THE EFFECTS OF THE USE OF THE CALCULATOR IN ALGEBRA I
CLASSES ON BASIC SKILLS MAINTENANCE
AND ALGEBRA ACHIEVEMENT

DISSERTATION

Presented to the Graduate Council of the
University of North Texas in Partial
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For the Degree of

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BY

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The purpose of this study was to determine whether there were any differences in basic skills maintenance between Algebra I students who used calculators during classroom mathematics instruction and Algebra I students who did not use calculators during classroom mathematics instruction. Another purpose of this study was to determine whether there were any differences in algebra achievement between Algebra I students who used calculators during classroom mathematics instruction and Algebra I students who did not use calculators during classroom mathematics instruction. This study also investigated the effects of the use of the calculator in Algebra I classes on students' attitudes toward mathematics.

Students selected for this study were from a large suburban school district in Texas. The students were from eight intact classes: two eighth-grade classes, four ninth-grade classes, and two classes with a combination of tenth- and eleventh-grade students. The control and experimental groups each consisted of one eighth-grade class, two ninth-grade classes, and one tenth- and
eleventh-grade class. Three teachers were involved in the study.

At the beginning of the seven months study all students were given the mathematics portion of the California Achievement Test which served as the pretest. At the conclusion of the study all students were given the mathematics portion of the California Achievement Test and the End of Year Test: Algebra I, published by Scott-Foresman and Company. Students were also given the Mathematics Attitude Inventory developed at the University of Minnesota at the beginning and at the end of the study.

All data were analyzed by computer using analysis of covariance. A significant statistical difference was found in the adjusted mean scores in both basic mathematics skills and in algebra achievement between Algebra I students who used calculators during classroom mathematics instruction and Algebra I students who did not use calculators during classroom mathematics instruction. In both cases the adjusted mean scores for the control group were higher than the adjusted mean scores for the experimental group. The greatest differences occured with the tenth- and eleventh-grade Algebra I students.

It is recommended that further studies be conducted to investigate the effects of the use of the calculator on basic skills maintenance and algebra achievement.
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CHAPTER I

INTRODUCTION

The twentieth century has seen numerous advances in technology and resulting changes in society. One product of modern technology, the electronic calculator, has made an impact on mathematics education and will continue to affect the way mathematics is taught in the future, with greater emphasis being given to conceptual development, to mathematical reasoning, and to problem solving and with less emphasis being placed on computational proficiency (Thompson and Rathmell, 1988).

In 1974 the National Council of Teachers of Mathematics (NCTM) urged that calculators be used in schools with the expectations that they would facilitate concept development, provide motivation, and encourage problem solving activities (Suydam, 1976). In 1975 the National Advisory Committee on Mathematical Education recommended that beginning no later than the end of the eighth grade, all students should be permitted to use calculators during mathematics instruction. In An Agenda for Action, published in 1980 by the National Council of Teachers of Mathematics, educators are challenged to take full advantage of the power of calculators and computers at all grade levels. An Agenda for Action is based principally on a series of studies funded by the
National Science Foundation and from two mathematics assessments of the National Assessment of Educational Progress. NCTM also recommends the integration of the calculator into the school mathematics program in classwork, homework, and evaluation. According to NCTM's Position Statement on Calculators in the Classroom (1986) the use of calculators in the classroom could free large amounts of the time students currently spend practicing computation and the time gained should be spent helping students to understand mathematics, to develop reasoning and problem-solving strategies, and to use and apply mathematics. The new Curriculum and Evaluation Standards for School Mathematics, written by the National Council of Teachers of Mathematics and supported by the Texas Education Association (1988), calls for the integration of calculators into the mathematics curriculum for grades K-12. The use of calculators is specifically recommended for increased use of discrete mathematics, including probability and statistics, approximating roots of equations, finding area under curves, and finding slopes of tangent lines.

Textbook Proclamation 65, adopted on March 12, 1988, by the Texas State Board of Education, reflects the increasing emphasis on the use of technology to teach mathematical concepts.

A major new thrust of Algebra I is that the use of current technology including calculators, graphing calculators, and computers should be
integrated throughout the course, with students using calculators and computers as problem-solving and discovery tools whenever possible, with the understanding that students will have access to scientific calculators ... (p. 92)

The Textbook Proclamation for Algebra I specifically states that calculators be used in evaluating quadratic functions, solving quadratic equations, performing operations on numbers in scientific notation, and approximating numerical radical expressions involving square roots. The Proclamation also states that instructional strategies should include the use of calculators and/or computers for teacher demonstration and student exploration and problem solving.

Although calculators are used extensively in society, their use in the mathematics classroom remains very limited. In 1982 Suydam reported that the calculator had not made the impact on mathematics curriculum that had been expected. Less than 20% of the elementary teachers and less than 36% of the secondary teachers in the United States had employed the calculator in mathematics instruction. Although many teachers welcome calculators into the classroom as tools to enrich learning experiences, others are opposed to their presence in the classroom. Many teachers, parents, and administrators remain hesitant to bring calculators into the mathematics classroom. The greatest opposition seems to be the fear that calculator usage will cause a deterioration of basic skills.
Dessart (1983) states that the use of calculators in the algebra classroom is still evolving. The total impact of the calculator and precisely how it will ultimately affect instruction in the algebra classroom of the future is not yet known. Dessart does predict that it will have a place in the mathematics classroom of the future.

George Polya (1957) views mathematics as both a method of inquiry and a body of organized knowledge. His works reveal that he sees the method of inquiry as the essence of mathematics. An eminent learning theorist, Jerome Bruner (1966) contends that students must be taught to "think mathematically" with emphasis being placed on the process. There is considerable support for the premise that the calculator can be utilized for these purposes. According to Hiatt (1979), the hand-held calculator should be used to improve students' mathematical thinking by providing nonroutine problems which require numerous calculations. He contends that by applying the process skills to nonroutine problems the students will also extend their understanding of the basic concepts and skills.

It is critical that additional research be done concerning the effects of the calculator in the mathematics classroom. Most studies conducted in this area have been concerned primarily with the effect of calculator usage on students' attitudes toward mathematics and with the effectiveness of the calculator in solving particular types
of problems. Teachers are primarily concerned with whether the calculator is a tool to aid in computation, an
instructional aid to enhance concept development, or whether it will become an electronic crutch. If, in fact, calculators are to be placed in mathematics classrooms, it is imperative that teachers and students learn to use them effectively. Ways must be found to use the calculator to enhance instruction without sacrificing competency in basic skills. John McConnell (1988) expresses the belief that technology gives us a challenge to move Algebra I away from the routine and toward the content and processes that will give the class of 2000 originality, insight, judgment, initiative, and understanding.

Statement of the Problem

The problem for this study is to investigate the effects of calculator-enhanced Algebra I curriculum on algebra achievement, on basic skills maintenance, and on students' attitudes toward mathematics.

Hypotheses

1. Students in Algebra I classes who use calculators during classroom mathematics instruction will score significantly higher on a standardized test of algebra achievement than those students in Algebra I classes who do not use calculators during classroom mathematics instruction.
2. Eighth-grade students in Algebra I classes who use calculators during classroom mathematics instruction will score significantly higher on a standardized test of algebra achievement than eighth-grade students in Algebra I classes who do not use calculators during classroom mathematics instruction.

3. Ninth-grade students in Algebra I classes who use calculators during classroom mathematics instruction will score significantly higher on a standardized test of algebra achievement than ninth-grade students in Algebra I classes who do not use calculators during classroom mathematics instruction.

4. Students in grades ten and eleven in Algebra I classes who use calculators during classroom mathematics instruction will score significantly higher on a standardized test of algebra achievement than students in grades ten and eleven in Algebra I classes who do not use calculators during classroom mathematics instruction.

5. There will be no significant difference in scores on a standardized test of basic mathematics skills between students in Algebra I classes who use calculators during classroom mathematics instruction and those who do not use calculators during classroom mathematics instruction.

6. There will be no significant difference in scores on a standardized test of basic mathematics skills between eighth-grade students in Algebra I classes who use
calculators during classroom mathematics instruction and eighth-grade students in Algebra I classes who do not use calculators during classroom mathematics instruction.

7. There will be no significant difference in scores on a standardized test of basic mathematics skills between ninth-grade students in Algebra I classes who use calculators during classroom mathematics instruction and ninth-grade students in Algebra I classes who do not use calculators during classroom mathematics instruction.

8. There will be no significant difference in scores on a standardized test of basic mathematics skills between students in Algebra I classes in grades ten and eleven who use calculators during classroom mathematics instruction and students in Algebra I classes in grades ten and eleven who do not use calculators during classroom mathematics instruction.

9. There will be no significant difference in attitudes toward mathematics between those students in Algebra I classes who use calculators during classroom mathematics instruction and those students in Algebra I classes who do not use calculators during classroom mathematics instruction.

Limitations

This study is to provide information on the effectiveness of calculator-enhanced instruction in Algebra
I classes on algebra achievement and basic skills maintenance. This study is also to provide information on the effect of the use of the calculator during classroom mathematics instruction on students' attitudes toward mathematics. Since the sample consists of students from only one school district broad generalizations may not be possible. A quasi-experimental design was used, so caution must be exercised when interpreting the results.

There is no valid way to control for student use of calculators outside the classroom. It is possible that students in the control group may have used calculators at home, even though they were instructed not to use calculators on their assignments. They were required to show all computational steps in the solutions of problems. The focus of the study is on the effects of calculators used in the instructional setting of the classroom.

Another possible limitation may be the number of teachers involved in the study. Three Algebra I teachers from the same district were involved in the study. There is a possibility of teacher bias in a sample of this size.

Definitions of Terms

**Algebra I**: the standard Algebra I course taught in the high school and includes topics such as real numbers, linear and quadratic equations, rational expressions, functions, and polynomials.
Calculator: The calculator used in this study is the solar powered TI 30. This particular calculator is the basic scientific model designed for educational use.

Calculator Enhanced Curriculum: The calculator is used as an integral part of the curriculum. It serves as both a computational tool and an instructional aid.

Algebra Achievement: Achievement in Algebra I is determined by student performance on the High School Subject Test for Algebra I published by Scott Foresman Company and available through American Testronics.

Basic Skills: For the purposes of this study, this term refers to the mathematical skills measured by the mathematics section of the California Achievement Test.

Mathematics Attitude: This is the students' attitude as measured by the Mathematics Attitude Inventory developed at the University of Minnesota.
CHAPTER II

REVIEW OF THE LITERATURE

Little is actually known about how the calculator affects learning. Evidence from research suggests only that students who have used calculators in the mathematics classroom score on paper-and-pencil achievement tests at least as well or better than students who have not used calculators (Suydam, 1978). Most research has concentrated on calculator usage in elementary grades or concentrated on the likelihood of harming basic skills, with little effort given to enhancing student achievement through a systematic use of calculators (Hembree and Dessart, 1986). Research is virtually nonexistent concerning the effectiveness of calculators in the teaching of algorithms or what algorithms might be more effectively taught with the aid of the calculator (Suydam & Dessart, 1980).

Although there is not universal agreement among educators about when and how calculators should be used, most mathematics educators do agree that they are here to stay and will continue to have a significant impact on mathematics curriculum. Research related to hand-held calculators includes investigations into the possible extent of their use and comparisons of classes using and not using them. Studies of their special uses for estimation in
education occurred from 1976 through 1980, at which time research attention seemed to turn toward the microcomputer (Suydam, 1981).

A study conducted by Jewell (1979) explores the extent to which calculators can be used in the present-day algebra curriculum. A search of current textbooks determined the proportion of algebra content with which the calculator might be appropriately used. Jewell surmises that about one-half of the algebra content would be inappropriate for calculators.

Studies conducted by Quinn (1975), Hutton (1976), and Lenhard (1976) compare classes using the calculator with those not using the calculator. They report no distinct advantages to the use of the calculator. The Quinn study involves eighth- and ninth-grade algebra students and used the calculator principally to evaluate algebraic expressions, to solve linear and quadratic equations, and to solve systems of equations. A conclusion of this study is that students studying with calculators have less anxiety toward mathematics than students studying without calculators.

Hutton (1976) compares traditional classes taught without the calculator with classes in which the calculator was used by students as a tool and classes in which the teacher incorporated the calculator into the instruction. No significant differences were found in the achievement
testing of the classes. Lenhard's research included seventh- and eighth-grade mathematics, general mathematics, business mathematics, geometry, trigonometry, and first- and second-year algebra classes. The study revealed little advantage to the use of calculators beyond a decrease in computational errors.

Shumway (1976) examines two opposing proposals concerning the use of calculators. His first proposal is that hand-held calculators should be made readily available to all children at all grade levels for school work. This would eliminate the need for paper and pencil algorithms and extensive drill and practice would become unnecessary, leaving more time available to teach mathematics in depth. Additional support given for this proposal includes arguments that the use of calculators will make math more enjoyable and will facilitate number sense and problem solving. The second proposal reflects the opposing view that hand-held calculators should be banned from classroom use for mathematics. The arguments offered in support of this proposal include the assumption that hand-held calculators would destroy all motivation for learning basic facts.

According to Jones and Bosley (1978), calculators will not eliminate the need for students to acquire paper-and-pencil computational skills; rather, they will aid students in understanding the concepts and algorithms
necessary to the development of computational skills. If a student does not know when or with which numbers to add, subtract, multiply, or divide, the calculator is useless. Calculators, appropriately used as an aid, can improve mathematics instruction. These authors suggest that calculators can be particularly useful in pattern perception, concept development, problem solving, applications, extensions, enrichment, and skill reinforcement.

Olson (1979) finds that the calculator makes it possible to examine patterns that were previously too difficult to pursue allowing the students to make conjectures and to verify those conjectures that are identities. Maletsky, Hirsch, and Yates (1981) offer suggestions and activities for using the calculator to reinforce the skills involved in solving linear equations and to promote opportunities for estimation and mental computation. Terrence Coburn (1986) illustrates how the calculator can be used to develop skills in the estimation and mental computation of percentages.

Larry Vaughn (1976) conducted an eight-week study to determine the effectiveness of the calculator in the teaching of decimals and percents. Based on this study, ninth-grade Fundamentals of Mathematics students can achieve at a higher level when using hand-held calculators and a specially designed curriculum. Vaughn's study indicates a
need for further development of specially designed curriculums to accompany calculators. Most new mathematics textbooks already include calculator activities.

An article written by Brian Garman (1984) implies that the calculator could be a motivator and an instructional aid in developing insight into many common algebraic concepts, laws, and skills. Henry Pollak (1977) suggests the question, "what are some of the most difficult problems we have in teaching school mathematics with which the calculator might help?"

Hembree and Dessart (1986) conducted a meta-analysis of research on the effects of hand-held calculators in precollege mathematics. Their study included 12 journal articles, 12 ERIC reports, a project report, an unpublished report, and 53 dissertations. Very little was reported concerning the enhancement of student achievement through a systematic use of calculators. In 66 of the studies analyzed, the calculator was used as an instructional tool to develop concepts or problem-solving strategies. The median length of the studies involving skills retention was only four weeks. Based on this meta-analysis, recommendations were made for classroom usage: calculators should be used in all mathematics classes of Grades K-12, calculator functions in Grade 4 should be approached with caution, and students in Grade 5 should be permitted to use calculators in all problem-solving activities.
Roberts (cited in Driscoll, 1982) reviewed thirteen studies of the effects of calculator use in the secondary mathematics classroom. Eleven of those studies measured effects on computational skills, nine measured effects on attitude, and eight measured effects on concept attainment. Six studies favored calculators for computational achievement, two for attitudes, and one for concept attainment. In the other studies there were no significant differences between calculator use and non-use. Roberts found most of these studies to be of short duration and expressed the need for studies that take advantage of the unique capabilities of the calculator and for studies that measure calculator effects over longer periods of time. Jewell (1979) also expresses the need for the development and testing of new materials to be used to incorporate the calculator into the mathematics curriculum in a meaningful way.

Although results from research indicate several advantages to calculator use, they also indicate a need for additional research in this area. There seems to be universal agreement that the calculator is going to make a significant impact on mathematics education. Research is needed to identify effective ways of integrating calculators into the curriculum. In the past, the role of the calculator in the classroom has been predominately to check answers and to perform routine computations. Yet, many
researchers predict the greatest benefits of the calculator to be in the areas of concept development and problem solving.
CHAPTER III

METHODS

Population

A suburban school district in North Central Texas was selected for this study. The town has a population of approximately 17,500 and is described as a predominately White, middle-class, bedroom community. The school district has a total enrollment of approximately 5000 students with one high school, one junior high school, and five elementary schools. The high school consists of grades ten, eleven and twelve. The ninth grade is located on the junior high campus, but is in a separate building from the seventh and eighth grade classes. Approximately 160 Algebra I students from the high school and junior high school were involved in the study. Students who take Algebra I in the eighth grade are carefully screened and are above level in mathematics. The screening process includes scores on the Orleans Hanna Algebra Prognosis Test, California Achievement Test scores, grades in seventh-grade mathematics classes and teacher recommendation. Students who take Algebra I in the ninth grade are considered to be on level in achievement and those who take Algebra I in the tenth- and eleventh-grades are considered slightly below level in mathematics achievement.
Table 1

Grade Level Division of Subjects

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<th>Grade 8</th>
<th>Grade 9</th>
<th>Grades 10-11</th>
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<td>Control</td>
<td>17</td>
<td>45</td>
<td>18</td>
<td>80</td>
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<tr>
<td>Experimental</td>
<td>15</td>
<td>43</td>
<td>24</td>
<td>82</td>
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Instrumentation

All students involved in this study were given the mathematics sections of the California Achievement Test in September and again in April to measure any change in basic skills. All students were also given the High School Subjects Test for Algebra I the second week in April to measure algebra achievement. Both of these tests are available commercially from the publishers. In addition to the achievement tests all students involved in this study were also given the Mathematics Attitude Inventory developed by the Minnesota Research and Evaluation Center. The attitude inventory was administered in September and again in April to determine any changes in students' attitudes toward mathematics.

The Algebra I Achievement Test, published by Scott Foresman Company, is available through American Testronics. It was normed on a random sample of schools chosen from public and private high schools across the United States as
listed in the school directory published by Curriculum Information Center, Inc., Denver, Colorado. A total of 316 schools and 3624 students participated in the norming study. The data from the norm sample were weighted to ensure that geographical region and socioeconomic status were represented in the proper proportions.

To be a valid measure of student achievement within a subject area, a test must meet two conditions: (1) the objectives must be valid in the sense that they represent the concepts being taught, and (2) the test items must be valid in the sense that items actually measure achievement of concepts stated in the objectives. Major content areas were determined through extensive analysis of curriculum materials from national organizations, leading textbooks, and materials and objectives from various school systems across the country. The content validity of the test is supported by the test development process employed. Subject matter specialists selected the objectives to represent the curriculum in most high schools and developed test items to measure the achievement of the objectives. Robert K. Gable and Francis X. Archambault (1986) found the objectives on the Algebra I test to be appropriate and found the test to be well developed, reflecting the typical content for an Algebra I course. Gary Phillips (1986) also found this particular instrument to have been well developed and easy to administer and score.
The reliability of a test is a measure of the precision of the test instrument and the extent to which the test scores are stable. It indicates the internal consistency of the test and the reproducibility of the test scores. The Kuder-Richardson Formula 20 was used to compute the reliability coefficient. For the algebra test, the reliability coefficient is reported to be .86.

The California Achievement Test is a nationally recognized standardized test used by many districts across the nation to assess basic skills achievement. The mathematics portion of the California Achievement Test, Form F, Level 19, was chosen as the instrument to measure the level of basic skills. This is a norm-referenced, objectives-based test designed to measure achievement in the basic skills commonly found in state and district curricula. Only scores from the mathematics sections were used in this study. There is one section for mathematics computation and one for mathematics concepts and applications. The mathematics computations section consists of 50 items and the mathematics concepts and applications section consists of 55 items.

To identify test objectives comprehensive reviews were made of state and district curriculum guides, textbook series, instructional programs, and norm-referenced and criterion-referenced assessment instruments. Mathematics computation items measure the basic operations of addition,
subtraction, multiplication, and division on whole numbers, fractions, and decimals. In items measuring mathematical concepts, particular emphasis is given to the reasoning skills needed for practical problem solving.

The Kuder Richardson Formula 20 applied to the mathematics portion of the California Achievement Test yielded a reliability coefficient of .96. An alternate form reliability, within a 2 1/2 week period, yielded a .86 reliability for Grade 9 and a .81 reliability for Grade 10.

The Mathematics Attitude Inventory, designed to measure the attitudes toward mathematics of secondary school students, consists of six scales: (1) Perception of the Mathematics Teacher, (2) Anxiety Toward Mathematics, (3) The Value of Mathematics in Society, (4) Self-Concept in Mathematics, (5) Enjoyment of Mathematics, and (6) Motivation in Mathematics. Reliabilities of the six scales, as determined by Cronbach's Alpha Coefficient, range from .68 to .89.

Research Design and Treatment

A quasi-experimental pretest-posttest design was chosen for this study. The main threat to internal validity is the possibility that group differences on the posttest are due to preexisting group differences rather than to treatment effects. A two-way analysis of covariance was used to reduce the effects of any initial group differences statistically by making compensating adjustments on the
posttest means of the two groups. The mean scores on the combined mathematics sections of the California Achievement Test given at the beginning of the school year served as the covariate to adjust the posttest means on the Algebra Achievement Test and on the California Achievement Test given near the end of the school year.

The sample consisted of two eighth grade classes and four ninth grade classes randomly selected from the junior high school and two Algebra I classes randomly selected from the high school. This study involved 171 students. These classes were randomly assigned to control and experimental groups so that there was one eighth grade Algebra I class, two ninth grade Algebra I classes, and one high school Algebra I class in each group.

Both the experimental group and the control group used HBJ Algebra I as the textbook for the course. The control group was taught in the traditional manner without calculators in the classroom. The teachers involved in the study attended workshops on effective use of the calculator in secondary mathematics. In the experimental classes, the calculator was used as both an instructional and a computational aid. The calculator was utilized to promote concept discovery and to facilitate problem solving activities. Teachers were cautioned not to use calculators during tutorial sessions with students in the control
groups. Teachers were also warned of the possibilities of the halo effect.

At the beginning of the school year all students involved in the study were given the mathematics sections of the California Achievement Test. At the end of the school year all students were again given the mathematics sections of the California Achievement Test. A two-way analysis of covariance was applied to pretest and posttest means to determine basic skills maintenance. All students were given the Scott Foresman Algebra I Test to serve as an indicator of achievement in Algebra I. Students were also given the Mathematics Attitude Inventory in September and in April.

Data Analysis

All hypotheses were stated in the null form for statistical analysis:
1. There will be no significant difference between the mean scores on a standardized test of algebra achievement of students in Algebra I classes who use calculators during mathematics instruction and students in Algebra I classes who do not use calculators during mathematics instruction.
2. There will be no significant difference between the mean scores on a standardized test of algebra achievement of eighth-grade students in Algebra I classes who use calculators during mathematics instruction and eighth-grade
students in Algebra I classes who do not use calculators during mathematics instruction.

3. There will be no significant difference between the mean scores on a standardized test of algebra achievement of ninth-grade students in Algebra I classes who use calculators during mathematics instruction and ninth-grade students in Algebra I classes who do not use calculators during mathematics instruction.

4. There will be no significant difference between the mean scores on a standardized test of algebra achievement of tenth- and eleventh-grade students in Algebra I classes who use calculators during mathematics instruction and tenth- and eleventh-grade students in Algebra I classes who do not use calculators during mathematics instruction.

A two-way analysis of covariance was applied to the posttest mean scores of the control and experimental groups on the Algebra I achievement test, using mean scores from the combined mathematics sections of the California Achievement Test as the covariate, to determine if there was a significant difference in algebra achievement between the control and experimental groups. The level of significance was chosen at the .05 level. This indicates that if the calculated value for F is greater than the critical value at the .05 level the difference is considered significant and the null hypothesis that there is no difference in means is rejected and the alternate hypothesis that there is a
difference is accepted. By choosing the .05 level of significance the chance of making a Type I error is less than five out of one hundred. This means the probability is less than .05 that there is not a true difference in the group means and the null hypothesis is true.

The remaining hypotheses were stated in the null form:
5. There will be no significant difference in basic skills maintenance between students in Algebra I classes who use calculators during mathematics instruction and those who do not use calculators during mathematics instruction.
6. There will be no significant difference in basic skills maintenance between eighth-grade students in Algebra I classes who use calculators during mathematics instruction and eighth-grade students in Algebra I classes who do not use calculators during mathematics instruction.
7. There will be no significant difference in basic skills maintenance between ninth-grade students in Algebra I classes who use calculators during mathematics instruction and ninth-grade students in Algebra I classes who do not use calculators during mathematics instruction.
8. There will be no significant difference in basic skills maintenance between students in Algebra I classes in grades ten and eleven who use calculators during mathematics instruction and students in Algebra I classes in grades ten and eleven who do not use calculators during mathematics instruction.
9. There will be no significant difference in attitudes toward mathematics between those students in Algebra I classes who use calculators during classroom mathematics instruction and those students in Algebra I classes who do not use calculators during classroom mathematics instruction.

Basic skills mean scores for each group were compared using analysis of covariance, with the mean scores on the pretest serving as the covariate. The level of significance was chosen at the .05 level.
CHAPTER IV

PRESENTATION AND ANALYSIS OF DATA

The purpose of this study is to investigate the effects of calculator usage in Algebra I classrooms during mathematics instruction on algebra achievement and basic mathematics skills maintenance. These effects were investigated by testing the nine hypotheses:

1. There will be no significant difference between the mean scores on a standardized test of algebra achievement of students in Algebra I classes who use calculators during mathematics instruction and students in Algebra I classes who do not use calculators during mathematics instruction.

2. There will be no significant difference between the mean scores on a standardized test of algebra achievement of eighth-grade students in Algebra I classes who use calculators during mathematics instruction and eighth-grade students in Algebra I classes who do not use calculators during mathematics instruction.

3. There will be no significant difference between the mean scores on a standardized test of algebra achievement of ninth-grade students in Algebra I classes who use calculators during mathematics instruction and ninth-grade students in Algebra I classes who do not use calculators during mathematics instruction.
4. There will be no significant difference between the mean scores on a standardized test of algebra achievement of tenth- and eleventh-grade students in Algebra I classes who use calculators during mathematics instruction and tenth- and eleventh-grade students in Algebra I classes who do not use calculators during mathematics instruction.

5. There will be no significant difference in scores on a standardized test of basic mathematics skills between students in Algebra I classes who use calculators during classroom mathematics instruction and students in Algebra I classes who do not use calculators during classroom mathematics instruction.

6. There will be no significant difference in scores on a standardized test of basic mathematics skills between eighth-grade students in Algebra I classes who use calculators during classroom mathematics instruction and eighth-grade students in Algebra I classes who do not use calculators during classroom mathematics instruction.

7. There will be no significant difference in scores on a standardized test of basic mathematics skills between ninth-grade students in Algebra I classes who use calculators during classroom mathematics instruction and ninth-grade students in Algebra I classes who do not use calculators during classroom mathematics instruction.

8. There will be no significant difference in scores on a standardized test of basic mathematics skills between tenth-
and eleventh-grade students in Algebra I classes who use calculators during classroom mathematics instruction and tenth- and eleventh-grade students in Algebra I classes who do not use calculators during classroom mathematics instruction.

9. There will be no significant difference in attitudes toward mathematics between those students in Algebra I classes who use calculators during classroom mathematics instruction and those students in Algebra I classes who do not use calculators during classroom mathematics instruction.

The first four hypotheses were tested using ANCOVA with the scores on the pretest in basic skills as the covariate and the scores on the test of algebra achievement as the dependent variable. The next four hypotheses were also tested using ANCOVA with the scores on the pretest in basic skills as the covariate and the scores on the posttest in basic skills as the dependent variable. The ninth hypothesis was tested using ANCOVA with the scores on the pretest of mathematics attitudes as the covariate and the scores on the posttest of mathematics attitudes as the dependent variable.

Hypothesis One

Hypothesis one states that there will be no significant difference between the mean scores on a standardized test of algebra achievement of students in Algebra I classes who use
calculators during mathematics instruction and students in Algebra I classes who do not use calculators during mathematics instruction.

This hypothesis was tested using ANCOVA with the pretest scores on the mathematics portion of the California Achievement Test as the covariate and the scores on the Scott Foresman Algebra I Test as the dependent variable. The means and standard deviations of the scores are presented in table 2.

Table 2
Means and Standard Deviations in Algebra Achievement Scores for All Subjects

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Deviation</th>
<th>Observed Mean</th>
<th>Adjusted Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>80</td>
<td>72.16</td>
<td>11.14</td>
<td>40.22</td>
<td>40.09</td>
<td>12.15</td>
</tr>
<tr>
<td>Treatment</td>
<td>82</td>
<td>71.80</td>
<td>10.92</td>
<td>36.80</td>
<td>36.93</td>
<td>13.24</td>
</tr>
<tr>
<td>Total</td>
<td>162</td>
<td>71.98</td>
<td>11.00</td>
<td>38.49</td>
<td>38.49</td>
<td>12.79</td>
</tr>
</tbody>
</table>

The results of the ANCOVA presented in table 3 show there is a significant difference (p < .05) in the adjusted mean posttest scores of algebra achievement for the control and experimental group. Thus the null hypothesis that there is no difference is rejected. Since the adjusted mean score for the control group (40.09) is greater than the adjusted
mean score for the experimental group (36.93) the original hypothesis that the experimental group would score significantly higher than the control group is also rejected.

Table 3

**Effect of Calculator Usage on Algebra Achievement**

*Controlling for Initial Differences Between Groups*

<table>
<thead>
<tr>
<th>Effect</th>
<th>Sum of Degrees of Mean Squares</th>
<th>Freedom</th>
<th>Mean Squares</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td>10135.99</td>
<td>1</td>
<td>10135.99</td>
<td>102.52</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Treatment</td>
<td>405.35</td>
<td>1</td>
<td>405.35</td>
<td>4.10</td>
<td>.0418</td>
</tr>
<tr>
<td>Within</td>
<td>15719.86</td>
<td>159</td>
<td>98.87</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Hypothesis Two**

Hypothesis two states that there will be no significant difference between the mean scores on a standardized test of algebra achievement of eighth-grade students in Algebra I classes who use calculators during mathematics instruction and eighth-grade students in Algebra I classes who do not use calculators during mathematics instruction.

This hypothesis was tested using ANCOVA with the pretest scores on the mathematics portion of the California Achievement Test as the covariate and the scores on the Scott Foresman Algebra I Test as the dependent variable.
The means and standard deviations of the scores for eighth-grade Algebra I students are presented in Table 4.

Table 4

Means and Standard Deviations in Algebra Scores for Eighth-Grade Algebra I Students

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean Pretest Mean</th>
<th>Standard Deviation</th>
<th>Observed Mean</th>
<th>Adjusted Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>17</td>
<td>69.92</td>
<td>9.82</td>
<td>39.71</td>
<td>41.92</td>
<td>8.29</td>
</tr>
<tr>
<td>Treatment</td>
<td>15</td>
<td>76.64</td>
<td>8.22</td>
<td>47.83</td>
<td>45.32</td>
<td>12.81</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
<td>73.07</td>
<td>9.59</td>
<td>43.52</td>
<td>43.52</td>
<td>11.25</td>
</tr>
</tbody>
</table>

The results of the ANCOVA presented in Table 5 show there is no significant difference ($p > .05$) in the adjusted mean posttest scores of algebra achievement for the control group and the experimental group. Thus the null hypothesis that there is no difference between the mean scores on a test of algebra achievement for eighth-grade algebra students who use calculators during mathematics instruction and eighth-grade algebra students who do not use calculators during mathematics instruction is accepted.
Table 5

Effect of Calculator Usage on Algebra Achievement of Eighth-Grade Algebra I Students Controlling for Initial Differences Between Groups

<table>
<thead>
<tr>
<th>Effect</th>
<th>Sum of Degrees of Mean</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Squares</td>
<td>Freedom</td>
<td>Squares</td>
<td>F</td>
<td>p</td>
</tr>
<tr>
<td>Covariate</td>
<td>1230.29</td>
<td>1</td>
<td>1230.27</td>
<td>16.47</td>
<td>.0005</td>
</tr>
<tr>
<td>Treatment</td>
<td>80.61</td>
<td>1</td>
<td>80.61</td>
<td>1.08</td>
<td>.3082</td>
</tr>
<tr>
<td>Within</td>
<td>2166.59</td>
<td>29</td>
<td>74.71</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Hypothesis Three

Hypothesis three states that there will be no significant difference between the mean scores on a standardized test of algebra achievement of ninth-grade students in Algebra I classes who use calculators during mathematics instruction and ninth-grade students in Algebra I classes who do not use calculators during mathematics instruction.

This hypothesis was tested using ANCOVA with the pretest scores on the mathematics portion of the California Achievement Test as the covariate and the scores on the Scott Foresman Algebra I Test as the dependent variable. The means and standard deviations of the scores for ninth-grade Algebra I students are presented in table 6.
Table 6

Means and Standard Deviations in Algebra Scores for
Ninth-Grade Algebra I Students

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Observed Mean</th>
<th>Adjusted Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>45</td>
<td>75.77</td>
<td>8.26</td>
<td>42.78</td>
<td>41.47</td>
<td>9.87</td>
</tr>
<tr>
<td>Treatment</td>
<td>43</td>
<td>71.12</td>
<td>12.17</td>
<td>35.99</td>
<td>37.35</td>
<td>12.78</td>
</tr>
<tr>
<td>Total</td>
<td>88</td>
<td>73.50</td>
<td>10.56</td>
<td>39.46</td>
<td>39.46</td>
<td>11.83</td>
</tr>
</tbody>
</table>

Table 7

Effect of Calculator Usage on Algebra Achievement of
Ninth-Grade Algebra I Students Controlling for Initial
Differences Between Groups

<table>
<thead>
<tr>
<th>Effect</th>
<th>Sum of Degrees of Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sqaures</td>
</tr>
<tr>
<td>Covariate</td>
<td>3035.93</td>
</tr>
<tr>
<td>Treatment</td>
<td>355.41</td>
</tr>
<tr>
<td>Within</td>
<td>8118.59</td>
</tr>
</tbody>
</table>

The results of the ANCOVA presented in table 7 show there is no significant difference (p > .05) in the adjusted mean posttest scores of algebra achievement for the control
group and the experimental group. Although there was a slight difference between the group means (\( p = .05 \)) the difference is not statistically significant at the .05 level and the null hypothesis that there is no difference is accepted.

**Hypothesis Four**

Hypothesis four states that there will be no significant difference between the mean scores on a standardized test of algebra achievement of tenth- and eleventh-grade students in Algebra I classes who use calculators during mathematics instruction and tenth- and eleventh-grade students in Algebra I classes who do not use calculators during mathematics instruction.

This hypothesis was tested using ANCOVA with the pretest scores on the mathematics portion of the California Achievement Test as the covariate and the scores on the Scott Foresman Algebra I Test as the dependent variable. The means and standard deviations of the scores for ninth-grade Algebra I students are presented in table 8.

The results of the ANCOVA presented in table 9 show there is a significant difference (\( p < .05 \)) in the adjusted mean posttest scores of algebra achievement for the control group and the experimental group. Thus the null hypothesis that there is no difference is rejected. Since the adjusted mean score for the control group (36.56) is greater than the adjusted mean score for the experimental group (29.66) the
original hypothesis that the students who used calculators would score higher than the students who did not use calculators is also rejected.

Table 8

Means and Standard Deviations in Algebra Scores for Tenth- and Eleventh-Grade Algebra I Students

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Pretest Mean</th>
<th>Pretest Deviation</th>
<th>Posttest Mean</th>
<th>Posttest Adjusted Mean</th>
<th>Posttest Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>18</td>
<td>65.24</td>
<td>14.78</td>
<td>34.31</td>
<td>36.56</td>
<td>17.74</td>
</tr>
<tr>
<td>Treatment</td>
<td>24</td>
<td>70.00</td>
<td>9.44</td>
<td>31.35</td>
<td>29.66</td>
<td>10.35</td>
</tr>
<tr>
<td>Total</td>
<td>42</td>
<td>67.96</td>
<td>12.09</td>
<td>32.62</td>
<td>32.62</td>
<td>13.88</td>
</tr>
</tbody>
</table>

Table 9

Effect of Calculator Usage on Algebra Achievement of Tenth- and Eleventh-Grade Algebra I Students Controlling for Initial Differences Between Groups

<table>
<thead>
<tr>
<th>Effect</th>
<th>Sum of Degrees of Squares</th>
<th>Freedom</th>
<th>Mean Squares</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td>3949.66</td>
<td>1</td>
<td>3949.66</td>
<td>39.90</td>
<td>.0001</td>
</tr>
<tr>
<td>Treatment</td>
<td>469.83</td>
<td>1</td>
<td>469.83</td>
<td>4.75</td>
<td>.0334</td>
</tr>
<tr>
<td>Within</td>
<td>3860.14</td>
<td>39</td>
<td>98.97</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Hypothesis Five

Hypothesis five states that there will be no significant difference in scores on a standardized test of basic mathematics skills between students in Algebra I classes who use calculators during classroom mathematics instruction and students in Algebra I classes who do not use calculators during classroom mathematics instruction.

This hypothesis was tested using ANCOVA with the pretest scores on the mathematics portion of the California Achievement Test as the covariate and the posttest scores on the mathematics portion of the California Achievement Test as the dependent variable. The means and standard deviations of the scores for all subjects are presented in table 10.

Table 10
Means and Standard Deviations in Scores on Test of Basic Mathematics Skills for Algebra I Students

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Pretest Mean</th>
<th>Pretest Standard Deviation</th>
<th>Posttest Mean</th>
<th>Posttest Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>80</td>
<td>72.16</td>
<td>11.14</td>
<td>75.01</td>
<td>11.88</td>
</tr>
<tr>
<td>Treatment</td>
<td>82</td>
<td>71.80</td>
<td>10.92</td>
<td>71.95</td>
<td>13.03</td>
</tr>
<tr>
<td>Total</td>
<td>162</td>
<td>71.98</td>
<td>11.00</td>
<td>73.46</td>
<td>12.53</td>
</tr>
</tbody>
</table>
The results of the ANCOVA presented in table 11 show there is a significant difference (p < .05) in the adjusted mean posttest scores on a test of basic mathematics skills for Algebra I students who used calculators during mathematics instruction and Algebra I students who did not use calculators during mathematics instruction. Thus the hypothesis that there is no difference between the mean scores of the two groups is rejected. The adjusted mean score (74.85) of students who did not use calculators is greater than the adjusted mean score (72.11) of students who used calculators.

Table 11

**Effect of Calculator Usage on Basic Mathematics Skills of Algebra I Students Controlling for Initial Differences Between Groups**

<table>
<thead>
<tr>
<th>Effect</th>
<th>Sum of Degrees of Freedom</th>
<th>Mean Squares</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td>16044.16</td>
<td>16044.16</td>
<td>288.21</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Treatment</td>
<td>303.84</td>
<td>303.84</td>
<td>5.46</td>
<td>.0195</td>
</tr>
<tr>
<td>Within</td>
<td>8851.25</td>
<td>159</td>
<td>55.67</td>
<td></td>
</tr>
</tbody>
</table>

**Hypothesis Six**

Hypothesis six states that there will be no significant difference in scores on a standardized test of basic
mathematics skills between eighth-grade students in Algebra I classes who use calculators during classroom mathematics instruction and eighth-grade students in Algebra I classes who do not use calculators during classroom mathematics instruction.

This hypothesis was tested using ANCOVA with the pretest scores on the mathematics portion of the California Achievement Test as the covariate and the posttest scores on the mathematics portion of the California Achievement Test as the dependent variable. The means and standard deviations of the scores for eighth-grade Algebra I students are presented in table 12.

Table 12
Means and Standard Deviations in Scores on Test of Basic Mathematics Skills for Eighth-Grade Algebra I Students

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Pretest Mean</th>
<th>Deviation</th>
<th>Posttest Mean</th>
<th>Adjusted Mean</th>
<th>Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>17</td>
<td>69.92</td>
<td>9.82</td>
<td>74.73</td>
<td>77.15</td>
<td>9.54</td>
</tr>
<tr>
<td>Treatment</td>
<td>15</td>
<td>76.64</td>
<td>8.22</td>
<td>80.00</td>
<td>77.27</td>
<td>9.56</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
<td>73.07</td>
<td>9.59</td>
<td>77.20</td>
<td>77.20</td>
<td>9.76</td>
</tr>
</tbody>
</table>

The results of the ANCOVA presented in table 13 show there is no significant difference (p > .05) in the adjusted
mean posttest scores of basic mathematics achievement for eighth-grade Algebra I students who use calculators during mathematics instruction and eighth-grade Algebra I students who do not use calculators during mathematics instruction. Thus the hypothesis that there is no difference is accepted.

Table 13

Effect of Calculator Usage on Basic Mathematics Skills of Eighth-Grade Algebra I Students Controlling for Initial Differences Between Groups

<table>
<thead>
<tr>
<th>Effect</th>
<th>Sum of Degrees of Mean Squares</th>
<th>Freedom</th>
<th>Sum of Degrees of Mean Squares</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td>1460.22</td>
<td>1</td>
<td>1460.22</td>
<td>33.26</td>
<td>.0003</td>
</tr>
<tr>
<td>Treatment</td>
<td>.10</td>
<td>1</td>
<td>.10</td>
<td>0.00</td>
<td>.9154</td>
</tr>
<tr>
<td>Within</td>
<td>1273.18</td>
<td>29</td>
<td>43.90</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Hypothesis Seven

Hypothesis seven states that there will be no significant difference in scores on a standardized test of basic mathematics skills between ninth-grade students in Algebra I classes who use calculators during classroom mathematics instruction and ninth-grade students in Algebra
I classes who do not use calculators during classroom mathematics instruction.

Table 14

Means and Standard Deviations in Scores on Test of Basic Mathematics Skills for Ninth-Grade Algebra I Students

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Pretest Mean</th>
<th>Pretest Standard Deviation</th>
<th>Posttest Mean</th>
<th>Posttest Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>45</td>
<td>75.77</td>
<td>8.26</td>
<td>76.89</td>
<td>10.83</td>
</tr>
<tr>
<td>Treatment</td>
<td>43</td>
<td>71.12</td>
<td>12.17</td>
<td>73.22</td>
<td>12.20</td>
</tr>
<tr>
<td>Total</td>
<td>88</td>
<td>73.50</td>
<td>10.56</td>
<td>75.10</td>
<td>11.60</td>
</tr>
</tbody>
</table>

This hypothesis was tested using ANCOVA with the pretest scores on the mathematics portion of the California Achievement Test as the covariate and the posttest scores on the mathematics portion of the California Achievement Test as the dependent variable. The means and standard deviations of the scores for ninth-grade Algebra I students are presented in table 14.

The results of the ANCOVA presented in table 15 show there is no significant difference ($p > .05$) in the adjusted mean posttest scores of basic mathematics achievement for the control group and the experimental group. Thus the hypothesis that there is no difference is accepted.
Table 15

Effect of Calculator Usage on Basic Mathematics Skills of Ninth-Grade Algebra I Students Controlling for Initial Differences Between Groups

<table>
<thead>
<tr>
<th>Effect</th>
<th>Sum of Degrees of Mean</th>
<th>Freedom</th>
<th>Squares</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td>8016.21</td>
<td>1</td>
<td>8016.21</td>
<td>200.72</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Treatment</td>
<td>9.30</td>
<td>1</td>
<td>9.30</td>
<td>.23</td>
<td>.6360</td>
</tr>
<tr>
<td>Within</td>
<td>3394.72</td>
<td>85</td>
<td>39.94</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Hypothesis Eight

Hypothesis eight states that there will be no significant difference in scores on a standardized test of basic mathematics skills between tenth- and eleventh-grade students in Algebra I classes who use calculators during classroom mathematics instruction and tenth- and eleventh-grade students in Algebra I classes who do not use calculators during classroom mathematics instruction.

This hypothesis was tested using ANCOVA with the pretest scores on the mathematics portion of the California Achievement Test as the covariate and the posttest scores on the mathematics portion of the California Achievement Test as the dependent variable. The means and standard deviations of the scores for tenth- and eleventh-grade
Algebra I students on the mathematics portion of the California Achievement Test are presented in Table 16.

**Table 16**

**Means and Standard Deviations in Scores on Test of Basic Mathematics Skills for Tenth- and Eleventh-Grade Algebra I Students**

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Pretest Mean</th>
<th>Pretest Standard Deviation</th>
<th>Posttest Mean</th>
<th>Posttest Adjusted Mean</th>
<th>Posttest Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>18</td>
<td>65.24</td>
<td>14.78</td>
<td>70.58</td>
<td>73.15</td>
<td>15.36</td>
</tr>
<tr>
<td>Treatment</td>
<td>24</td>
<td>70.00</td>
<td>9.44</td>
<td>64.64</td>
<td>62.72</td>
<td>13.03</td>
</tr>
<tr>
<td>Total</td>
<td>42</td>
<td>67.96</td>
<td>12.09</td>
<td>67.19</td>
<td>67.19</td>
<td>14.21</td>
</tr>
</tbody>
</table>

**Table 17**

**Effect of Calculator Usage on Basic Mathematics Skills of Tenth- and Eleventh-Grade Algebra I Students Controlling for Initial Differences Between Groups**

<table>
<thead>
<tr>
<th>Effect</th>
<th>Sum of Degrees of Freedom</th>
<th>Mean Squares</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td>1</td>
<td>5123.83</td>
<td>71.59</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Treatment</td>
<td>1</td>
<td>1075.60</td>
<td>15.03</td>
<td>.0006</td>
</tr>
<tr>
<td>Within</td>
<td>39</td>
<td>2791.16</td>
<td>71.57</td>
<td></td>
</tr>
</tbody>
</table>
The results of the ANCOVA presented in table 17 show there is a significant difference ($p < .05$) in the adjusted mean posttest scores of basic mathematics achievement for the control group and the experimental group. Thus the hypothesis that there is no difference is rejected.

Hypothesis Nine

Hypothesis nine states that there will be no significant difference in attitudes toward mathematics between those students in Algebra I classes who use calculators during classroom mathematics instruction and those students in Algebra I classes who do not use calculators during classroom mathematics instruction. The Mathematics Attitude Inventory was administered at the beginning of this study and again at the conclusion to check for any differences in attitudes toward mathematics.

The Mathematics Attitude Inventory (MAI) was developed at the Minnesota Research and Evaluation Center in connection with an evaluation program sponsored by the National Science Foundation as a research tool for the determination of group attitudes toward mathematics and the changes in these attitudes. The MAI consists of forty-eight statements about the study of mathematics and is designed to measure six different constructs of mathematics attitude: perception of the mathematics teacher, anxiety toward mathematics, value of mathematics in society, self-concept in mathematics, enjoyment of mathematics, and motivation in
mathematics. The reliability of each scale, as determined by Cronbach's alpha coefficient, ranges from .68 for the motivation scale to .89 for the enjoyment scale. This is based on the data from 5034 students.

Each of the six scales was investigated individually using ANCOVA with the posttest score on the individual scale as the dependent variable and the pretest score on the same scale as the covariate. Group membership, control or experimental, served as the independent variable.

Scale One: Perception of the Mathematics Teacher

This scale indicates a student's view regarding the teaching characteristics of the mathematics teacher. The hypothesis tested is that there will be no significant difference between the mean scores on the MAI scale measuring perception of the mathematics teacher for students in Algebra I classes who use calculators during mathematics instruction and students in Algebra I classes who do not use calculators during mathematics instruction. The means and standard deviations for this scale are given in table 18.

The results of the ANCOVA presented in table 19 show there is no significant difference (p > .05) in the adjusted mean posttest scores on this scale for the Algebra I students who used calculators during mathematics instruction and those Algebra I students who did not use calculators during mathematics instruction. Thus the hypothesis that there is no difference is accepted.
Table 18
Means and Standard Deviations in Scores on Perception of Mathematics Teacher Scale

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Pretest Mean</th>
<th>Pretest Standard Deviation</th>
<th>Posttest Observed Mean</th>
<th>Posttest Adjusted Mean</th>
<th>Posttest Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>80</td>
<td>27.18</td>
<td>4.15</td>
<td>26.44</td>
<td>26.57</td>
<td>4.41</td>
</tr>
<tr>
<td>Treatment</td>
<td>82</td>
<td>27.70</td>
<td>3.47</td>
<td>25.96</td>
<td>25.83</td>
<td>4.53</td>
</tr>
<tr>
<td>Total</td>
<td>162</td>
<td>27.44</td>
<td>3.82</td>
<td>26.20</td>
<td>26.20</td>
<td>4.46</td>
</tr>
</tbody>
</table>

Table 19
Effect of Calculator Usage on Student Perception of the Mathematics Teacher for Algebra I Students Controlling for Initial Differences Between Groups

<table>
<thead>
<tr>
<th>Effect</th>
<th>Sum of Degrees of Mean Squares</th>
<th>Freedom</th>
<th>Mean Squares</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td>585.23</td>
<td>1</td>
<td>585.23</td>
<td>35.58</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Treatment</td>
<td>21.73</td>
<td>1</td>
<td>21.73</td>
<td>1.32</td>
<td>.2507</td>
</tr>
<tr>
<td>Within</td>
<td>2615.35</td>
<td>159</td>
<td>16.45</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Scale Two: Anxiety Toward Mathematics

This scale indicates the uneasiness a student feels in situations involving mathematics. The hypothesis tested is
that there will be no significant difference between the mean scores on the MAI scale measuring anxiety toward mathematics of students in Algebra I classes who use calculators during mathematics instruction and students in Algebra I classes who do not use calculators during mathematics instruction. The means and standard deviations for this scale are given in table 20.

Table 20
Means and Standard Deviations for Anxiety Scale

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Pretest Mean</th>
<th>Pretest Standard Deviation</th>
<th>Posttest Observed Mean</th>
<th>Posttest Adjusted Mean</th>
<th>Posttest Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>80</td>
<td>11.81</td>
<td>3.54</td>
<td>12.79</td>
<td>12.75</td>
<td>3.25</td>
</tr>
<tr>
<td>Treatment</td>
<td>82</td>
<td>11.52</td>
<td>2.87</td>
<td>12.21</td>
<td>12.25</td>
<td>3.20</td>
</tr>
<tr>
<td>Total</td>
<td>162</td>
<td>11.67</td>
<td>3.21</td>
<td>12.49</td>
<td>12.49</td>
<td>3.23</td>
</tr>
</tbody>
</table>

The results of the ANCOVA presented in table 21 show there is no significant difference (p > .05) in the adjusted mean posttest scores on the scale for anxiety toward mathematics for the Algebra I students who used calculators during mathematics instruction and those Algebra I students who did not use calculators during mathematics instruction. Thus the hypothesis that there is no difference is accepted.
Table 21
Effect of Calculator Usage on Anxiety Toward Mathematics of Algebra I Students Controlling for Initial Differences Between Groups

<table>
<thead>
<tr>
<th>Effect</th>
<th>Sum of Degrees of Mean</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Squares</td>
<td>Freedom</td>
<td>Squares</td>
<td>F</td>
<td>p</td>
</tr>
<tr>
<td>Covariate</td>
<td>117.73</td>
<td>1</td>
<td>117.73</td>
<td>12.12</td>
<td>.0009</td>
</tr>
<tr>
<td>Treatment</td>
<td>10.24</td>
<td>1</td>
<td>10.24</td>
<td>1.05</td>
<td>.3068</td>
</tr>
<tr>
<td>Within</td>
<td>1545.13</td>
<td>159</td>
<td></td>
<td>9.72</td>
<td></td>
</tr>
</tbody>
</table>

Scale Three: Value of Mathematics in Society

This scale indicates a student's view regarding the usefulness of mathematical knowledge. The hypothesis tested is that there will be no significant difference between the mean scores on the MAI scale measuring the value of mathematics in society for students in Algebra I classes who use calculators during mathematics instruction and students in Algebra I classes who do not use calculators during mathematics instruction. The means and standard deviations for this scale are given in table 22.

The results of the ANCOVA presented in table 23 show there is no significant difference (p > .05) in the adjusted mean posttest scores on the scale measuring the students' value of mathematics in society for the Algebra I students who used calculators during mathematics instruction and
those Algebra I students who did not use calculators during mathematics instruction. Thus the hypothesis that there is no difference in the value of mathematics in society by students in Algebra I who use calculators and students in Algebra I who do not use calculators is accepted.

Table 22
Means and Standard Deviations for Value of Mathematics in Society Scale

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Pretest Mean</th>
<th>Pretest Standard Deviation</th>
<th>Observed Mean</th>
<th>Adjusted Mean</th>
<th>Posttest Mean</th>
<th>Posttest Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>80</td>
<td>23.78</td>
<td>3.22</td>
<td>23.46</td>
<td>23.60</td>
<td>3.39</td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>82</td>
<td>24.44</td>
<td>2.56</td>
<td>23.46</td>
<td>23.33</td>
<td>3.55</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>162</td>
<td>24.11</td>
<td>2.91</td>
<td>23.46</td>
<td>23.46</td>
<td>3.46</td>
<td></td>
</tr>
</tbody>
</table>

Table 23
Effect of Calculator Usage on Value of Mathematics Controlling for Initial Differences Between Groups

<table>
<thead>
<tr>
<th>Effect</th>
<th>Sum of Degrees of Mean</th>
<th>Mean Squares</th>
<th>Freedom</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td></td>
<td>215.69</td>
<td>1</td>
<td>20.03</td>
<td>.0009</td>
</tr>
<tr>
<td>Treatment</td>
<td></td>
<td>2.80</td>
<td>1</td>
<td>.26</td>
<td>.6173</td>
</tr>
<tr>
<td>Within</td>
<td></td>
<td>1712.59</td>
<td>159</td>
<td>10.77</td>
<td></td>
</tr>
</tbody>
</table>
Scale Four: Self-Concept in Mathematics

This scale indicates a student's perception of his or her own competence in mathematics. The hypothesis tested is that there will be no significant difference between the mean scores on the MAI scale measuring self-concept in mathematics of students in Algebra I classes who use calculators during mathematics instruction and students in Algebra I classes who do not use calculators during mathematics instruction. The means and standard deviations for this scale are given in table 24.

Table 24
Means and Standard Deviations for Self-Concept in Mathematics Scale

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Deviation</th>
<th>Observed Mean</th>
<th>Adjusted Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>80</td>
<td>17.74</td>
<td>4.00</td>
<td>16.18</td>
<td>16.21</td>
<td>3.88</td>
</tr>
<tr>
<td>Treatment</td>
<td>82</td>
<td>17.90</td>
<td>2.62</td>
<td>16.94</td>
<td>16.91</td>
<td>3.20</td>
</tr>
<tr>
<td>Total</td>
<td>162</td>
<td>17.82</td>
<td>3.36</td>
<td>16.56</td>
<td>16.56</td>
<td>3.56</td>
</tr>
</tbody>
</table>

The results of the ANCOVA presented in table 25 show there is no significant difference (p > .05) in the adjusted mean posttest scores on this scale for the Algebra I students who used calculators during mathematics instruction...
and those Algebra I students who did not use calculators during mathematics instruction. Thus the hypothesis that there is no difference is accepted.

Table 25

**Effect of Calculator Usage on Self-Concept in Mathematics for Algebra I Students Controlling for Initial Differences Between Groups**

<table>
<thead>
<tr>
<th>Effect</th>
<th>Sum of Degrees of Mean Squares</th>
<th>Freedom</th>
<th>Mean Squares</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td>270.04</td>
<td>1</td>
<td>270.04</td>
<td>24.56</td>
<td>.0003</td>
</tr>
<tr>
<td>Treatment</td>
<td>19.86</td>
<td>1</td>
<td>19.86</td>
<td>1.81</td>
<td>.1775</td>
</tr>
<tr>
<td>Within</td>
<td>1748.21</td>
<td>159</td>
<td>11.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Scale Five: Enjoyment of Mathematics

This scale indicates the pleasure a student derives from engaging in mathematical activities. The hypothesis tested is that there will be no significant difference between the mean scores on the MAI scale measuring enjoyment of mathematics for students in Algebra I classes who use calculators during mathematics instruction and students in Algebra I classes who do not use calculators during mathematics instruction. The means and standard deviations for this scale are given in table 26.
Table 26
Means and Standard Deviations for Enjoyment of Mathematics Scale

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Deviation</th>
<th>Pretest Standard</th>
<th>Observed Mean</th>
<th>Adjusted Mean</th>
<th>Posttest Standard</th>
<th>Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>80</td>
<td>18.98</td>
<td>4.33</td>
<td>17.79</td>
<td>17.97</td>
<td>17.97</td>
<td>4.32</td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>82</td>
<td>19.67</td>
<td>3.57</td>
<td>18.44</td>
<td>18.26</td>
<td>18.26</td>
<td>4.04</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>162</td>
<td>19.33</td>
<td>3.97</td>
<td>18.12</td>
<td>18.12</td>
<td>18.12</td>
<td>4.18</td>
<td></td>
</tr>
</tbody>
</table>

The results of the ANCOVA presented in table 27 show there is no significant difference (p > .05) in the adjusted mean posttest scores indicating enjoyment of mathematics for the Algebra I students who used calculators during mathematics instruction and those Algebra I students who did not use calculators during mathematics instruction. Thus the hypothesis that there is no difference in enjoyment of mathematics is accepted.

The results of the ANCOVA presented in table 27 show there is no significant difference (p > .05) in the adjusted mean posttest scores on this scale for the Algebra I students who used calculators during mathematics instruction and those Algebra I students who did not use calculators during mathematics instruction. Thus the hypothesis that there is no difference is accepted.
Table 27

**Effect of Calculator Usage on Enjoyment of Mathematics for Algebra I Students Controlling for Initial Differences Between Groups**

<table>
<thead>
<tr>
<th>Effect</th>
<th>Sum of Degrees of Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Squares</td>
</tr>
<tr>
<td>Covariate</td>
<td>678.88</td>
</tr>
<tr>
<td>Treatment</td>
<td>3.38</td>
</tr>
<tr>
<td>Within</td>
<td>2118.70</td>
</tr>
</tbody>
</table>

Scale Six: Motivation in Mathematics

This scale indicates a student's desire to increase his or her knowledge and understanding of mathematics. The hypothesis tested is that there will be no significant difference between the mean scores on the MAI scale measuring motivation in mathematics for students in Algebra I classes who use calculators during mathematics instruction and students in Algebra I classes who do not use calculators during mathematics instruction. The means and standard deviations for this scale are given in table 28.

The results of the ANCOVA presented in table 29 show there is no significant difference (p > .05) in the adjusted mean posttest scores indicating motivation in mathematics for the Algebra I students who used calculators during
mathematics instruction and those Algebra I students who did not use calculators during mathematics instruction. Thus the hypothesis that there is no difference in enjoyment of mathematics is accepted.

Table 28

Means and Standard Deviations for Motivation in Mathematics Scale

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Deviation</th>
<th>Mean</th>
<th>Mean</th>
<th>Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>80</td>
<td>7.75</td>
<td>2.02</td>
<td>7.49</td>
<td>7.56</td>
<td>1.96</td>
</tr>
<tr>
<td>Treatment</td>
<td>82</td>
<td>8.31</td>
<td>2.36</td>
<td>7.82</td>
<td>7.75</td>
<td>2.11</td>
</tr>
<tr>
<td>Total</td>
<td>162</td>
<td>8.04</td>
<td>2.21</td>
<td>7.65</td>
<td>7.65</td>
<td>2.04</td>
</tr>
</tbody>
</table>

Table 29

Effect of Calculator Usage on Motivation in Mathematics for Algebra I Students Controlling for Initial Differences Between Groups

<table>
<thead>
<tr>
<th>Effect</th>
<th>Sum of Degrees of Freedom</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td>1</td>
<td>50.48</td>
<td>13.08</td>
<td>.0007</td>
</tr>
<tr>
<td>Treatment</td>
<td>1</td>
<td>1.36</td>
<td>0.35</td>
<td>.5611</td>
</tr>
<tr>
<td>Within</td>
<td>159</td>
<td>613.76</td>
<td>3.86</td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER V

SUMMARY OF FINDINGS, CONCLUSIONS, AND
RECOMMENDATIONS

This research study was an investigation of the effect of the use of the calculator during mathematics instruction in Algebra I classes on algebra achievement and basic skills maintenance. The experimental group used calculators during classroom mathematics instruction and the control group did not use calculators during classroom mathematics instruction. The study used differences in achievement levels in algebra and in basic mathematics skills between these two groups as a basis of comparison. Differences in achievement for various grade levels were also investigated.

Summary of Findings

The study involved 162 Algebra I students enrolled in a predominately White middle-class suburban school district in North Central Texas. Students in grades eight and nine were enrolled in the junior high school and students in grades ten and eleven were enrolled in the senior high school. Eight Algebra I classes participated in the study: two eighth-grade Algebra I classes, four ninth-grade Algebra I classes, and two tenth- and eleventh-grade Algebra I classes. Three teachers, two from the junior high school
and one from the high school, participated in the study. One teacher taught four of the classes which consisted of two eighth grade Algebra I classes and two ninth grade Algebra I classes. One eighth grade class and one ninth grade class were randomly assigned to the experimental group and the other two were assigned to the control group. The second teacher also taught two of the ninth grade Algebra I classes. One of these classes was randomly assigned to the experimental group and the other was assigned to the control group. The remaining teacher taught the two Algebra I classes selected at the senior high school. These classes were made up of both tenth- and eleventh-grade students. One class was randomly assigned to the experimental group and the other was assigned to the control group. The experimental group consisted of 82 students and the control group consisted of 80 students.

At the beginning of the study all students were given the mathematics portion of the California Achievement Test and the Mathematics Attitude Inventory. At the conclusion of the study all students were given the mathematics portion of the California Achievement Test, the Mathematics Attitude Inventory, and an algebra achievement test. The California Achievement Test and the algebra test were machine scored. The scores used represented the percent of correct responses. These scores were statistically analyzed by computer using analysis of covariance (ANCOVA) to examine
each hypothesis in the research study. The Mathematics Attitude Inventory was hand scored and the raw scores were statistically analyzed by computer using ANCOVA to compare students' attitudes toward mathematics.

Findings

The major findings resulting from the analysis of the statistical data presented in the study were the following:

1. A statistically significant difference (p < .05) was found between the adjusted mean scores on a test of algebra achievement for Algebra I students who used calculators during mathematics instruction and Algebra I students who did not use calculators during mathematics instruction.

2. The adjusted mean score on a test of algebra achievement for Algebra I students who did not use calculators during mathematics instruction was found to be significantly higher than Algebra I students who used calculators during mathematics instruction.

3. No significant statistical difference was found between the adjusted mean scores on a test of algebra achievement for eighth-grade Algebra I students who used calculators during mathematics instruction and eighth-grade Algebra I students who did not use calculators during mathematics instruction.

4. No significant statistical difference (p = .05) was found between the adjusted mean scores on a test of algebra
achievement for ninth-grade Algebra I students who used
calculators during mathematics instruction and ninth-grade
Algebra I students who did not use calculators during
mathematics instruction. The adjusted mean score for the
ninth-grade Algebra I students who did not use calculators
during mathematics instruction was slightly higher than the
ninth-grade Algebra I students who used calculators during
mathematics instruction.

5. A statistically significant difference \((p < .05)\)
was found in the adjusted mean scores on a test of algebra
achievement for tenth- and eleventh-grade Algebra I students
who used calculators during mathematics instruction and
tenth- and eleventh-grade Algebra I students who did not use
calculators during mathematics instruction.

6. The adjusted mean score on a test of algebra
achievement for the tenth- and eleventh-grade Algebra I
students who did not use calculators during mathematics
instruction was found to be significantly higher than the
tenth- and eleventh-grade Algebra I students who used
calculators during mathematics instruction.

7. A statistically significant difference \((p < .05)\)
was found between the adjusted mean scores on a test of
basic mathematics skills for Algebra I students who used
calculators during mathematics instruction and Algebra I
students who did not use calculators during mathematics
instruction.
8. The adjusted mean score on a test of basic mathematics skills for Algebra I students who did not use calculators during mathematics instruction was found to be significantly higher than Algebra I students who used calculators during mathematics instruction.

9. No significant statistical difference was found between the adjusted mean scores on a test of basic mathematics skills for eighth-grade Algebra I students who used calculators during mathematics instruction and eighth-grade Algebra I students who did not use calculators during mathematics instruction.

10. No significant statistical difference was found between the adjusted mean scores on a test of basic mathematics skills for ninth-grade Algebra I students who used calculators during mathematics instruction and ninth-grade Algebra I students who did not use calculators during mathematics instruction.

11. A statistically significant difference (p < .05) was found in the adjusted mean scores on a test of basic mathematics skills for tenth- and eleventh-grade Algebra I students who used calculators during mathematics instruction and tenth- and eleventh-grade Algebra I students who did not use calculators during mathematics instruction.

12. The adjusted mean score on a test of basic mathematics skills for the tenth- and eleventh-grade Algebra I students who did not use calculators during mathematics
instruction was found to be significantly higher than the tenth- and eleventh-grade Algebra I students who used calculators during mathematics instruction.

13. No significant statistical difference was found in students' attitudes toward mathematics as measured by the Mathematics Attitude Inventory between Algebra I students who used calculators during mathematics instruction and Algebra I students who did not use calculators during mathematics instruction.

Conclusions

Based on the findings of this research study, the following conclusions are offered:

1. As measured by the instrument in this study the use of calculators during classroom mathematics instruction did not increase algebra achievement for eighth-grade Algebra I students.

2. As measured by the instrument in this study the use of calculators during classroom mathematics instruction did not significantly affect algebra achievement for ninth-grade Algebra I students, but a slight negative effect was indicated.

3. As measured by the instrument in this study the use of calculators during classroom mathematics instruction had a negative effect on algebra achievement for tenth- and eleventh-grade Algebra I students.
4. As measured by the instrument in this study, the use of calculators during classroom mathematics instruction did not affect basic mathematics skills maintenance for eighth-grade Algebra I students.

5. As measured by the instrument in this study, the use of calculators during classroom mathematics instruction did not affect basic mathematics skills maintenance for ninth-grade Algebra I students.

6. As measured by the instrument in this study, the use of calculators during classroom mathematics instruction had a negative effect on basic mathematics skills maintenance for tenth- and eleventh-grade Algebra I students.

7. As measured by the instrument in this study, the use of calculators during classroom mathematics instruction did not have a significant statistical effect on students' attitudes toward mathematics.

**Recommendations**

Based on the findings and conclusions of this study, the following recommendations are made:

1. A longitudinal study should be conducted to determine whether the use of calculators in the mathematics classroom over a prolonged period of time has an effect on the learning and retention of basic mathematics skills.

2. Additional studies should be conducted with different populations to further assess whether the use of
calculators in Algebra I classes has an effect on algebra achievement for students of different ability levels.

3. Additional studies should be conducted with different populations to further assess whether the use of calculators in Algebra I classes has an effect on algebra achievement for students of different socio-economic backgrounds.

The calculator is apparently here to stay and it is disturbing that the only significant statistical differences found in this study indicated that students who did not have classroom access to calculators scored better on tests of algebra achievement and tests of basic mathematics skills than students who did have classroom access to calculators. Researchers need to focus on the role of the calculator in mathematics education and then teachers need to be instructed as to the best educational use of the calculator. The calculator is a powerful tool and researchers must determine ways in which it can be used to enhance and improve the learning of mathematics and assure that it does not become a substitute for learning.
APPENDIX
REPEATING DECIMALS

NOTE: This activity serves more as a focus for the lesson than to teach the concept.

Have students:

Choose a one digit number, then
divide by 9
divide by 99
divide by 999

Choose a two digit number, then
divide by 9
divide by 99
divide by 999

Repeat the exercises using 11, 111, 1111 as the divisors.

Have students discuss the patterns they observe. Use this to lead into a discussion on repeating decimals.
EXONENTS

Identify the power key on the calculator and demonstrate how it is used.

Have students use calculators to evaluate the following:

\[
\begin{align*}
2 \times 2 \times 2 \times 2 &= 2^4 \\
3 \times 3 \times 3 \times 3 \times 3 &= 3^5 \\
4 \times 4 \times 4 &= 4^3 \\
6 \times 6 \times 6 &= 6^3
\end{align*}
\]

Allow about five minutes for students to complete this exercise and to explore further on their own.

QUESTIONS FOR DISCUSSION:

Can someone tell me what an exponent does?

NOTE: Most calculators will not accept a negative base so after students have established that an exponent indicates how many times a number is a factor, have them repeat the left column of the above exercise using negative numbers. Have them offer suggestions about negative numbers raised to both odd and even powers.
SUMS OF REAL NUMBERS

Addition Rule (Two numbers with the same sign)

To add two numbers that have the same sign, either both positive or both negative:

a) Add their absolute values;

b) Give the sum the same sign as the sign of each number.

Addition Rule (Two numbers with different signs)

To add two numbers that have different signs:

a) Find their absolute values and subtract the smaller absolute value from the larger;

b) Give the result the same sign as the sign of the number with the larger absolute value.

Have students use calculators to evaluate the following:

10 + (-5) -15 + (-6)
-23 + 32 -45 + -56
28765 + (-578954) -3876 + (-5783)
-2985 + 59870 2398 + 2879

Allow about five minutes for students to complete this exercise and to explore on their own.

QUESTIONS FOR DISCUSSION

Can someone tell me what happens when we add two numbers that both have the same sign?

Can someone tell be what happens when we add two numbers that have different signs?

Can you state some general rules for addition of integers?
PRODUCTS OF REAL NUMBERS

Rule: When you multiply two numbers with the same sign, the product is positive.

Rule: When you multiply two numbers with different signs, product is negative.

Have students use calculators to evaluate the following:

\[
(567)(382) \quad (-389.7)(526.9) \\
(-57)(-98) \quad (65)(-32) \\
(-7896)(-8956) \quad (-897)(648) \\
(45.98)(54.78) \quad (-65)(25)
\]

Allow about five minutes for the students to complete this exercise and to explore on their own.

QUESTIONS FOR DISCUSSION

What is the sign of the product when we multiply two negative numbers together?

What is the sign of the product when we multiply two positive numbers together?

What is the sign of the product when we multiply a positive number and a negative number together?

Can someone suggest a rule for multiplying two numbers with the same signs.

Can someone suggest a rule for multiplying two numbers with different signs.

What do you suppose would happen if we multiplied three (four, five, etc.) negative numbers together?
MULTIPLICATION THEOREM FOR EXPONENTS

THEOREM: If $x$ is a real number and $a$ and $b$ are positive integers, then $(x^a)(x^b) = x^{a+b}$.

Have students use calculators to complete the following:

Note: Many calculators will not raise negative numbers to powers. For this reason students may need to enter $(-3)^3$ as $(-3)(-3)(-3)$.

$2^4 \times 2^3$ \hspace{1cm} $2^7$

$3^2 \times 3^4$ \hspace{1cm} $3^6$

$(-4)^3 \times (-4)^2$ \hspace{1cm} $(-4)^5$

$5^3 \times 5^4$ \hspace{1cm} $5^7$

Allow about five minutes for students to complete this exercise and to explore further on their own.

QUESTIONS FOR DISCUSSION:

When you multiply powers of the same base what happens to the exponents?

Can someone tell me why we must add the exponents when we multiply powers of the same base?

Does this work if the bases are not the same?

Based on what we have observed, if $x$ is any positive integer, then

$(2x^2)(x^3) =$

$(3x^7)(5x^9) =$

$(7x^4)(6x^5) =$
POWERS OF MONOMIALS

THEOREMS:

1. If \( x \) is a real number and \( a \) and \( b \) are positive integers, then \( (x^a)^b = x^{ab} \).

2. If \( x \) and \( y \) are real numbers and \( a \) is a positive integer, then \( (xy)^a = x^a y^a \).

Have students use calculators to evaluate the following:

Note: Many calculators will not raise negative numbers to a power. Students may need to enter \((-3)^3\) as \((-3)(-3)(-3)\).

\[
\begin{align*}
(2^3)^4 & \quad 2^{12} & \quad 8^4 \\
(3^2)^3 & \quad 3^6 & \quad 9^3 \\
(-3)^4 \cdot 3 & \quad (-3)^{12} & \quad 81^3 \\
(2 \times 5)^4 & \quad 2^4 \times 5^4 & \quad 10^4 \\
(3 \times 4)^5 & \quad 3^5 \times 4^5 & \quad 12^5
\end{align*}
\]

Allow about five minutes for students to complete this exercise and to explore on their own.

QUESTIONS FOR DISCUSSION:

Can someone give me a rule for raising a power to a power? What happens to the exponents?

Can someone give me a rule for raising a product to a power? Would this work for sums?

Based on what we have just observed, answer the following:

\[
\begin{align*}
(x^3)^5 & \quad (x^3 y^4)^3 \\
(3x^4)^2 & \quad (2x^3 y^4)^4
\end{align*}
\]

Find the value of \( x^5 y^4 \) when \( x = 2 \) and \( y = 3 \).
DIVIDING MONOMIALS

THEOREM: If \( x \) is a real number, \( x \neq 0 \), and \( a \) and \( b \) are positive integers such that \( a > b \), then \( x^a/x^b = x^{a-b} \).

Have students use calculators to evaluate the following:

\[
\begin{align*}
3^5/3^3 & = 3^2 \\
5^4/5 & = 5^3 \\
(2)^7/(2)^3 & = (2)^4 \\
2^8/2^3 & = 2^5
\end{align*}
\]

Allow about five minutes for students to complete this exercise and to explore on their own.

QUESTIONS FOR DISCUSSION:

Can someone give me a rule for dividing numbers raised to powers?

Would this rule work if the bases were different? Why not?

Simplify the following without using your calculator. Leave answers in exponential form.

\[
\begin{align*}
\frac{x^8}{x^2} & = x^6 \\
\frac{5^6}{5x^3} & = 5^3x^{-3} \\
\frac{w^{10}}{w^3} & = w^7 \\
\frac{2^4}{2^2w^2} & = 2^2/w^2
\end{align*}
\]
DIFFERENCE OF TWO SQUARES

THEOREM: For all real numbers $a$ and $b$,
$$a^2 - b^2 = (a + b)(a - b)$$

Have students use calculators to evaluate the following:

- $(72 + 43)(72 - 43) = 72^2 - 43^2$
- $(80 + 3)(80 - 3) = 80^2 - 3^2$
- $(362 + 157)(362 - 157) = 362^2 - 157^2$
- $(39 + 2)(39 - 2) = 39^2 - 2^2$
- $(61)(59) = (60 + 1)(60 - 1) = 60^2 - 1^2$
- $(93)(87) = (90 + 3)(90 - 3) = 90^2 - 3^2$

Allow about five minutes for students to complete this exercise and to explore on their own.

QUESTIONS FOR DISCUSSION:

- What kind of pattern did you observe in these problems?
- Can someone put these observations into a rule?
- Try to do the following problems without a calculator or a pencil:
  - $23 \times 17$
  - $64 \times 56$
  - $72 \times 68$
  - $37 \times 43$
  - $58 \times 62$
  - $77 \times 83$
WRITING ALGEBRAIC EXPRESSIONS

NOTE: This activity should be used as a focus for the section on writing algebraic expressions.

Have students use calculators as they follow the following steps:

1. Select any number (write it down).
2. Multiply your number by 3.
3. Add 9 to this product.
4. Multiply this sum by 5
5. Subtract 45 from this product.
6. Divide your answer by 15.
7. The quotient should be your original number.

Allow students to go through this sequence with two or three different numbers. Then lead them through the steps letting "n" represent the original number.

Let \( n \) = the original number, then write an algebraic expression for each step.

1. \( n \)
2. \( 3n \)
3. \( 3n + 9 \)
4. \( 5(3n + 9) \)
5. \( 5(3n + 9) - 45 \)
6. \( \frac{5(3n + 9) - 45}{15} \)

Have students make up other "puzzles" to try.
ALGEBRAIC PROOF

THEOREM: If \( a - b = 1 \), then \( a^2 - a = b^2 + b \)

Have students use calculators to evaluate the following:

\[
\begin{align*}
5^2 - 5 & = 4^2 + 4 \\
7^2 - 7 & = 6^2 + 6 \\
8^2 - 8 & = 7^2 + 7 \\
4^2 - 4 & = 3^2 + 3 \\
\end{align*}
\]

Allow about five minutes for students to complete the exercises and to explore on their own.

QUESTIONS FOR DISCUSSION:

Describe the pattern you observed in this exercise.

Can you make a generalization of this pattern?

Can you prove that your general statement is always true?

NOTE: Lead students through this complete exercise before formally introducing the idea of algebraic proof.
REFERENCES


