first administered in the spring of 1987. The MMAT reported scores for individual students at three levels: a key skill-level score, a cluster score which represented a group of closely associated key skills, and a score for the total test. To control for possible initial differences in mathematical achievement between the calculator and noncalculator groups, an analysis of covariance was performed on the total test and on each cluster within the test. An examination of performance on items within specific key skills for both calculator and noncalculator groups demonstrated advantages which favored the calculator group for instructional and evaluative purposes. In both the eighth grade and tenth grade assessments, the calculator groups showed a clear advantage only when the task was fairly straightforward and required tedious computation. When tedious computation was necessary, but the task was complex from a problem solving perspective, calculator usage made no significant difference. The researchers concluded that the use of calculators on state tests allowed students to demonstrate mastery of particular mathematics applications and operations.

The impact of the use of calculators on scores of mathematics problem solving tests was reported by Lewis and Hoover (1981). The study involved eighth grade students measured by the ITBS. It was found that calculator use raised scores on the Mathematics Computation and Mathematics Problem Solving portions of the test, but not on the Mathematics Concepts portion. These findings were supported by Loyd (1991), who constructed a test with four item types to determine how useful calculators were for obtaining the correct answer. Findings indicated significant calculator effects only for the item type that required complex computations; for items in which hand computations were relatively easy, there was a nonsignificant trend which favored the calculator group.

Bridgeman, Harvey, and Braswell (1995) conducted a study as a part of research involving the Scholastic Aptitude Test Version I (SAT I), which was introduced in 1994. The study examined the effects on total scores for various subgroups of the test, and identified which item types were most sensitive to calculator effects. The use of calculators resulted in a modest score increase on a test composed of the type of mathematical reasoning items found on the SAT, although effects on individual items ranged from positive through neutral to negative. Prior experience in use of calculators in test situations appeared to be very beneficial. Calculator effects were found on items at all difficulty levels, and calculator use appeared beneficial for students at all ability levels. However, the analyses of individual items suggested that in any given test, calculator use might benefit either high-scoring or low-scoring students. As the analysis of individual items showed, construct validity may have been decreased for some items and increased for other items when calculator use was permitted. Questions that measured estimation skills or that required some mathematical insight in a noncalculator group might have measured trivial computational skills when calculator use was permitted. Other items could have become purer measures of mathematical reasoning when calculators were used to reduce computational errors that were secondary to the main focus of the items. The recommendation was made that test developers give attention to these issues. The researchers concluded that calculator use on mathematics tests had the potential for increased construct validity and equity for students who had been taught to rely on calculators for routine computations.

A number of researchers have presented position statements on the use of calculators on standardized tests. Heid (1988) proposed that in much the same manner as test results have sounded the warning signal for a misguided curriculum, tests have often served as sentries to guard against needed change in that same curriculum. It was posited that one major barrier to curriculum change was limitations placed on calculator use during tests. Heid indicated that students perceived the most important aspect of mathematics was learning to execute computational procedures by hand because of limited use of calculators on some tests. Further, if calculators were a standard accoutrement during tests, students who understood the mathematical concepts and principles could enter test situations more confident of their ability to produce correct results.

As suggested by Collis and Romberg (1989), Madaus, West, Harmon, Lomax, and Viator (1992), and Romberg and Wilson (1992), one powerful barrier for the implementation of change in mathematics education involved mandated standardized tests. Stiggins and Conklin (1992) reported secondary school teachers were far less influenced by standardized tests than are elementary teachers. Studies such as these prompted Senk, Beckmann, and Thompson (1997) to conduct research related to assessment and grading in high school mathematics classrooms. The assessment and grading practices in 19 mathematics classes in five high schools in three states were studied. Test items were at a cognitively low level, were stated without reference to a realistic context, involved very little reasoning, and were rarely open-ended. Most test items were either neutral or inactive with respect to technology usage. The teachers' knowledge and beliefs influenced the characteristics of test items and other assessment instruments. Findings indicated that the teachers' perceptions of the impact of technology on assessment were much greater than indications from the reported use of technology.

In an 1988 study Romberg, Zarinnia, and Williams reported that 30% of the teachers surveyed indicated that because of the school district test, greater emphasis was placed on basic skills. Additionally, 25% reported greater emphasis on paper-and-pencil computation, and 16% reported that they gave less emphasis to activities involving calculators. Thus, substantial numbers of teachers were placing emphasis on paper-and-pencil computation and restrictions on the use of calculators because of a district testing program. The authors sensed that the use of calculators on the district test would allow teachers to emphasize other aspects of mathematics.

Chambers (1989) followed this point of view by proposing that if students used calculators on district tests that emphasized computational scores, performance would increase. According to Chambers, the purpose of allowing calculator use was not to find an easy way to increase pupils' performance on tests, but rather to redesign the commercially and locally developed standardized achievement tests to reflect the mathematical goals espoused by the NCTM Standards. This philosophy was concurred by a statement from the Association of State Supervisors of Mathematics which encouraged the use of calculators on state and local district mathematics tests.

Kenelly (1990) proposed that standardized tests achieved importance because they give independent benchmarks of educational achievement. As such, they supply the accountability through external comparisons that must be made in order to obtain the support of the educational community. The use of calculators on standardized tests, however, raises complex problems. Kenelly noted that for each examination, academic experts must certify that the material is appropriate for the subject. Equally important, professional psychometricians must certify that the examinations measured what they purported to measure. Furthermore, when calculators are used during an examination, test experts must be certain that the calculator's ability to perform mathematics does not interfere with the test's ability to measure the candidate's performance in mathematics. "Choosing whether or not to use a calculator when addressing a particular test question is an important skill. Thus, not all questions on calculator-based mathematics achievement tests should require the use of a calculator" (Kenelly 1989, p. 47).

Harvey (1991) envisioned mathematics instruction and assessment as different sides of a single coin. It was proposed that if students used calculators as tools while learning, solving problems, and applying mathematics, it should follow that those students utilized calculators when their learning was assessed. As the methods of teaching mathematics have changed to incorporate calculator usage, so must the types of questions used to measure the effects of that instruction. Some questions on tests would need to be modified or eliminated for assessment of students using calculators. Harvey stated that certain questions would no longer be appropriate because they would measure only students' abilities to manipulate the calculator and not the students' knowledge of mathematics. Two assessment environments were proposed: with and without calculator use permitted. Harvey concluded that when calculator use is not allowed, it should be made clear that (a) the content tested was not taught using calculators and (b) the paper-and-pencil skills and algorithms tested are ones that students should know and have been taught.

If this conclusion is valid, then as revisions are made on current tests and in the generation of new tests, efforts should be made to include calculator-active questions. The tests should not be comprised totally of this type of question any more than tests should be devoid of any calculator-active questions. The problems on tests that require calculator use are termed "calculator-active." Determining whether a test question is calculator-active is a matter of judgment and may be somewhat difficult. In an earlier study, Harvey (1989) defined a calculator-active test item as "one that (a) contains data that can usefully be explored and manipulated using a calculator and (b) has been designed so as most likely to require calculator use."

Romberg, Wilson, Khaketla, and Chavarria (1992) reported information gathered from two studies related to the Evaluation Standard 1 of the NCTM Standards. Romberg, Wilson, and Khaketla's 1989 study " An Examination of Six Standard Mathematics Tests for Grade 8" followed an earlier large-scale survey conducted by Romberg, Zarinnia, and Williams (1989). The survey was conducted to determine how mandated testing influenced the teaching of mathematics. Results indicated that nearly 70% of the teachers reported their students were assessed by a mandated test, either at the district level or state level, or both. Teachers also reported a decreased emphasis on calculator activities due to calculator restrictions on standardized tests (25%), while less than 10% of the teachers reported an increased use of calculators in their classrooms.

Six commercially developed tests were listed as the most widely used for grade eight, both at the district and state level: the California Achievement Test (CAT), the Metropolitan Achievement Test (MAT), the Stanford Achievement Test (SAT), the Science Research Associates Survey of Basic Skills (SRA), the Comprehensive Test of Basic Skills (CTBS), and the Iowa Test of Basic Skills (ITBS). As reported by Romberg, Wilson, and Khaketla (1989), these tests were found to be inappropriate assessment instruments for the content, process, and levels of thinking called for in the

Standards. Emphasis was placed on procedures rather than on development and application of mathematical concepts.

The aim of the follow-up study by Romberg, Wilson, and Chavarria (1990) was to demonstrate the existence of test items that were more closely aligned with the Standards than are the items found in the six tests of the first study. The conclusion of the investigation was that test items existed which were more closely aligned with the Standards than the six standardized tests examined. The feature shared by all of these tests and test items was that they were open response; thereby, assessing higher-order thinking with greater ease than typical multiple-choice questions.

Harvey (1992) proposed three approaches that permitted students to use calculators while taking tests. These approaches were as follows:

1. Calculator-passive testing would permit students to use calculators, but using tests that make no provision for calculator use.

2. Calculator-neutral testing would permit students to use calculators on tests developed so that none of the items required calculator use.

3. Calculator-based testing presupposes that students would need calculators while taking the test. The test is developed so that, for a majority of students, some portion of the items require calculator use in order to be solved successfully.

Several instances of calculator-passive testing have been reported. In six instances (Colefield, 1985; Connor, 1981; Elliott, 1980; Golden, 1982; Hopkins, 1978; Lewis & Hoover, 1981), standardized mathematics achievement tests were used. Three of these studies (Colefield, 1985; Hopkins, 1978; Lewis & Hoover, 1981) reported scores of students permitted to use calculators as significantly higher than were the scores of those students not permitted calculator use. A similar result was reported by

Murphy (1981), who used the Problem Solving Achievement Test. Gimmestad (1982) studied the effects of calculator use on the College Board's Advanced Placement Calculus Examination. The frequency of checking by retracing steps for the students who used calculators was twice that of students not using calculators. Gimmestad concluded "this may be an important difference between testing calculus with and without the calculator" (p. 3). With the exception of Gimmestad's study, there seems to have been an implicit assumption that the objectives tested by an item remained unchanged when calculator use was permitted. Lewis and Hoover (1981) concluded, based on this assumption, that the only change necessary to permit the use of calculators on a standardized test would be to renorm the test using data from calculator administrations of it. According to Harvey (1992), item objectives could change when calculators are used, especially on computational items. Harvey stated that "As a result, at least the 'strictly' computational items on standardized tests are no longer testing mathematics achievement but instead are testing students' calculator facility" (p. 149).

Calculator-neutral tests permit, but do not require, the use of calculators (Harvey, 1992). An examination of a calculator-neutral test was reported by Leitzel and Waits (1989). The test examined in the study was the Ohio Early Mathematics Placement Testing Program for High School Juniors (EMPT). Data indicated that higher scores resulted for students who used calculators than for students who did not. Leitzel and Waits neither reported, nor statistically compared, the means of the two groups of students.

A study by Long, Reys, and Osterlind (1989) investigated the differences between the scores of calculator use and no calculator use students in Grades 8 and 10 on the Missouri Mastery and Achievement Tests (MMAT). At the eighth grade level, results favored significantly the calculator group on the total test and on three of the four MMAT subtests. At the tenth grade level the calculator group scored significantly higher than the noncalculator group on the total test and two of its three subsections. Similar outcomes were reported in studies by Abo-Elkhair (1980), Casterlow (1980), and Mellon (1985).

Harvey (1992) cautioned that care must be exercised in the development of calculator-neutral test items. Lack of rigor in the development of these items could result in an inaccurate test of the objectives stated for the item, or in an item that is calculator-sensitive. In order for statistical comparisons to be made, Harvey further recommended separate norming of scores for the two groups.

In an earlier work, Harvey (1989) provided definitions for calculator-based mathematics tests and calculator-active test items:

> A calculator-based mathematics test is one that (a) tests mathematics achievement, (b) has some calculator-active test items on it and (c) has no items on it that could be, but are not, calculator-active except for items that are better solved using non-calculator based techniques.
> A calculator-active test item is an item that (a) contains data that can be usefully explored and manipulated using a calculator and (b) has been designed to require active calculator use. (p. 78)

These definitions were used to classify research reported in this section.

Teacher Attitudes Toward Calculator Usage

Brekke (1990) stated that surveys conducted in 1981 and 1982 indicated that calculators were not widely used in mathematics classrooms and that the use was primarily for tasks such as checking answers. Teachers appeared to have a rather negative attitude toward the use of calculators. The statistical analysis of the results of a teacher attitude survey in the study found no significant differences between black and white teachers or between male and female teachers in change in attitude as measured by any of the three scales utilized.

Graeber and Unks (1977), after conducting a survey of 1343 teachers in Delaware, New Jersey, and Pennsylvania, concluded that first grade teachers used calculators most frequently for drill. Above first grade, the most frequent use was for checking work. The survey also noted that 74.4% of the seventh grade teachers had not used calculators in their classes. Weiss (1978) reported that a national survey conducted in 1977 showed that in grades 7-9, 70% of the teachers did not use calculators in their classes and 42% felt that calculators were not needed. Cohen and Fliess (1979) conducted a survey of teachers in grades 9-12 in Allegheny County, Pennsylvania. Although high school teachers were more likely to use calculators than elementary or middle school teachers, the researchers found that 46.4% of the teachers reported never or seldom using calculators in their classes. Almost 21% were opposed to the use of calculators.

Reys, Bestgen, Rybolt, and Wyatt (1980) conducted a survey of teachers in Missouri in 1979. The researchers found that 58% of the teachers stated that students were not allowed to use calculators in their classes. In addition, 84% of the teachers stated that children should master basic facts before being allowed to use calculators and 43% felt that calculators would cause students' ability to compute to decline. Suydam (1980) reported that results from the Priorities in School Mathematics Project (PRISM) conducted in 1979 indicated that 67% of the educators surveyed believed that calculator use should be postponed until after paper-and-pencil algorithms are learned, and only 40% would allow slower students to use calculators.

Jaji (1986), summarizing results from the Second International Mathematics Study in 1981, reported that eighth graders used calculators mainly at home, for homework, checking answers, and recreation. In the United States, only 6% of eighth grade students reported using calculators in school during one or more periods per week. Most of the teachers (64%) did not encourage the use of calculators for problem solving. Crosswhite (1985), in another summary report of the study, stated that one-third of classes reported never using calculators and that eighth grade students used calculators most commonly for checking answers, for recreation, and for projects.

Schmitt (1996) reported findings of a survey of 27 Louisiana participants in the Middle School Teachers Enhancement Project (MSTEP). An assessment was made to determine the teachers' existing knowledge of the use of the Texas Instruments Math Explorer calculator. Following participation in MSTEP, the teachers were able to identify and use an average of 25 out of the 28 keys on this particular calculator model. Further, the teachers showed statistically significant changes in the positive direction on the instrument used to measure their attitude toward mathematics reform, including calculator usage.

Terranova (1990) investigated barriers to calculator use in elementary school classrooms. Teachers (N = 348) and principals (N = 30) in western New York State were surveyed about their feelings and beliefs concerning calculator use. Analysis of the responses found that teachers and principals believed that calculators should be used in elementary classrooms; however, teachers appeared to harbor fears about the effects of the use of calculators on students' learning. Principals appeared to be less concerned about negative effects. Teachers and principals reported that inservice programs would be most helpful in learning to integrate calculators in the K-6 elementary mathematics curriculum and that calculators needed to be readily available for instruction in the classroom.

Fleener reported the findings of two major studies in 1995 which examined the impact of philosophical orientation (1995a) and the relationship between experience and philosophical orientation (1995b) on calculator use. The first study examined the responses of 94 middle school and secondary mathematics teachers on the Attitude Instrument for Mathematics and Applied Technology (AIM-AT). Teachers participating in the study had similar beliefs about the motivational effects of calculators for mathematics instruction; however, beliefs about the cognitive benefits of calculator use were not as well defined. Interactions between mastery orientation and experience were suggested when analysis of responses on AIM-AT items revealed responses were divided by mastery groups and experience with calculators. Experience with calculators for instructional purposes and beliefs about whether students should have conceptual mastery before calculators are used were identified as important factors in decisions related to calculator use.

The second study conducted by Fleener (1995b) examined the relationship between experience and philosophical orientation by identifying preservice and practicing teachers' contextual frameworks related to calculator use as expressed through Habermasian interest categories. The 29-item Attitude Instrument for Mathematics and Applied Technology-Version II (AIM-AT-II) was adapted from the AIM-AT. Questions focused on beliefs about how calculators can be used and the consequences of calculator use. Results of this study suggested that philosophical orientation pertaining to calculator use was a function of both experience and attitudes related to the conceptual mastery issue.

Summary

Calculator usage during classroom instruction has evolved from the developmental stage to a position of prominence in mathematics education. Recommendations from leading mathematics education organizations for teachers to use calculators more extensively were supported by research concerning calculator usage. This research indicated that calculators do not have harmful effects on students' computational abilities and that calculator usage often resulted in increased learning of mathematics, particularly in problem solving skills.

Kaput and Thompson (1994) responded to the status of technology in mathematics education research as reported in the first 25 years of the Journal of Research in Mathematics Education. The authors expressed surprise at how little technology-related research had appeared in the journal. Overall, less than four dozen studies appeared, approximately two-thirds of the issues had no technology-related articles, and entire years passed without a single article related to the use of electronic technology. Kaput and Thompson proposed that the situation reflected, in part, the mathematics education research community's lack of technological engagement. An additional rationale posited was the development of a technology-oriented research and development community with its own venues for dissemination. Kaput and Thompson stated:

> The availability of such non-research-oriented venues suggests that (a) these technologies, although growing in importance and penetration of practice, are not part of the mainstream activity of mathematics education researchers and (b) they are regarded as the province of specialists in the development and use of these technologies. (p. 680)

Kaput and Thompson further proposed that with few exceptions, the mathematics education community, and especially researchers, had a passive attitude toward technology (p. 681). The latest technological innovation, often a tool created for another audience and set of purposes, was too commonly accepted without criticism. This led to sometimes awkward marriages between learning environments and technological innovations, or curriculum and instruction that were retrofitted to accommodate the innovation (p. 682).

Still, without the official sanction by standardized tests, calculators have been slow to achieve complete integration into classrooms. Suydam (1979) expressed the situation as a "stalemate" and noted the inappropriateness of calculator use on tests developed for noncalculator use, "since both tests and norms were developed without calculators being used. On the other hand, tests which allow the use of calculators will not be available until calculators are in much wider use." As noted in the review of literature, the stalemate appeared to have been broken. Many state assessments were reported which allowed for the use of calculators and nationally normed standardized tests have been developed which allow for calculator usage.

The key to complete integration of calculators into the mathematics curriculum appeared to be mathematics teachers and administrators who bear accountability for the success of their programs. Teacher attitude toward calculator use was shown significantly to influence the degree to which calculators were used. Teacher training was shown to assist in the movement of teachers from an attitude of distrust and dissatisfaction with using calculators to one which viewed the calculator as an instructional tool with great potential. Through identification of existing attitudes, the mathematics community more effectively addressed the needs of teachers as they moved toward full implementation of calculators for both instructional and assessment purposes.

CHAPTER III

METHODOLOGY

In this chapter, the research design and procedures followed in conducting the research are outlined. The sample selection process is described, the instruments used in the collection of data are listed, and the methods used in validating the instruments and determining their reliability are given. The statistical methods for analyzing the data are discussed and the probability level for decisions to reject or fail to reject the null hypotheses listed.

Research Design

A quasi-experimental design was utilized for the student mathematics achievement section of this study. Intact classes were assigned randomly to treatment or control groups. More specifically, a non-equivalent posttest-only group design was utilized (Huck, Cormier, & Bounds, 1974). The independent variable was calculator usage and the dependent variable was mathematics achievement. Group, gender, race, grade, and level served as factors for the dependent variable. Student Calculator Survey responses were examined through descriptive statistics. Analyses of mean differences on Student Calculator Survey items were conducted for the variable of group. Teacher attitude responses on the Attitude Instrument for Mathematics and Applied Technology-Version II (AIM-AT-II) were examined through descriptive statistics and for differences along the variables of philosophical orientation (mastery) and training

(LaSIP). Data analyses were used to test the four null hypotheses and to address the six research questions.

Sample Selection

The original sample included all seventh and eighth grade mathematics teachers and students in two north central Louisiana school systems. The school systems were selected in order to provide a research basis for decisions involving calculator usage for both instructional and assessment purposes at the local school system level. The original sample consisted of all ten middle and junior high schools located within the participating school systems. Due to scheduling difficulties and time limitations for student mathematics achievement testing, one school did not participate. It was determined that a sufficient sample of both teachers and students could be obtained from the nine remaining schools. Teacher participation from the individual schools was voluntary. Of the 34 seventh and eighth grade mathematics teachers, 33 chose to participate which represented a teacher consent rate of 97%. In order for the teachers to utilize the student achievement testing as a review for semester examinations and preparation for spring standardized tests, all students present on the date of tests for this study were requested to participate. The Mathematics Concepts and Applications sections of the California Achievement Test (CAT) were administered to 2668 students. Student credit was assigned by their teachers on the basis of participation rather than on actual CAT performance. The CAT scores of the 1070 students who returned participant consent forms were used for this study, representing a 40% consent rate for student participation. Students who returned consent forms but did not complete the CAT test were not used in the study.

Random assignment of intact classes to treatment (calculator) or control (no calculator) groups was made by the researcher and school principal on the day of the tests by the toss of a coin. In the event that a teacher had only one mathematics class from the selected grade levels, the class was assigned randomly to either the treatment or the control group. Teachers were required to allow calculator usage in the tests for the treatment group, regardless of the current status of calculator usage during instructional or assessment practices.

The racial composition of one school system was reported as 24% black, 75% white, and 1% other. The second school system was racially composed of 88% black, 11% white, and 1% other. Of the 1070 students who returned consent forms for participation in the study, 525 students were black, 534 white, and 11 other (Asian or Hispanic). The control group consisted of 491 students while the treatment group had 579 students. The student sample by grade consisted of 446 seventh grade students and 624 eighth grade students. The teacher sample consisted of 33 teachers of seventh and eighth grade mathematics. Racial composition of the teacher sample was 12% black ($n = 4$) and 88% white ($n = 29$). Males ($n = 5$) represented 15% of the teacher sample whereas females ($n = 28$) accounted for the remaining 85%.

Instrumentation

The instruments used in this study were the California Achievement Tests (CAT) Mathematics Concepts and Applications sections to measure student mathematics achievement, the Student Calculator Survey to measure student attitudes toward calculator usage, and the Attitude Instrument for Mathematics and Applied Technology-Version II (AIM-AT-II) to measure teacher attitudes toward calculator usage. Selection of the CAT as the instrument to measure student mathematics achievement was made on the basis of test reliability and previous usage by the school systems in the study as the standardized norm-referenced measure of student achievement. Further, the discontinued use of the CAT by the school systems in the study eliminated some of the problems associated with test security. Permission to use the CAT for this study was granted by CTB/McGraw-Hill. The Student Calculator Survey was developed by Bitter (1993) specifically to measure the attitudes of seventh and eighth grade students toward calculator usage. Permission to use the Student Calculator Survey for this study was granted by the instrument's author. The Student Calculator Survey is presented in Appendix A. Selection of the AIM-AT-II was made on the basis of research conducted by Fleener (1995) that specifically addressed the attitudes of teachers toward calculator usage. Permission to use of the AIM-AT-II for this study was granted by the instrument's author. The AIM-AT-II is presented in Appendix B.

Mathematics Achievement Instruments

The instruments used to measure student mathematics achievement were the California Achievement Tests, Fifth Edition, Form A, Level 17 and 18, Mathematics Concepts and Applications sections. Level 17 was designed for use in tests of seventh grade students while Level 18 was designed for use in tests of eighth grade students. The 50 item test was allotted 44 minutes for administration as specified in the Examiner's Manual. As reported in the Technical Bulletin 1 CAT 5 (CTB Macmillan/McGraw-Hill, 1992, p. 50), the reliability of the Level 17 test is .77; the Level 18 reliability was reported as .75. A reliability test of the instrument for this study was not conducted due to previously published results.

Student Attitude Instrument

The Student Calculator Survey was developed by Bitter (1993) in conjunction with a study designed to examine student attitudes toward calculator usage. The study explored the effects of a long-term professional development plan to integrate calculators into the teaching and learning of mathematics at the seventh and eighth grade levels. Agreement with statements concerning calculator use was measured by the 21-item Likert response instrument. Choices among the four response options were Strongly Agree, Agree, Disagree, or Strongly Disagree. Cronbach's alpha used to determine instrument reliability for this study was reported as .71. The Student Calculator Survey is presented in Appendix A.

Teacher Attitude Instrument

The 29-item Attitude Instrument for Mathematics and Applied Technology-Version II (AIM-AT-II) was adapted from the original version developed by Fleener (1994). Forced response Likert scale items were designed to encourage participant reflection and commitment. Choices among the four response options were Strongly Agree, Agree, Disagree, or Strongly Disagree. Responses were categorized through contextual frameworks which revealed philosophical orientation. For this study, Cronbach's alpha was reported as .68 which exceeded the .65 reliability level reported in the original AIM-AT-II study by Fleener. The AIM-AT-II survey is presented in Appendix B.

Procedures

Data for this study were collected during the first semester of the 1997-98 school year. The time frame was designed in order to provide the participating school systems with information regarding calculator usage prior to the spring administration of standardized tests. A schedule of test dates for the schools was established during meetings with school principals and guidance counselors in November and December. Prior to the administration of tests at a particular site, the researcher met with the mathematics teachers to discuss test administration and survey procedures. A copy of the research proposal summary was provided to each teacher and principal. Testing was scheduled during December and January in order for the teachers to incorporate the procedure as a problem solving review for semester examinations and as a preparation for spring standardized tests. Participation in the study was voluntary; 33 of 34 teachers chose to participate from nine school. This represented a 97% teacher participation rate for the study. Assignment of intact classes to treatment or control groups was made the day of the mathematics achievement tests through the toss of a coin by the school principal or designee.

The following sections detail the administration of the mathematics achievement tests, the Student Calculator Survey, and the AIM-AT-II teacher survey. The procedures that were followed for the administration of each instrument are described along with the measures taken to ensure data security.

Administration of Mathematics Achievement Tests (CAT)

In conjunction with the school system testing coordinators, the researcher reviewed with the teachers the standardized procedures for administration of the Mathematics Concepts and Applications sections of the CAT. Particular attention was given to directions in the examiner's manual, and a standardized statement was provided by the researcher for use with the treatment groups. The statement read: "Please turn on your calculator. If your calculator is not working, raise your hand and you will be given another calculator. If your calculator should stop working during the test, raise your hand and you will be given another calculator. The test monitor cannot answer questions about how to use the calculator." Teachers were advised by the researcher to have students print the following information on the answer sheets: name, school, teacher name, and class code. The information regarding race, gender, and teacher LaSIP training was coded by the students prior to the achievement test. The researcher emphasized that the 44 minute time allotment for the test was essential in order for the test results to be considered valid.

Students in the treatment group were allowed to use calculators brought to the test sites. According to teacher preference, treatment group students were allowed to use personal calculators, classroom calculators, or calculators provided by the researcher. The calculator provided by the researcher was the Texas Instrument TI-108. Additional calculators of this model were available should a student experience calculator failure during the test. There were no reported incidents of calculator failure for the study.

Classes were monitored randomly by the researcher to ensure that standardized testing procedures were followed and to answer procedural questions. Some incidents of test interruption were reported. In the event that the test interruption prevented the completion of the test, the answer sheet for that student was considered void and the data discarded from the study. Upon completion of the student tests, the researcher collected all test instruments and answer forms. Answer forms were clearly labeled "treatment" or "control" group and were filed by teacher and class period. Completed materials were secured until submission for scoring and data analysis in order to reduce the possibility of data corruption.

Administration of Student Calculator Surveys

Student Calculator Surveys were distributed to teachers at the time of the mathematics achievement tests. Distribution of the surveys to students who returned consent forms was accomplished by classroom teachers during the week which followed the CAT tests. Explanation of the four-point Likert scale was presented by the classroom teachers. Students were allowed class time to complete the survey; most students completed the survey within ten minutes. Students surveys were collected by teachers and placed in a folder marked "confidential." The researcher collected completed surveys from the teachers during the month which followed the CAT. Completed surveys without the required participant consent form or from students who did not complete the CAT were considered invalid data and were not used in the study. Upon return to the researcher, all surveys were secured until submission for data coding and analysis in order to reduce the possibility of data corruption.

Administration of AIM-AT-II Surveys

Teacher attitude surveys (AIM-AT-II) were distributed to teachers during the time of the student CAT tests. Demographic information, calculator usage and availability data, and comments were collected through completion of a cover form to the AIM-AT-II. Teachers were allowed one month following the CAT administration in which to complete the survey, although most teachers completed the survey the day of student tests. The researcher was available to answer questions regarding statements on the AIM-AT-II. Completed teacher surveys were returned directly to the researcher and placed in a folder marked "confidential." Upon return to the researcher, all surveys were secured until submission for data coding and analysis in order to reduce the possibility of data corruption.

Internal Validity

In order to minimize threats to internal validity, this study was conducted within the first semester of the current school year. The posttest-only control group design, through random assignment of subjects to groups, controlled for threats of selection, history, maturation, and statistical regression. Threats of testing and instrumentation were controlled in that none of the subjects was measured twice. Random assignment of intact classes to treatment or control groups controlled for the threat of subject selection. Threats of maturation and history were further controlled through collection of all data within a six-week time frame.

Data Analysis

Scoring of the student achievement tests (CAT) was conducted by the data processing department of one of the participating school systems. Prior to submission of the answer sheets for scoring, the forms were checked to make sure that the proper answer section and information required by the scoring program was correctly marked. Scoring was conducted using the Test Mate program for the California Achievement Tests, Form A. Data used in this study were the raw scores for number correct and number attempted. Student answer sheets which had the improper answer section completed were scored manually. The student scores for an individual teacher were provided to that teacher for informational purposes. Only the scores of the 1070 students who returned participant consent forms were used in this study.

The survey responses for both the Student Calculator Survey and the AIM-AT-II were hand coded by the researcher prior to entering the data on the mainframe computer. In order to ensure the accuracy of response coding, random checks of both the student data and the teacher data were made by an outside observer. Upon completion of the data entry into the mainframe computer, random checks were made to ensure the accuracy of data entry.

Prior to analysis, data for the mathematics achievement section were checked to ensure that none was out of the expected range. The mathematics achievement data were analyzed using t-tests to determine initial differences between the means of the control group and the treatment group, as intact classes were assigned randomly to control or treatment groups. Additional analyses were conducted through a series of one-way ANOVAs to determine significant differences for the variables of gender, race, grade, and level. Follow-up tests of mean differences were conducted through Scheffe's procedure of the SPSS-X program. The level of $p < .05$ was used as the level of significance for all data analyses.

Prior to analysis, data from the Student Calculator Survey and the AIM-AT-II (teacher survey) were checked to ensure that none was out of the expected range. Categorical data from the student and teacher survey responses were analyzed for frequencies and percentages through the descriptives routine of the SPSS-X program . Mean scores and standard deviations were reported for both the Student Calculator Survey and the AIM-AT-II (teacher survey). Significant differences of student responses for the variable of group were analyzed through t-tests. AIM-AT-II responses were analyzed through t-tests for the variables of philosophical orientation (mastery) and training (LaSIP). The level of $p < .05$ was used as the level of significance for all data analyses.

CHAPTER IV

DATA ANALYSIS

This study was designed to determine the effects of calculator usage on the mathematics achievement of seventh and eighth grade students. The mean scores of the treatment group and the control group were examined for significant differences with respect to the number of correct responses (number correct) and the number of problems attempted (number attempted) on the Mathematics Concepts and Applications sections of the California Achievement Test (CAT). Data analysis of mean score differences between the treatment group and the control group were conducted utilizing t-tests. Significant differences for the variables of gender, race, grade, and level were examined with respect to the number of correct responses and the number of problems attempted. Cell means were calculated for the variable of group with the other dependent variables for the number correct and number attempted. Data analyses for the mathematics achievement section of this study were used to reject or fail to reject the four null hypotheses at the $p < .05$ level of significance.

The study also investigated the relationship of student and teacher attitudes and perceptions with respect to calculator usage. Data from student survey responses were analyzed through descriptives and t-tests and were used to address research questions one, two, and three. Teacher survey responses were analyzed through descriptives and t-tests for the variables of philosophical orientation (mastery) and training (LaSIP). These data were used to address research questions four, five, and six.

In this chapter, the results of reliability tests of the Student Calculator Survey and the Attitude Instrument for Mathematics and Applied Technology-Version II (AIM-AT-II) are discussed. The statistical procedures for this study are described along with the results and findings from the data analysis.

Reliability Testing of Survey Instruments

Items for the Student Calculator Survey and the Attitude Instrument for Mathematics and Applied Technology-Version II (AIM-AT-II) were worded in both positive and negative directions to avoid response set. Results for individual items for the Student Calculator Survey ranged from a mean response of 1.70 with a standard deviation of .80 to a mean response of 3.37 with a standard deviation of .65. Cronbach's alpha, computed for reliability testing, was .71 which indicated that the instrument was reliable. Results for items on the AIM-AT-II ranged from a mean response of 1.91 to a mean response of 3.33 with item standard deviations ranging from .58 to .65, respectively. Cronbach's alpha for the AIM-AT-II was reported as .68, indicating a reliability coefficient which exceeded the .65 found in the original study for this instrument.

Statistical Procedures

Data for each hypothesis and research question were analyzed for descriptive statistics through the descriptives routine of the SPSS-X program. Data from both student and teacher responses were checked to ensure that none of the data was out of the expected range, that survey data had been properly coded, and that no incorrect data entry had occurred. The mathematics achievement data were analyzed using t-tests to determine initial differences between the control group and the treatment group, as intact classes were assigned randomly to control or treatment groups. Additional analyses were conducted through a series of one-way ANOVAs to determine significant mean differences for the variables of gender, race, grade, and level. Follow-up tests of mean differences were conducted through Scheffe's procedure of the SPSS-X program.

Prior to data analysis, data from the Student Calculator Survey and the AIM-AT-II were checked to ensure that none was out of the expected range. Categorical data from the student and teacher responses were analyzed for frequencies and percentages through the descriptives routine of the SPSS-X program. Mean scores and standard deviations were reported for the Student Calculator Survey and the AIM-AT-II. Significant differences for student responses for the variable of group were analyzed using t-tests. AIM-AT-II responses were analyzed through t-tests for the variables of philosophical orientation (mastery) and training (LaSIP). The level of $p < .05$ was used as the level of significance for all data analyses. Results of the data analysis discussed in Chapter III as related to each of the hypotheses and research questions in the study are presented.

Mathematics Achievement Data Analyses

The instruments used to gather data for this portion of the study were the Mathematics Concepts and Applications sections of the California Achievement Test (CAT), Level 17 and 18. The Level 17 test was designed for measurement of the mathematics achievement of seventh grade students; the Level 18 test was designed for use in the measurement of mathematics achievement of eighth grade students. The Level 17 (seventh grade) and Level 18 (eighth grade) tests consist of 50 items each. Mean scores for the number of correct responses and number of problems attempted are presented in Table 1. Data presented in Table 1 were used in decisions to reject or fail to reject the four null hypotheses and in the conclusions and discussions related to mathematics achievement.

Table 1

Mean Scores for Mathematics Achievement Test (CAT)

	NC	NA	N
Total Population	24.99	44.99	1070
Group			
Control	24.34	44.29	491
Treatment	25.54	45.58	579
Gender			
Male	26.52	45.82	426
Female	23.98	44.44	644
Race			
Black	20.59	42.90	525
White	29.30	47.09	534
Other	25.73	43.18	11
Grade			
Seventh	24.02	44.78	446
Eighth	25.69	45.14	624

Table 1 Continued

	NC	NA	N
Level			
Low	17.95	43.48	243
Regular	24.13	44.87	464
High/Honor	30.81	46.16	363

Note. NC = mean number correct, NA = mean number attempted. Maximum number possible = 50.

Hypothesis One

There is no statistically significant difference between the mean number of correct responses of the treatment group and the control group as measured by the Mathematics Concepts and Application sections of the California Achievement Test (CAT).

Table 2 reflects the results of the t-test for the mean number of correct responses for the Mathematics Concepts and Applications sections of the CAT. A statistically significant difference ($p < .05$) between the mean score of the control group and the treatment group resulted which favored the treatment group. The mean score of the control group was 24.34 correct compared with a mean score of 25.54 correct for the treatment group.

Table 2

t-Test for Mean Number Correct

Group	M	SD	N	t
C	24.34	9.34	491	
T	25.54	9.32	579	
				2.11*

*$p < .05$.

Hypothesis Two

There is no statistically significant difference between the mean number of correct responses for the variables of gender, race, grade, and level as measured by the Mathematics Concepts and Applications sections of the CAT.

Significant differences with regard to the variables of gender, race, grade, and level were indicated by one-way ANOVAs for number correct. The selection of one-way ANOVAs as the analysis procedure allowed for comparisons of F-ratios among all variables. Table 3 summarizes the results of the one-way ANOVAs for number correct for the variables of gender, race, grade, and level.

Table 3

One-way ANOVA for Number Correct by Gender

Source	df	SS	MS	F
Between Groups	1	1662.99	1662.99	19.39***
Within Groups	1068	91602.92	85.77	
Total	1069	93265.91		

One-way ANOVA for Number Correct by Race

Source	df	SS	MS	F
Between Groups	2	20059.48	10029.74	146.19***
Within Groups	1067	73206.42	68.61	
Total	1069	93265.91		

One-way ANOVA for Number Correct by Grade

Source	df	SS	MS	F
Between Groups	1	726.95	726.95	8.39**
Within Groups	1068	92538.95	86.65	
Total	1069	93265.91		

Table 3 Continued

One-way ANOVA for Number Correct by Level

Source	df	SS	MS	F
Between Groups	2	24696.22	12348.11	
Within Groups	1067	68569.69	64.26	
Total	1069	93265.91		
				192.15***

***$p < .001$, **$p < .01$, *$p < .05$.

The mean score of male students (26.52) was significantly higher ($p < .001$) than that of female students (23.98). The results of the one-way ANOVA for number correct by race showed significant differences at the $p < .001$ level. Scheffe's procedure indicated significant differences between the mean score of black students (20.59), Asian and Hispanic students (25.73), and white students (29.30) at the $p < .05$ level. The mean score by grade showed significant differences ($p < .01$) between the grades with eighth grade students (25.68) scoring higher than seventh grade students (24.00). The one-way ANOVA for number correct by level was significant at the $p < .001$ level. Mean scores reported by level also showed significant differences ($p < .05$) between low level (17.95), regular level (24.13) and high/honor level students (30.81). Scheffe's procedure indicated a further significant difference between regular level and high/honor level students in favor of the high/honor level students. Table 4 contains the cell means for number correct for the variables of gender, race, grade, and level.

Table 4

Cell Means for Number Correct

Variable	M
Gender	
Male	26.52
Female	23.98
Race	
Black	20.59
White	29.30
Other	25.73
Grade	
Seventh	24.02
Eighth	25.69
Level	
Low	17.95
Regular	24.13
High/Honor	30.81

Note. Maximum number possible = 50.

Comparisons of mean scores for number correct for the variables of gender, race, grade, and level by group were made through examination of cell means. Cell means were examined by treatment and control group for the variables of gender, race, grade, and level in order to determine which groups of students benefited from calculator usage in assessment situations. Implications from these results are discussed in Chapter V. Table 5 contains the cell means for the variables of group by gender, race, grade, and level.

Table 5

Cell Means by Group for Number Correct

Group by Gender	Male	Female	
Treatment	26.71	24.85	
Control	26.33	22.85	
Group by Race	Black	White	Other
Treatment	21.25	29.55	23.88
Control	19.88	28.98	30.67
Group by Grade	Seventh	Eighth	
Treatment	25.27	25.73	
Control	22.59	25.63	
Group by Level	Low	Regular	High/Honor
Treatment	18.93	24.05	31.78
Control	17.09	24.25	29.78

Note. Maximum number possible = 50.

Hypothesis Three

There is no statistically significant difference between the mean number of problems attempted by the treatment group and the control group as measured by the Mathematics Concepts and Applications sections of the CAT.

Analysis of these data was accomplished through t-tests for independent samples. Students in the treatment group attempted a mean of 45.58 problems compared with a mean score of 44.29 problems attempted for the control group. A statistically significant t-ratio with respect to comparisons between treatment and control group subjects resulted that favored the treatment group. The results of the t-test of this hypothesis are displayed in Table 6.

Table 6

t-Test for Mean Number Attempted

Group	M	SD	N	t
C	44.29	8.56	491	
T	45.58	6.75	579	
				2.71**

$^{**}p < .01$.

Hypothesis Four

There is no statistically significant difference between the mean number of problems attempted for the variables of gender, race, grade, and level as measured by the Mathematics Concepts and Applications sections of the CAT.

Significant differences with regard to the variables of gender, race, grade, and level were indicated by one-way ANOVAs for number attempted. The selection of one-way ANOVAs as the analysis procedure allowed for comparison of F-ratios among all variables. Table 7 contains the results of the one-way ANOVAs for number attempted for the variables of gender, race, grade, and level.

Table 7

One-way ANOVA for Number Attempted by Gender

Source	df	SS	MS	F
Between Groups	1	487.05	487.05	
Within Groups	1068	62211.84	58.25	
Total	1069	62698.89		
				8.36**

Table 7 Continued

One-way ANOVA for Number Attempted by Race

Source	df	SS	MS	F
Between Groups	2	4685.98	2342.99	
Within Groups	1067	58012.91	54.37	
Total	1069	62698.89		
				43.09***

One-way ANOVA for Number Attempted by Grade

Source	df	SS	MS	F
Between Groups	1	32.84	32.84	
Within Groups	1068	62666.05	58.68	
Total	1069	62698.89		
				.56

One-way ANOVA for Number Attempted by Level

Source	df	SS	MS	F
Between Groups	2	1059.81	529.91	
Within Groups	1067	61639.07	57.77	
Total	1069	62698.89		
				9.17***

***$p < .001$, **$p < .01$, *$p < .05$.

Significant differences were found with regard to the variables of gender, race, and level. Male students attempted a mean of 45.82 problems, whereas female students attempted a mean of 44.44 problems. No two groups of race showed significant differences at the $p < .05$ level as determined by Scheffe's procedure. Black students attempted a mean of 42.90 problems, white students 47.09 problems, and Asian/Hispanic students 43.18 problems. Scheffe's procedure produced significant results ($p < .05$) for mean number of problems attempted between students classified as low level (43.48) and high/honor level students (46.16), but not between low level and regular level students (44.87), nor between regular level and high/honor level students. A one-way analysis of variance indicated no significant difference with regard to grade. A mean of 44.78 problems attempted was reported for seventh grade students, compared with a mean of 45.14 problems attempted by eighth grade students. Table 8 contains the cell means for the number attempted.

Table 8

Cell Means for Number Attempted

Variable	M
Gender	
Male	45.82
Female	44.44
Race	
Black	42.90
White	47.09
Other	43.18

Table 8 Continued

Variable	M
Grade	
Seventh	44.78
Eighth	45.14
Level	
Low	43.48
Regular	44.87
High/Honor	46.16

Note. Maximum possible = 50.

Comparisons of mean scores for the number attempted for the variables of gender, race, grade, and level by group were made through examination of cell means. Cell means were examined by treatment and control groups for the variables of gender, race, grade, and level in order to determine which groups of students benefited from calculator usage with regard to number of problems attempted. Implications from these results are discussed in Chapter V. Cell means for the variables of group by gender, race, grade, and level are presented in Table 9.

Table 9

Cell Means by Group for Number Attempted

Group by Gender	Male	Female	
Treatment	46.13	45.26	
Control	45.50	43.38	
Group by Race	**Black**	**White**	**Other**
Treatment	43.74	47.40	41.38
Control	41.98	46.69	48.00
Group by Grade	**Seventh**	**Eighth**	
Treatment	46.04	45.27	
Control	43.36	44.98	
Group by Level	**Low**	**Regular**	**High/Honor**
Treatment	44.66	45.09	47.03
Control	42.30	44.74	45.22

Note. Maximum number possible = 50.

Student Calculator Survey Analysis

Data from the Student Calculator Survey were used to address students' perceptions of calculator availability and usage. These data were utilized in addressing research questions one, two, and three. Demographic data were used to examine calculator availability. Mean score responses on the Student Calculator Survey were examined for perceptions toward calculator usage and for differences in attitude between the treatment and control groups.

Research Question One

What perceptions do students have regarding calculator availability as measured by self-report responses on the Student Calculator Survey?

Student perceptions regarding calculator availability were measured through self-report survey responses. A four-point Likert scale was used to determine the availability of calculators during class time with 4 = All the time; 3 = Most of the time; 2 = Some of the time; and 1 = Rarely or never. The mean score for this item was 1.84 with a standard deviation of .80 which indicated that the students perceived calculators as available "Some of the time" during class time. The percentage of responses by category is summarized in Table 10.

Table 10

Calculator Availability During Class Time

Category	N	Percent
All the time	58	5.4
Most of the time	96	9.0
Some of the time	530	49.5
Rarely or never	396	36.1
Total	1070	100.0

Further analysis of calculator availability was conducted through crosstabs programs of SPSS-X for the variables of gender and students of LaSIP trained teachers. Table 11 contains the results of these analyses.

Table 11

Calculator Availability During Class Time by Gender and LaSIP Training

Category	M	F	Non-LaSIP	LaSIP
All of the time	7.0%	4.3%	5.6%	5.2%
Most of the time	8.2%	9.5%	5.9%	12.8%
Some of the time	48.4%	50.3%	36.9%	65.2%
Rarely or never	36.4%	35.9%	51.6%	16.8%

Analysis of calculator availability was examined through responses to the statement: "If calculators are used, I ____ Use my own calculator or _____ Use a classroom calculator." "No" or blank responses were coded as 1 and "yes" or marked responses were coded as 2. Table 12 displays the summary of frequencies and percentages for responses to this statement.

Table 12

Availability of Calculators

Category	Response	N	Percent
Use Own	No	773	72.2
	Yes	297	27.8
Total		1070	100.0
Use Classroom	No	287	26.8
	Yes	783	73.2
Total		1070	100.0

The data regarding this statement indicated that students preferred to use a classroom calculator, if calculators are used. Implications for the limitations of calculator usage and availability are discussed in Chapter V.

Research Question Two

What attitudes do students have regarding calculator usage as measured by mean responses to the Student Calculator Survey?

The Student Calculator Survey contains 21 statements regarding mathematics and calculators. Items for this instrument were worded in both positive and negative directions to avoid response set. A four-point Likert scale was used to measure responses with 4 = Strongly Agree; 3 = Agree; 2 = Disagree; and 1 = Strongly Disagree. The Student Calculator Survey is found in Appendix A. Table 13 contains the mean scores and standard deviations for the responses for the student sample (N = 1070).

Table 13

Student Calculator Survey Responses

Statement	M	SD
1. Students should not be allowed to use a calculator while taking math tests.	1.97	1.02
2. The calculator will hinder students' understanding of the basic computation skills.	2.39	.95
3. Calculators make mathematics fun.	3.21	.81
4. Since I have a calculator, I do not need to learn to do computations on paper.	1.70	.80

Table 13 Continued

Item	M	SD
5. Mathematics is easier if a calculator is used to solve problems.	3.26	.79
6. I understand mathematics better if I solve problems with paper and pencil.	2.66	.91
7. I know how to use a calculator very well.	3.37	.70
8. It is important that everyone learn how to use a calculator.	3.31	.65
9. I would do better in math if I could use a calculator.	3.08	.89
10. I prefer working word problems with a calculator.	3.02	.89
11. I would try harder in math if I had a calculator to use.	2.70	.97
12. Using a calculator to solve money problems is confusing.	1.81	.78
13. Calculators should be used only to check my answers once I have worked the problems with paper and pencil.	2.48	1.03
14. Calculators are not useful for solving fraction problems.	2.32	.97

Table 13 Continued

Item	M	SD
15. I feel calculators should not be used on math homework.		
	1.90	.91
16. I am good in mathematics.		
	3.00	.83
17. Using a calculator in math will cause me to forget how to do basic computation skills.		
	2.11	.90
18. I would appreciate math better if I had a calculator to use.		
	2.92	.87
19. I would do better in problem solving if I had a calculator to use.		
	3.06	.83
20. If I use a calculator, my estimation skills will decrease.		
	2.10	.83
21. Mathematics is boring.		
	1.96	.99

Note. 4 = Strongly Agree, 3= Agree, 2 = Disagree, and 1 = Strongly Disagree.

Research Question Three

Are there statistically significant differences between the attitude toward calculator usage responses of the treatment group and the control group as measured by the Student Calculator Survey?

Data from the Student Calculator Survey were analyzed using t-tests for the categories of treatment group and control group. Item one (Students should not be allowed to use a calculator while taking math tests) was the only item with a significant difference at the $p < .05$ level. The mean of the treatment group for this statement was 1.90 with a standard deviation of .99; the mean for the control group for this statement was 2.05 with a standard deviation of 1.05. Although there was a significant difference between the treatment group and the control group means, student responses seemed to suggest that students felt calculator use should be allowed in test situations. Analysis through t-tests revealed no significant differences between the responses of the treatment group and the control group with regard to items 2-21.

Teacher Data Analysis

Data in this section were utilized to address research questions four, five, and six. Demographic information regarding the teacher sample is presented as well as responses to the AIM-AT-II Survey. Demographic data were used to describe the perceptions of calculator usage, teacher training (LaSIP), and the sources by which classroom calculators were obtained. The demographic data were also used in the conclusions and recommendations presented in Chapter V. Data from the AIM-AT-II were examined for mean and standard deviation for individual question responses and for significant differences with regard to philosophical orientation and teacher training.

Teacher Demographics

The teacher sample for this study consisted of 33 teachers from the nine participating schools. The mean number of years teaching experience was 16.33 with a standard deviation of 10.63. Years teaching experience ranged from 0 (first year) to 37 years experience. The mean number of years teaching experience for seventh or eighth grade mathematics was 10.36 with a standard deviation of 8.72. The number of years mathematics teaching experience ranged from 0 (first year) to 34 years of mathematics teaching experience for seventh and eighth grade levels. Males (n = 5) accounted for 15.2% of the sample with females (n = 28) representing 84.8% of the sample. The racial composition of the sample was 12.1% black (n = 4) and 87.9% white (n = 29). No other racial categories were reported. Certification areas were reported for elementary (78.8%), middle school (30.3%), and secondary mathematics (27.3%). Additional training in LaSIP mathematics was reported by 30.3% (n = 10). Teacher demographics are summarized in Table 14.

Table 14

Teacher Demographics

Teaching Experience	Range	M	SD
Years Teaching Experience	0-37	16.33	10.63
Years Teaching Experience 7/8 Math	0-34	10.36	8.72

Gender	N	Percent
Male	5	15.2
Female	28	84.8

Race	N	Percent
Black	4	12.1
White	29	87.9

Table 14 Continued

Certification Areas	N	Percent
Elementary	26	78.8
Middle School	10	30.3
Secondary Mathematics	9	27.3

Additional Training	N	Percent
LaSIP Mathematics	10	30.3

Note. Multiple certification areas possible.

Teacher Self-Report Data

Data from the survey self-report responses are presented in this section. Self-report responses were used to describe the perceptions of calculator availability and usage in addition to the sources by which classroom calculators were obtained. These data were used to address research question four.

Research Question Four

What perceptions do teachers have regarding calculator availability as measured by survey self-report responses?

Information regarding the availability of classroom calculators and the sources for obtaining calculators was collected through survey self-report responses. Responses were coded to indicate "yes" if the response area was marked in any manner. Blank responses were coded to equal "no." The amount of time calculators are used during class was classified according to a 4-point scale: 4 = All of the time; 3 = Most of the time; 2 = Some of the time; and 1 = Rarely/never. Data regarding classroom calculators are presented in Table 15.

Table 15

Classroom Calculators

Category			N	Percent
Have Classroom Calculators				
		No	5	15.2
		Yes	28	84.8
Obtained through:				
	LaSIP	No	25	75.8
		Yes	8	24.2
	School District	No	19	57.6
		Yes	14	42.4
	Grant	No	29	87.9
		Yes	4	12.1
	Other	No	23	69.7
		Yes	10	30.3

Table 15 Continued

Calculator Use During Class	N	Percent
4 = All of the time	0	0.0
3 = Most of the time	2	6.1
2 = Some of the time	27	81.8
1 = Rarely/never	4	12.1

Note. Multiple categories possible for "Obtained through."

Teacher AIM-AT-II Survey

Items for the AIM-AT-II were worded in both positive and negative directions to avoid response set. The results for individual items ranged from a mean response of 1.67 with a standard deviation of .65 to a mean response of 3.30 with a standard deviation of .47. No items acted as an outlier, thus the initial 29 items of the survey instrument were retained. Internal reliability for the AIM-AT-II using Cronbach's alpha was .68 indicating a reliability comparable to the .65 found in the original study. The AIM-AT-II survey is presented in Appendix B.

Data from the AIM-AT-II were used to address teachers' perceptions of calculator usage. Results of item responses for individual items for the teacher sample are reported by means and standard deviations in Table 16. These data are used to address research question five.

Research Question Five

What attitudes do teachers have regarding calculator usage as measured by mean responses to the Attitude Instrument for Mathematics and Applied Technology-Version II (AIM-AT-II)?

Table 16

AIM-AT-II Survey Responses

Statement	M	SD
1. Students should not be allowed to use calculators on standardized tests.	3.06	.43
2. Calculator use will cause a decline in basic arithmetic facts.	2.18	.68
3. Calculators make mathematics fun.	3.09	.52
4. When solving problems with calculators, students don't need to show their work.	2.09	.58
5. More difficult mathematics problems can be done when students have access to calculators.	3.09	.68
6. Students understand math better if they solve problems using paper and pencil.	2.30	.59
7. Students should not be allowed to use calculators until they have mastered the concept.	2.97	.73
8. If students don't know their basic arithmetic facts by the 5th grade, they should be allowed to use a calculator.	2.09	.80
9. Using calculators will free students to explore alternative strategies.	2.97	.59

Table 16 Continued

Statement	M	SD
10. Calculators should be used only to check work once the problem has been worked on paper.	2.09	.58
11. Calculators should not be used on math homework.	2.12	.48
12. Using calculators will cause students to lose basic computational skills.	2.15	.57
13. Math is easier if a calculator is used to solve problems.	2.67	.54
14. Calculator skills are as important as paper and pencil computational skills.	3.15	.62
15. Continued use of calculators will cause a decrease in student estimation skills.	2.12	.55
16. The calculator can be used to explore mathematical concepts.	3.21	.48
17. Students should be allowed to use calculators even before they understand the underlying concepts.	2.09	.68
18. Calculators are only tools for doing calculations more quickly.	2.61	.79
19. Calculators should not be used until students know their basic arithmetic facts.	2.94	.56

Table 16 Continued

Statement	M	SD
20. The teacher should decide when it is appropriate for students to use calculators.	3.30	.47
21. Calculator use encourages problem solving.	3.12	.48
22. Calculators should only be used by advanced students.	1.67	.65
23. Incorporating calculators into teaching requires changing the types of problems assigned.	2.73	.80
24. Students can gain understanding of computational procedures by using calculators.	3.03	.47
25. Calculators can be used effectively to check answers to homework problems.	3.09	.46
26. Students should learn the paper and pencil long division algorithm before using the calculator to divide.	3.09	.58
27. The major value of calculators in mathematics classes is to save time performing computations.	2.79	.48
28. It is not necessary to change what is taught in order to effectively use calculators.	2.79	.60

Table 16 Continued

Statement	M	SD
29. It is not appropriate for calculators to be used in some mathematics classes.	2.36	.70

Note. 4 = Strongly Agree, 3 = Agree, 2 = Disagree, and 1 = Strongly Disagree.

Research Question Six

Are there statistically significant differences between the teacher attitude responses as measured by the AIM-AT-II with respect to the variables of philosophical orientation and teacher training?

Teacher responses on the AIM-AT-II were examined to determine if significant differences existed for the variables of philosophical training (mastery) and training (LaSIP). Previous research regarding this instrument by Fleener (1994b) suggested that there are at least two distinct categories of teachers divided on the issue of whether students should be allowed to use calculators before they have achieved conceptual mastery, with a third group falling between the two extreme positions. In order to ensure sufficient cell size, teachers in this study were divided into two mastery groups, MASTERY = YES and MASTERY = NO, based on responses to AIM-AT-II items 7 and 17. Participants who agreed with item 7 (Students should not be allowed to use calculators until they have mastered the concept) and disagreed with item 17 (Students should be allowed to use calculators even before they understand the underlying concepts) formed the MASTERY = YES group (n = 19). Teachers who answered inconsistently (agreeing or disagreeing with both items) or who consistently answered against the mastery requirement (disagreeing with item 7 and agreeing with item 17) were placed in the MASTERY = NO group (n = 14). Significant differences by the category of mastery were examined through t-tests. The mean scores of individual items for which significant differences ($p < .05$) were found are reported in Table 17.

Table 17

Mean Scores of AIM-AT-II Items by Mastery

Item	M
2. Calculator use will cause a decline in basic arithmetic facts.	
Mastery = No	1.86
Mastery = Yes	2.42
7. Students should not be allowed to use calculators until they have mastered the concept.	
Mastery = No	2.43
Mastery = Yes	3.37
8. If students don't know their basic arithmetic facts by the 5th grade, they should be allowed to use a calculator.	
Mastery = No	2.50
Mastery = Yes	1.79

Table 17 Continued

Item	M
17. Students should be allowed to use calculators even before they understand the underlying concepts.	
Mastery = No	2.50
Mastery = Yes	1.79
19. Calculators should not be used until student know their basic arithmetic facts.	
Mastery = No	2.57
Mastery = Yes	3.21
26. Students should learn the paper and pencil long division algorithm before using the calculator to divide.	
Mastery = No	2.79
Mastery = Yes	3.32

Note. Only items with a significant difference ($p < .05$) reported. 4 = Strongly Agree, 3 = Agree, 2 = Disagree, and 1 = Strongly Disagree.

As a portion of the Louisiana Systemic Initiatives Program (LaSIP) mathematics training, teachers are instructed in methods which strive to incorporate the NCTM Standards into the classroom. A major emphasis of LaSIP training has been the development of problem solving skills and the utilization of the calculator as a problem solving tool. LaSIP training also was designed to promote change in teacher attitudes as a means of educational reform (Louisiana Systemic Initiatives Program, 1997). Analysis of teacher responses on the AIM-AT-II sought to determine if the LaSIP mathematics training resulted in significant differences between LaSIP trained ($n = 10$) and non-LaSIP trained teachers ($n = 23$), and if so, on which survey items. Significant differences by the variable of LaSIP training were examined through t-tests of the AIM-AT-II responses. The mean scores of individual items for which significant differences ($p < .05$) were found are reported in Table 18.

Table 18

Mean Scores of AIM-AT-II Items by LaSIP Training

Item	M
9. Using calculators will free students to explore alternative strategies.	
LaSIP = No	2.83
LaSIP = Yes	3.30
10. Calculators should be used only to check work once the problem has been worked on paper.	
LaSIP = No	2.22
LaSIP = Yes	1.80
16. Continued use of calculators will cause a decrease in student estimation skills.	
LaSIP = No	3.09
LaSIP = Yes	3.50

Table 18 Continued

Item	M
20. The teacher should decide when it is appropriate for students to use calculators.	
LaSIP = No	3.17
LaSIP = Yes	3.60

Note. Only items with a significant difference ($p < .05$) reported. 4 = Strongly Agree, 3 = Agree, 2 = Disagree, and 1 = Strongly Disagree.

Summary of Data Analyses

Data analyses for this study were conducted to address two major areas of focus: the effects of calculator usage on student mathematics achievement and the attitudes of students and teachers toward calculator usage. Analyses of the mathematics achievement data were conducted to test the four null hypotheses. Significant differences between the treatment group and the control group were reported for both the number of problems correct and the number of problems attempted. Significant differences between the mean scores were also reported for the variables of gender, race, grade, and level. Mean scores favored the treatment groups for the variables of gender, race, grade, and level for both number correct and number attempted. Student perceptions regarding calculator usage were presented along with the results of the Student Calculator Survey. Data from the teacher survey (AIM-AT-II) were examined for differences by the variables of philosophical orientation and LaSIP training. The six research questions were addressed through data analyses of the Student Calculator Survey and AIM-AT-II responses. Implications and conclusions from the analysis of data as well as recommendations are presented in Chapter V.

CHAPTER V

CONCLUSIONS, DISCUSSION, AND RECOMMENDATIONS FOR FURTHER RESEARCH

In this chapter conclusions and discussions are presented based on the research findings of this study. Conclusions are presented for the results of the student achievement tests first, followed by those for the student and teacher survey responses. Recommendations to the participating school systems are presented as well as recommendations for further research.

Summary and Conclusions

This study was designed to determine the effects of calculator usage on the mathematics achievement of seventh and eighth grade students. The mean scores of the treatment group and the control group were examined for significant differences with respect to the number of correct responses and the number of problems attempted on the Mathematics Concepts and Applications sections of the California Achievement Test (CAT). The variables of gender, race, grade, and level were examined for significant differences with respect to both the number of correct responses and the number of problems attempted. Data analyses were used in the decision to reject or fail to reject the four null hypotheses. The study also explored the relationship of student and teacher attitudes and perceptions with respect to calculator usage. Student responses on the Student Calculator Survey were examined for significant differences between the treatment group and the control group. Teacher responses on the

Attitude Instrument for Mathematics and Applied Technology-Version II (AIM-AT-II) were examined for significant differences for the variables of philosophical orientation (mastery) and training (LaSIP). Student attitude responses were used to address research questions one, two, and three; teacher attitude responses were used to address research questions four, five, and six. Results and conclusions for the mathematics achievement section are presented first, followed by results and conclusions from the survey responses.

Mathematics Achievement

Data from the mathematics achievement section were used to test the four null hypotheses. With regard to mathematics achievement, significant differences were found between the mean scores of the treatment group and the control group both for the number of correct responses and the number of problems attempted. Students in the treatment group had a mean score of 25.54 problems correct compared with a mean score of 24.34 for the control group. This finding supported the rejection of the first null hypothesis A significant difference between groups also was found for the number of problems attempted on the 50 item tests. Treatment group students attempted a mean of 45.58 problems compared to a mean of 44.29 problems attempted by the control group. Analysis of these data led the researcher to reject the third null hypothesis. The findings from this study indicated that calculator usage significantly favored the students in the treatment group both for the number of correct responses and for the number of problems attempted on the Mathematics Concepts and Applications sections of the CAT.

Analyses for the variables of gender, race, grade, and level revealed significant differences for each of the variables, both for the number of correct responses and the number of problems attempted. The mean score for the number correct by male students (26.52) was greater than that of female students (23.98). This gender difference was also present for the number of problems attempted; male students attempted a mean of 45.82 problems whereas female students attempted a mean of 44.44 problems. Treatment group mean scores for both male students and female students were higher for number correct and number attempted than control group means. The mean for male treatment group students (26.71) was higher than that of male control group students (26.33) for number correct and for number of problems attempted (46.13 vs. 45.50). Mean scores for number correct by female students were 24.85 for the treatment group compared with 22.85 for the control group. The mean score for the number attempted by female treatment group students was 45.26 compared with 43.38 mean number attempted by female control group students. With respect to gender, calculator usage in assessment situations appeared to have benefited both male students and female students for the number of correct responses and the number of problems attempted on the CAT.

Racial comparisons for the number correct revealed significant differences between the mean scores of black students (20.59), white students (29.30), and Asian and Hispanic students (25.73). Comparisons of number attempted by race showed significant differences between the mean scores of black students (42.90), white students (47.09), and Asian and Hispanic students (43.18). Comparisons by race and group for number correct revealed higher mean scores in favor of the treatment group for black students (21.25 vs. 19.88) and for white students (29.55 vs. 28.98). The mean number correct by group for Asian and Hispanic students favored the control group (30.67) over the treatment group (23.88). The mean scores for number attempted favored the treatment groups for black students and for white students. Black students in the treatment group attempted a mean of 43.74 problems compared with a mean of 41.98 problems attempted by black students in the control group. White students in the treatment group attempted a mean of 47.40 problems compared with a mean of 46.69 problems attempted by white students in the control group. For number attempted, Asian and Hispanic students in the control group (48.00) scored higher than those in the treatment group (41.38). The results for both number correct and number attempted for Asian and Hispanic students may have been influenced by the small representation of these races in the study (n = 11). The number of Asian and Hispanic students in the treatment group was eight, whereas the control group number was three students for these races. Of the three students in the control group, two were classified as high/honor level and one as regular level. Due to the small number of students in the control group (n = 3), extreme scores may have influenced the mean score. With all of the control group students in either the high/honor level or the regular level, the mean scores for Asian and Hispanic students may have been influenced by ability level. Differences by race indicated that calculator use benefited both black students and white students for the number correct and the number of problems attempted. Asian and Hispanic control groups were favored for both the number correct and the number attempted.

Significant differences by grade resulted for number correct. Seventh grade students had a mean score of 24.02 and eighth grade students scored a mean of 25.69 problems. No significant differences were found with respect to the number of problems attempted by grade; seventh grade students attempted a mean of 44.78 problems and eighth grade students attempted a mean of 45.14 problems. Treatment group mean scores for number correct were higher for both seventh grade students (25.27) and eighth grade students (25.73) than seventh and eighth grade control group scores (22.59 and 25.63, respectively). Students in the treatment groups had greater mean scores for number attempted (46.04 and 45.27) than did control groups (43.36 and 44.98) for seventh grade and eighth grade.

Analysis by level revealed significant differences for the number correct and the number attempted. Low level students had a mean of 17.95 problems correct with a mean of 43.48 problems attempted. Regular level students scored a mean of 24.13 problems correct with 44.87 problems attempted. High/honor level students' mean score for number correct was 30.81 with 46.16 problems attempted. The mean scores for number correct by treatment groups and level revealed higher scores for low level (18.93), regular level (24.05), and high/honor level (31.78) students than those in control groups (17.09, 24.25, and 29.78, respectively). The mean scores of number attempted for treatment groups by level (44.66, 45.09, and 47.03) were higher than control groups for low level (42.30), regular level (44.74), and high/honor level (45.22) students. The mean scores of treatment group students were higher for all levels for both number correct and number attempted than the mean scores of control group students.

Data analyses of significant differences among the variables of gender, race, grade, and level for number correct were used to reject the second null hypothesis. Significant differences for the variables of gender, race, grade, and level were reported for the number of problems correct. Data analyses of significant differences among the variables of gender, race, grade, and level for number attempted led to rejection of the fourth null hypothesis. For the number of problems attempted, a significant difference was reported for the variables of gender, race, grade, and level.

Student Survey

Student survey responses were used to address research questions one, two, and three. Student responses regarding availability of calculators during class time were 49.5% for the category "Some of the time" while "Rarely or never" was reported by 36.1% of the students. Comparisons by gender revealed 48.4% of the male students reported calculator availability as "Some of the time" and 50.3% of female students responded in the same category. For the category "Rarely or never," 36.4% of male students responded; 35.9% of the females reported usage in this category. Students of LaSIP trained teachers reported higher percentages of usage for the categories "Most of the time" (12.8%) and "Some of the time" (65.2%) than did students of teachers without LaSIP training (5.9% and 36.9%, respectively). Responses regarding the availability of calculators seemed to suggest that students perceived calculators were available "Some of the time" or "Rarely or never." Responses on the Student Calculator Survey showed a significant difference between the treatment group and the control group with respect to the statement "Students should not be allowed to use a calculator while taking math tests." Although a significant difference existed between the mean scores of the treatment group (1.90) and the control group (2.05), both groups appeared to disagree with the statement (4 = Strongly Agree, 3 = Agree, 2 = Disagree, and 1 = Strongly Disagree). Data from the Student Calculator Survey were used to address research questions one, two, and three.

Teacher Survey

Teacher survey responses were used to address research questions four, five, and six. Analysis of teacher demographics indicated the majority of the teachers for this study reported elementary certification (78.8%) compared to 30.3% with middle school certification and 27.3% with secondary mathematics certification. Additional training through LaSIP was reported by 30.3% of the teachers. Certification and LaSIP training data indicated that most teachers in this sample were not secondary mathematics certified nor LaSIP trained. In regard to availability of a classroom set of calculators, 84.8% of the teachers responded in the affirmative. For the statement regarding calculator use during class time, 81.1% of the teachers reported use in the category "Some of the time" while 12.1% responded in the category "Rarely or never." The data seemed to indicate that teachers used calculators "Some of the time" for classroom instruction.

Responses on the AIM-AT-II differed significantly for the variable of philosophical orientation (mastery). The Mastery = No group consisted of 14 teachers; 19 teachers were in the Mastery = Yes group. Significant differences were found for 7 of the 29 statements. These items dealt with the issue of mastery and were represented by the following statements:

2. Calculator use will cause a decline in basic arithmetic facts.
7. Students should not be allowed to use calculators until they have mastered the concept.
8. If students don't know their basic arithmetic facts by the 5th grade, they should be allowed to use a calculator.

17. Students should be allowed to use calculators even before they understand the underlying concepts.
19. Calculators should not be used until students know their basic arithmetic facts.
26. Students should learn the paper and pencil long division algorithm before using the calculator to divide.

Although significant differences existed between the Mastery = No (n = 14) and the Mastery = Yes (n = 19) responses on the items, both groups appeared to disagree with the statement: "Calculator use will cause a decline in basic skills" (Mastery = No, 1.86; Mastery = Yes, 2.42). The mean score of the Mastery = No group (2.43) for the statement: "Students should not be allowed to use calculators until they have mastered the concept" differed significantly from the mean score of the Mastery = Yes group (3.37). Comparisons of the mean score of the Mastery = No (2.50) and the Mastery = Yes (1.79) groups for the statements: "If students don't know their basic arithmetic facts by the 5th grade, they should be allowed to use a calculator" and "Students should be allowed to use calculators even before they understand the underlying concepts" revealed significant differences between the groups. However, the results of the Mastery = No group (2.50) did not indicate agreement or disagreement with the statements (4 = Strongly Agree, 3 = Agree, 2 = Disagree, and 1 = Strongly Disagree). Responses to the statement: "Calculators should not be used until students know their basic arithmetic facts" indicated agreement for the Mastery = No (2.57) and the Mastery = Yes (3.21) teachers. Agreement was also found between the Mastery = No (2.79) and Mastery = Yes (3.32) responses for the statement: "Students should learn the paper and pencil long division algorithm before using the calculator to divide." The results of AIM-AT-II responses for the category of mastery revealed significant differences on 7 of the 29 items on the survey. This suggested that philosophical orientation (mastery) significantly influenced responses on the AIM-AT-II.

The variable of LaSIP training was examined for significant differences between the responses of the LaSIP = Yes group (n = 10) and the LaSIP = No group (n = 23). Significant differences by the variable of training (LaSIP) were found for 4 of the 29 items:

9. Using calculators will free students to explore alternative strategies.
10. Calculators should be used only to check work once the problem has been worked on paper.
16. Continued use of calculators will cause a decrease in student estimation skills.
20. The teacher should decide when it is appropriate for students to use calculators.

Although significant differences existed between the LaSIP = No and the LaSIP = Yes responses on the items, both groups appeared to agree with the statement: "Using calculators will free students to explore alternative strategies" (LaSIP = No, 2.83; LaSIP = Yes, 3.30). The mean scores of LaSIP = No (2.22) and LaSIP = Yes (1.80) for the statement: "Calculators should be used only to check work once the problem has been worked on paper" seemed to suggest that both groups disagreed with this statement. Both the LaSIP = No (3.09) and LaSIP = Yes (3.50) groups agreed with "Continued use of calculators will cause a decrease in student estimation skills." Agreement was also indicated by LaSIP = No (3.17) and

LaSIP = Yes (3.60) teachers for the statement: "The teacher should decide when it is appropriate for students to use calculators." The responses of teachers by the variable of LaSIP training seemed to indicate that both groups agreed that calculator usage was beneficial for the exploration of alternative strategies, but that estimation skills may have been adversely affected by calculator usage. As indicated by survey responses, teachers in both groups appeared to agree that the teacher should decide when calculator usage is appropriate. Data from the teacher survey responses were used to address research questions four, five, and six.

Discussion

This study addressed two major areas of concern regarding calculator usage at the seventh and eighth grade levels: mathematics achievement and the attitudes of students and teachers. Using the results of the study as presented in Chapter IV, these areas of concern are addressed along with implications for the findings of this study.

Significant differences were found between the mean scores of the control group and the treatment group with regard to the Mathematics Concepts and Applications sections of the CAT. These differences were reported for both the number correct and the number attempted. The results contradict the findings of Ansley, Spratt, and Forsyth (1989) who reported that the use of calculators did not appear to be advantageous on a test of problem solving ability. However, the results supported the findings of Colefield (1985), Hopkins (1978), and Lewis and Hoover (1981) which reported significantly higher scores for the calculator group when measured by standardized tests. Similar findings were reported by Murphy (1981) and Colefield (1985). The analyses of the variables of gender, race, grade, and level revealed significant differences for all variables with respect to the number of correct responses.

The mean score of male students was higher than that of female students. Examination of the number correct by race indicated a significant difference that favored white students. Differences by grade indicated eighth grade students scored significantly higher than seventh grade students, although tests for each grade level were designed for that specific grade. Differences were noted between low and regular levels, low and high/honor levels, and between regular and high/honor levels, contrary to the findings of Kasnic (1978) who reported no significant differences between ability levels. Analyses of the same variables for number attempted revealed the same results with the exception of grade. No significant differences were found by grade with respect to the number of problems attempted. These results suggest that for the variables of gender, race, and level, calculator use may have a significant effect for the number of problems attempted. Analysis of the variables gender, race, grade, and level for number correct indicated that, for all variables except race, treatment group mean scores were higher than those of the control group. The mean scores of Asian and Hispanic students for number correct favored the control group. This result may have been due to the small number of Asian and Hispanic students in the study ($n = 11$). With the exception of Asian and Hispanic students, it appeared that calculator usage benefited both genders, both races, both grades, and all levels with respect to the number of problems correct. Analysis of the variables gender, race, grade, and level for number attempted indicated that for all variables, except race, treatment group mean scores were higher than those of the control group. The mean scores of Asian and Hispanic students for number attempted favored the control group. Again, this result may have been due to the small number of Asian and Hispanic students in the study ($n = 11$) and to the composition of the control group ($n = 3$) and the treatment group ($n = 8$). As previously discussed, the control group for Asian and Hispanic students was comprised of students from regular and high/honor level classes, whereas the treatment group was comprised of students from the low and regular levels. With the exception of Asian and Hispanic students, it appeared that both genders, both races, both grades, and all levels attempted more problems when calculators were used. This indicates that calculator usage can positively influence test performance. When standardized tests allow for calculator use, the benefits of such usage appear to be significant, particularly for the above mentioned groups of students. This finding is in concert with the that of Meel (1997), who reported that the inclusion of calculators in assessment situations offers a number of benefits. Students have a better attitude about the assessment process and feel empowered (Bitter & Hatfield, 1992; Finley, 1992; Hopkins, 1992). They are able to engage in problem solving activities in realistic tasks rather than with contrived problems (Hopkins, 1992). However, complications may be present for the use of calculators on tests. If calculators are used in a timed assessment, students might spend more time on particular items and be unable to complete the assessment. Another difficulty is that differing capabilities of calculators may give some students an unfair advantage. A student may be at a technological advantage when using a calculator with fractions or graphing capabilities (Meel, 1997). The use of calculators in assessment situations is not a panacea. The advantages presented by calculator usage must be placed within the context of the overall instructional and assessment structure.

Responses regarding the availability of calculators during class time revealed the categories "Some of the time" and "Rarely or never" accounted for 85.6% of the responses. These results support findings by Jaji (1986) in which only 6% of the eighth grade students reported having used a calculator in school one or more periods per week. Crosswhite (1985) found that one-third of the eighth grade students in the Second International Mathematics Study reported never using calculators. Findings of this study indicate that the situation remained relatively stable even a decade later. Students of LaSIP trained teachers were more likely to report use as "Most of the time" (12.8% vs. 5.9%) than students of teachers without LaSIP training. This finding indicates that while teacher LaSIP training may result in increased calculator usage for the students of LaSIP trained teachers, the percentage of students reporting use as "Most of the time" remains relatively small. LaSIP teacher training did not appear to increase significantly the availability of calculators. The reporting of calculator availability may have been influenced by the time of the school year in which this study was conducted. Comments on the teacher survey indicated that increased calculator usage normally occurred during the second semester of the school year and varied based on the content of the lesson.

Responses on the Student Calculator Survey indicated that students perceived calculator use as a motivational tool. This perception was supported through agreement with the statements: "Calculators make mathematics fun," "Mathematics is easier if a calculator is used to solve problems," "I would do better in math if I could use a calculator," "I would try harder in math if I had a calculator to use," "I would appreciate math better if I had a calculator to use," and "I would do better in problem solving if I had a calculator to use." Disagreement was found with the statement "Mathematics is boring," which indicated an overall positive attitude toward mathematics. The Student Calculator Survey responses were examined for significant differences between the control and treatment groups. The statement "Students should not be allowed to use a calculator while taking math tests" was the only statement that indicated significant differences. Although the difference was significant, both groups indicated disagreement with this statement. This finding suggested that students felt calculator use should be allowed on tests. No significant differences between treatment and control groups, but overall positive attitudes toward calculators were reported by Gaslin (1975), Fischman (1976), Quinn (1976), and Anderson (1977).

Implications from the Student Calculator Survey portion of this study may be linked to the availability of calculators for use in both instructional and assessment settings. It appears that students perceive calculator usage as a motivational factor for both instructional and assessment purposes. This finding supports the research of Hopkins (1992) who stated: "the presence of the calculator made them [the students] feel more confident, and therefore more positive, about the testing situation" (p. 165). However, calculator use may be limited by teacher control of usage and by policies of the school districts regarding calculator use on standardized tests. It is recommended, based on findings of this study, that calculator use be allowed on standardized tests.

Responses from teacher surveys indicated 84.8% of the teachers reported having classroom calculators. The usage of calculators during class time was reported at 81.8% for the category "Some of the time" and 12.1% for the category "Rarely/never." These data indicated that most teachers have classroom calculators and that usage most often occurred for the category "Some of the time." Weiss (1978) reported the results of a national survey which indicated that 70% of the teachers did not use calculators in their classrooms and 42% felt that calculators were unnecessary. In a study by Cohen and Fleiss (1979), 46.4% of the teachers reported never or seldom using calculators in their classroom and almost 21% of the teachers were opposed to the use of calculators. Findings from the present study indicate that no substantial progress in teacher acceptability of calculator usage has occurred in the past two decades.

Responses on the AIM-AT-II were examined for significant differences along the categories of philosophical orientation and LaSIP training. For the category of philosophical orientation teacher responses were divided into two groups: "Mastery = Yes" and "Mastery = No" based on responses to items 7 and 17. Statements where significant differences were noted included: "Calculator use will cause a decline in basic arithmetic facts," "Students should not be allowed to use calculators until they have mastered the concept," "If students don't know their basic arithmetic facts by the 5th grade, they should be allowed to use a calculator," "Students should be allowed to use calculators even before they understand the underlying concepts," "Calculators should not be used until students know their basic arithmetic facts," and "Students should learn the paper and pencil long division algorithm before using the calculator to divide." Within the categories of mastery there was agreement that "Calculators should not be used until students know their basic arithmetic facts" and "Students should learn the paper and pencil long division algorithm before using the calculator to divide." These findings seemed to indicate that mastery of the long division algorithm and of basic facts were issues for the teachers in this study. Similar findings were reported by Suydam (1980) who found 67% of the teachers in the study felt calculators should be used only after paper-and-pencil algorithms were learned. In a study conducted by Reys, Bestgen, Rybolt, and Wyatt (1980), 58% of the teachers did not allow calculator usage. Mastery of the basic facts prior to calculator usage was an issue for 84% of the teachers in the study. Implications for this study suggested that the issue of mastery may have affected teacher perceptions and attitudes with regard to the usefulness of calculators in instructional and assessment situations.

Information regarding LaSIP training revealed that 10 of the 33 teachers, or 30.3%, had received LaSIP training. Examination of AIM-AT-II responses by the category of LaSIP training revealed significant differences for the items: "Using calculators will free students to explore alternative strategies," "Calculators should be used only to check work once the problem has been worked on paper," "Continued use of calculators will cause a decrease in student estimation skills," and "The teacher should decide when it is appropriate for students to use calculators." Teachers in both groups disagreed with the use of calculators only after the problem had been worked with paper and pencil. Both LaSIP trained and non-LaSIP trained teachers agreed that the teacher should decide when calculator use is appropriate and that calculator usage could encourage exploration of alternative strategies. The concept of calculator use to explore alternative strategies was supported by findings of Reys (1989). Implications for this study suggest that LaSIP training may affect teacher attitudes toward calculator usage. The responses of the LaSIP trained teachers indicated a stronger sense of agreement or disagreement with AIM-AT-II statements than the responses of teachers without LaSIP training. The implication for this study suggests that LaSIP training may influence teachers to respond more positively to statements which promote calculator usage and more negatively to statements which limit or question the usefulness of calculators.

A statement which did not indicate significant differences between either group (mastery or LaSIP) was the statement: "Students should not be allowed to use calculators on standardized tests." The mean response score of the teachers seemed to indicate agreement with this statement. Written comments from teachers in the space provided on the survey indicated that calculator usage for both instructional and assessment practices was influenced by district polices concerning calculator use on standardized tests. Teacher responses on the AIM-AT-II may have been influenced by the current district practices of not allowing the use of calculators on standardized tests. Studies by Romberg, Zarinnia, and Williams (1988) and by Romberg, Wilson, Khaketla, and Chavarria (1992) reported decreased emphasis on calculator skills due to restricted calculator use on tests. Based on findings from this study, it is recommended that more opportunities for teacher training through LaSIP and inservice programs be made available at the local school system level. Increased teacher training in the use of calculators appeared to have a positive influence on the availability of calculators for classroom use and attitudes toward calculator usage. However, as Bitter and Hatfield (1993) noted, knowing how to integrate calculator usage and deciding to integrate calculator usage are not equivalent. LaSIP training did not ensure the implementation of calculators for instructional and assessment practices.

Recommendations

Based on the findings from this study and from previous studies, several recommendations were made to the participating school systems. The recommendations are as follows:

1. A classroom set of calculators should be made available to all seventh and eighth grade mathematics teachers. An overhead model of the same calculator should be available for demonstration purposes. This recommendation partially addresses the issue of equity with respect to calculator accessibility. Meel (1997) suggested that the variety of calculators available might pose a problem of technological equity. The set of

available calculators should not unduly advantage one group of students over others. Findings from this study suggest that students perceive calculator use as motivational and that calculator use may be beneficial for both genders, both races, both grades, and all levels of students. In particular, low ability level students may be motivated by calculator use to attempt more problems, thereby potentially increasing performance on standardized tests. Hembree and Dessart (1986) had previously concluded that calculator usage increased the performance of students in problem solving as a result of improved computation and strategy selection.

2. Provide for teacher training in the use of calculators through inservice workshops or through increased opportunities to participate in LaSIP mathematics training. This training should be accompanied by materials which incorporate calculator usage in a manner that promotes problem solving skills and techniques. Meel (1997) addressed the issue of the amount of time required in instruction of calculator techniques. LaSIP training is designed to deliver calculator training effectively and appropriately.

3. Adopt formats of standardized tests which allow for calculator usage on the non-computational portions of the test. The items of a calculator-neutral test should focus on concepts, ideas, and calculations that can be easily attained by hand or by calculator (Meel, 1997). As noted in a study by Romberg, Wilson, Khaketla, and Chavarria (1992), teachers reported a decreased emphasis on calculator activities due to calculator restrictions on standardized tests. The findings of this study indicated that teachers were in agreement with the statement "Students should not be allowed to use calculators on standardized tests." However, it is not clear if this perception existed due to the practice of prohibiting calculator usage on standardized tests or to philosophical

orientation and training. Adoption of a calculator format of standardized tests may be a significant step toward the formation of more positive teacher attitudes toward calculator use.

Recommendations for Further Research

In this section recommendations are made for additional research areas that would extend the results of this study.

1. Research should be conducted on the effects of calculator usage on standardized tests at the elementary and high school levels. The results of calculator usage at these levels may vary significantly from the results found at the seventh and eighth grade levels.

2. The effects of calculator usage on criterion-referenced assessments of mathematics achievement for the seventh and eighth grade levels should be studied.

3. Research should be conducted to determine the effects of increased teacher training on the availability and usage of calculators in instructional and assessment settings.

4. The relationship of LaSIP teacher training to philosophical orientation should be examined for possible interactions between the factors of training and philosophical orientation with respect to attitude toward calculator usage.

5. The effects of calculator training and instruction on the problem solving strategies and abilities of seventh and eighth grade students should be researched. This study examined only the effects of calculator usage on mathematics achievement and not the specific strategies which were involved in the problem solving process.

6. Possible changes in student and teacher attitudes toward calculator use should be studied after incorporating the use of calculators on standardized tests.

7. Research should be conducted to explore the attitudes of administrators and curriculum developers toward calculator usage for both instructional and assessment practices.

APPENDIX A

STUDENT CALCULATOR SURVEY

STUDENT CALCULATOR SURVEY

Please take time to consider these 21 statements regarding math and calculators. For this survey, SA = Strongly Agree; A = Agree; D = Disagree; SD = Strongly Disagree. Circle the response for your choice. Thank you for your time and participation.

1. Students should not be allowed to use a calculator while taking math tests.
SA A D SD

2. The calculator will hinder students' understanding of the basic computation skills.
SA A D SD

3. Calculators make mathematics fun.
SA A D SD

4. Since I have a calculator, I do not need to learn to do computations on paper.
SA A D SD

5. Mathematics is easier if a calculator is used to solve problems.
SA A D SD

6. I understand mathematics better if I solve problems with paper and pencil.
SA A D SD

7. I know how to use a calculator very well.
SA A D SD

8. It is important that everyone learn how to use a calculator.
SA A D SD

9. I would do better in math if I could use a calculator.
SA A D SD

10. I prefer working word problems with a calculator.
SA A D SD

11. I would try harder in math if I had a calculator to use.
SA A D SD

12. Using a calculator to solve money problems is confusing.
SA A D SD

13. Calculators should be used only to check my answers once I have worked the problems with paper and pencil.
SA A D SD

14. Calculators are not useful for solving fraction problems.
SA A D SD

15. I feel calculators should not be used on math homework.
SA A D SD

16. I am good in mathematics.
SA A D SD

17. Using a calculator in math will cause me to forget how to do basic computation skills.
SA A D SD

18. I would appreciate math better if I had a calculator to use.
SA A D SD

19. I would do better in problem solving if I had a calculator to use.
SA A D SD

20. If I use a calculator, my estimation skills will decrease.
SA A D SD

21. Mathematics is boring.
SA A D SD

APPENDIX B

ATTITUDE INSTRUMENT FOR MATHEMATICS AND APPLIED TECHNOLOGY-VERSION II

ATTITUDE INSTRUMENT FOR MATHEMATICS AND APPLIED TECHNOLOGY-VERSION II

Please take time to consider these 29 statements regarding calculator usage. For this survey, SA = Strongly Agree; A = Agree; D = Disagree; SD = Strongly Disagree. Circle the response for your choice. Thank you for your time and participation.

1. Students should be allowed to use calculators on standardized tests.
   SA A D SD

2. Calculator use will cause a decline in basic arithmetic facts.
   SA A D SD

3. Calculators make mathematics fun.
   SA A D SD

4. When solving problems with calculators, students don't need to show their work.
   SA A D SD

5. More difficult mathematics problems can be done when students have access to calculators.
   SA A D SD

6. Students understand math better if they solve problems using paper and pencil.
   SA A D SD

7. Students should not be allowed to use calculators until they have mastered the concept.
   SA A D SD

8. If students don't know their basic arithmetic facts by the 5th grade, they should be allowed to use a calculator.
   SA A D SD

9. Using calculators will free students to explore alternative strategies.
   SA A D SD

10. Calculators should be used only to check work once the problem has been worked on paper.

    SA A D SD

11. Calculators should not be used on math homework.

    SA A D SD

12. Using calculators will cause students to lose basic computational skills.

    SA A D SD

13. Math is easier if a calculator is used to solve problems.

    SA A D SD

14. Calculator skills are as important as paper and pencil computational skills.

    SA A D SD

15. Continued use of calculators will cause a decrease in student estimation skills.

    SA A D SD

16. The calculator can be used to explore mathematical concepts.

    SA A D SD

17. Students should be allowed to use calculators even before they understand the underlying concepts.

    SA A D SD

18. Calculators are only tools for doing calculations more quickly.

    SA A D SD

19. Calculators should not be used until students know their basic arithmetic facts.

    SA A D SD

20. The teacher should decide when it is appropriate for students to use calculators.

    SA A D SD

21. Calculator use encourages problem solving.

    SA A D SD

22. Calculators should only be used by advanced students.

    SA A D SD

23. Incorporating calculators into teaching requires changing the types of problems assigned.
SA A D SD

24. Students can gain understanding of computational procedures by using calculators.
SA A D SD

25. Calculators can be used effectively to check answers to homework problems.
SA A D SD

26. Students should learn the paper and pencil long division algorithm before using the calculator to divide.
SA A D SD

27. The major value of calculators in mathematics classes is to save time performing computations.
SA A D SD

28. It is not necessary to change what is taught in order to effectively use calculators.
SA A D SD

29. It is not appropriate for calculators to be used in some mathematics classes.
SA A D SD

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VITA

Tracie B. Ellerman was born August 17, 1961 in El Dorado, Arkansas. Following her graduation from El Dorado High School as salutatorian of her class, she pursued a degree in Instrumental Music Education at Louisiana Tech University. She graduated summa cum laude in 1983 and was named to "Who's Who Among American Colleges and Universities." During her employment with the Ouachita Parish School System, Mrs. Ellerman earned a Masters of Music Education degree in 1988 from Northeast Louisiana University. Upon completion of the certification requirements for secondary mathematics, she taught mathematics, and instrumental and vocal music for a number of years before entering the Louisiana Education Consortium. There, she completed the degree of Doctor of Education in Curriculum and Instruction.

Mrs. Ellerman maintains an active career as a musician, serving as an organist and horn player in local and regional ensembles. She holds memberships in the American Guild of Organists and the Monroe Symphony Orchestra. Mrs. Ellerman also serves as a mathematics teacher and consultant for local school systems. She serves as a MATHCOUNTS coach and has presented programs on the Louisiana Frameworks for Mathematics and Family Math. She has received additional mathematics training through the Louisiana Systemic Initiatives Program (LaSIP) mathematics component. Mrs. Ellerman has been named "Who's Who Among America's Teachers" and is a member of Phi Delta Kappa.

Mrs. Ellerman may be contacted through e-mail at ellerman@linknet.net or by phone at (318) 768-2084. Her address is 1933 Strickland Road, Ruston, LA 71270.