EFFECTIVENESS OF USING HAND-HELD CALCULATORS FOR LEARNING
DECIMAL QUANTITIES, AND THE METRIC SYSTEM

by

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DEDICATION

This manuscript is dedicated to all those individuals who have provided me with inspiration and guidance throughout my life and career. Special thanks go to my husband, George S. Allen; mother, Mrs. Essie M. Kemp; father, Mr. Raymond A. Bogues; sister, Mrs. Ramona Merriwether; grandparents, Mr. & Mrs. Roscoe Bogues; and aunts, Mrs. Maryland B. Stancil and Mrs. Margaret E. Davis.
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M. B. A.
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Chapter 1

INTRODUCTION

With the coming of the metric system of measurement to the United States, students now in school will probably use this system most of their lives. Use of metric measures in the classroom will require a working knowledge of decimals. Elementary students are introduced to decimals but some do not achieve a working knowledge of their uses (DeLucia, 1972). Since the metric system utilizes decimal notation, this extra use should help students better understand decimals. Familiarity with decimals is needed as a foundation for subsequent school work by middle school students.

According to Judd (1975), decimal manipulations that are a part of metric measurements can be handled easily and quickly on a calculator. By illustrating mathematical principles, the calculator can be useful in achieving the objective that students should understand mathematics. The calculator may be used to check answers and also to find errors in a problem. Calculators can also serve the same purpose as flash cards with quick oral or written response by the student and immediate reinforcement. A student can be asked to enter a number, an operation, and another number. The student can give the answer and then depress the equal (=) key and find out whether he is right.

Schott (1957) stated that skills in computation are less essential since calculating machines are available to everyone at
prices which are in keeping with their needs. Schott also stated that the calculating machine has increased rather than lessened the importance of arithmetic. The demand is now for the understanding of arithmetic, its logical structure, and its practical application. Certain topics in mathematics and science have been limited in classrooms because of long and difficult computations; the calculator eliminates this barrier.

Critics argue that elementary students risk becoming so dependent on calculators that they will forget or fail to learn basic computational skills. Henry Mullish, senior research scientist at New York University's Courant Institute of Mathematical Sciences, does not believe using electronic aids will create a dependency in future generations to the point where they would have difficulty in doing computation on their own (Higgins, 1974). Proponents also contend that minicalculators can be a significant force in moving away from answer-oriented instruction, freeing students for concentration on more important concepts because it permits the student to concentrate more on concepts and less on computations. Calculators do only what they are told to do, therefore, students have to know the mathematics in order to press the right keys on the machine. Critical thinking is required for setting up the problems or models.

The National Council of Teachers of Mathematics has taken the following position:

With the decrease in cost of the minicalculator, its accessibility to students at all levels is increasing rapidly. Mathematics teachers should recognize the potential contribution of this calculator as a valuable
instructional aid. In the classroom, the minicalculator should be used in imaginative ways to reinforce learning and to motivate the learner as he becomes proficient in mathematics (NCTM, 1974).

A report on classroom trials of hand-held calculators used with sixth grade students in New York in 1973 indicated that the calculators motivated and supported topics such as averages, percent, and above all, decimal fractions. This project was exploratory, therefore, no specific outcomes were reported (Barrett and Keefe, 1973).

Although calculators are still in minor use in schools, inexpensive ones are being purchased and used outside of the schools by school age children. Some experimentation has been done with calculating devices, but few scientific studies have been reported. There is a need for investigation of the effect of the hand-held calculator as a teaching device: this study concerns itself with this problem in teaching decimals and metric measurement.

PURPOSE OF THE STUDY

The purpose of this study was to determine the effectiveness of an instructional program utilizing hand-held calculators for improving the abilities of students in working with decimals and metric measures. Specifically, it was to determine whether using the hand-held calculator was more effective for the acquisition and retention of concepts and skills on decimal algorithms and metric units than the use of pencil and paper computation only.
HYPOTHESES

Relative to the statement of the problem, the following hypotheses were made:

\( H_1 \) There will be no difference between the adjusted mean posttest score of the experimental group and the adjusted mean posttest score of the control group on the decimal test.

\( H_2 \) There will be no difference between the adjusted mean posttest score of the experimental group and the adjusted mean posttest score of the control group on the metric test.

\( H_3 \) There will be no difference between the adjusted mean retention test score of the experimental group and the adjusted mean retention test score of the control group on the decimal test.

\( H_4 \) There will be no difference between the adjusted mean retention test score of the experimental group and the adjusted mean retention test score of the control group on the metric test.

DEFINITION OF TERMS

Hand-Held Calculator is defined to be an automatic electronic machine which displays the results of addition, subtraction, multiplication, and division operations and has a floating decimal point. It is small enough to hold in the hand (minicalculator, pocket calculator).
Floating Decimal Point is a term used in machine computation when the decimal point is not fixed at a certain machine position but is placed by the machine as each operation is performed.

Experimental Group refers to the set of all students in the experiment who used the hand-held calculator in learning decimals and metric measurement.

Control Group refers to the set of all students in the experiment who used pencil and paper in learning decimals and metric measurement but who did not use the hand-held calculator.

DELIMITATIONS OF THE INVESTIGATION

This study was limited in that it was conducted in just two elementary schools in two school districts in Virginia--Norfolk Public School System and Portsmouth Public School System. The study was limited to students of six sections of sixth grade during the Fall semester of 1975.

The study was limited to the study of decimal quantities and the metric system. Treatments lasted twenty-five math class days.
Chapter 2

REVIEW OF RELATED LITERATURE

The research relevant to this study is examined in three categories: (1) research related to the learning of decimals, (2) research related to the learning of the metric system, and (3) research related to the effects of calculating devices on mathematics achievement.

TEACHING DECIMALS

Educators differ in opinions as to the best way to introduce decimal quantities. Some educators advocate the use of the relation between decimal fractions and common fractions, while others prefer teaching decimal fractions as an extension of place value. This study utilized the latter approach.

O'Brien (1968) conducted an investigation of three methods for teaching decimals to sixth grade students. One method, the numeration approach, introduced decimals without common fractions based on the principle of numeration. A second method, the fraction-numeration approach, first introduced the relationship between decimals and common fractions and then emphasized numeration. The third method, the rule-method, introduced rules with no mention of fractions or numeration. Achievement scores of students in the numeration group were significantly lower than means of the rule-method groups and the fraction-numeration approach group. The retention test mean of students
in the numeration approach group was significantly lower than that of the rule-method, but not significantly different from that of students using the fraction-numeration approach.

Suydam and Weaver (1970) found evidence indicating that skills with whole numbers were reinforced when decimal fractions were taught before common fractions, but that emphasis should be placed on both common fractions and place value in teaching decimals.

A study by Henry (1971) revealed that there was no need to teach separate rules for common fractions and decimal fractions. Results of Henry's study revealed better results by teaching decimal notation by converting decimal fractions to common fractions. He stated that as students worked with decimals, they looked for short cuts and later found that they understood the basis for computation dealing with decimal quantities.

Harp and Mapes (1936) investigated a method of teaching decimal quantities to students by utilizing real life experiences. Results indicated that the learning of decimals was facilitated by presentation of lessons in relation to real life situations.

A study comparing a programmed instructional method and a classroom teacher method of teaching decimals was conducted with fifth grade students by Northcutt (1964). Students who received teacher instruction made greater gains than students who worked independently on programmed material.

De Lucia (1973) developed thirteen packages of reinforcement materials to help correct students' lack of working knowledge by
calling their attention to practical uses of decimal fractions. These materials were tested with sixth grade students and results revealed that the material did strengthen the students' ability to perform decimal operations.

Early studies were made concerning student errors in working with decimal quantities. Brueckner (1928) found that students in grades six, seven, and eight did not have an adequate conception of the numerical value of a decimal quantity. His investigation also revealed that the major difficulty in addition and subtraction of decimal quantities was the misplacement of the decimal point, and that the major difficulties in multiplication and division were misplacement and omission of the decimal point.

Grossnickle (1941) conducted an investigation with students in grades six through nine on division of decimal fractions. He also concluded that misplacement of the decimal point was the major problem and that the mechanical movement of the decimal point by use of the carets was the cause of most incorrect answers given by students. Grossnickle recommended replacement of the caret method by a method in which the divisor was made an integer by multiplication of the divisor and the dividend by the same power of ten.

Guiler (1946) investigated the difficulties in decimals encountered by ninth grade students. Results of this investigation revealed that the primary problem was the misplacement of the decimal point or faulty computation. Thus, the early studies indicated a major problem
was misplacement of decimal points. Recent studies indicated a disagreement on the best way of teaching decimals.

TEACHING THE METRIC SYSTEM

Measurement is a significant skill tool of mathematics that is used in science. It is one of those persistent life skills which people use almost everyday (Zafforoni, 1962). The process of measurement links the world of reality to the world of numbers, and greater emphasis on measurement is a way to make mathematics more relevant to students at all school levels (Higgins, 1974).

Wilson and Cassell (1953) conducted a study involving grade and high school students in 380 cities and towns in 43 states and the District of Columbia. Results revealed 205 different answers in response to judging the height of a dining room table, and only a small percentage were close to the correct answer. The authors concluded that students have not been taught to develop clear concepts of units of distances and to apply them to objects that are encountered daily. They also concluded that not enough portions of the school program are devoted to measurement and that most teaching of weights and measures is ineffective.

Westmeyer and McAda (1966) suggested that students should be made to realize the importance of the metric system and should memorize only a few prefixes involved, along with the knowledge of properly moving the decimal points. They stated that if a student needs to change from English measures to metric measures, there will always be charts available to assist him.
According to McFee (1967), education in metric principles was imperative and methods of instruction were inadequate. His study revealed that teaching conversion techniques between metric and English measures did not inhibit the ability of seventh grade students to perform tasks in metric measures.

Based on a study which revealed that students perform as well on measurement items as on discrete items, Scott (1966) recommended that school not continue to avoid measurement. Almost all the participants in the United States Metric Study stressed the importance of education in any change to metric. They concluded that metric measurement needed to be taught more vigorously in the schools. The National Education Association urged that, as early as possible, all children be taught metric as the primary language of measurement (U. S. Department of Commerce, 1971).

Bargmann (1973) conducted a study with students in grades three through six to identify the appropriate grade level for teaching various phases of the metric system. Results revealed that differences in grade level had no significant effect in achievement for students' understanding the meaning and approximate sizes of metric units, understanding use of measurement equipment, understanding the organization of the metric system, and the ability to measure length in the metric system using whole numbers. Grade three achieved significantly lower than other grades on measuring liquid volume and weight using whole numbers. Grades five and six achieved significantly higher on measurements with decimals.
Results reported by the National Assessment of Educational Progress mathematics assessment for 1972-73 indicated that nine-year-olds had difficulty with all measurement exercises except the simple ones requiring a one-step solution process. The thirteen-year-olds performed much better than the nine-year-olds but still had difficulty with many basic measurement concepts. Both groups performed lower on the conversion of one unit to another than on the comparison of units. The report suggested that with the increased use of the metric system, which does not require complex conversion factors, problems of conversion will be easier to solve (Carpenter, 1975).

Exum (1972) examined the effectiveness of a method of teaching the metric system to undergraduate non-science majors using the booklet, *Metric Supplement to Science and Mathematics*, in combination with a physical science textbook. He concluded that the ability of the students to think in metric measures was significantly improved by using the booklet.

The same booklet was used in a study conducted by Dod (1974). He compared the booklet with the Earth Science Curriculum Project (ESCP) for improving the abilities of eighth grade students in working with metric measures. Dod also concluded that the *Metric Supplement to Science and Mathematics* was better. Low scores on the McFee Metric Test indicated that more material should be devoted to teaching the metric system prior to or at the eighth grade level.

Odom (1972) stated that the changeover to the metric system would provide an opportunity for needed curriculum changes such as
early introduction to decimals, with corresponding reinforcement of the place value system and a considerable downplay of unessential skills with fractions.

Hough (1960) lists three factors which make the metric system preferable to the English system from an educational view. These factors are:

1. The memory burden of numbers is substantially less.
2. The decimal expressions are used instead of fractions.
3. There is a simple and direct relationship between length, area, and volume; additionally, the unit of mass is related to a unit volume of water.

The changeover to the metric system will serve as a tremendous boost in the effort to help students understand decimals. Since the metric system encourages decimal notation, it makes little sense to write measurements as fractions. The decimal manipulations that are a part of the metric measurements are easily handled on a calculator (Judd, 1975). All studies related to teaching the metric system emphasized the need for teaching decimals.

EFFECTS OF CALCULATING DEVICES

A limited number of research studies have dealt with calculating devices. Most articles dealing with the effects of calculating devices are descriptive in nature and are conducted in an informal setting.
As early as 1936, Betts conducted an investigation with sixth grade students using hand-operated calculating machines for group instruction in arithmetic. The sample consisted of thirteen sixth grade students with average I.Q. 109, ranging from 79 to 131. There was no control group. The experiment lasted seven weeks covering such arithmetic content as: addition, subtraction, multiplication, and division of whole numbers and decimals (Betts, 1937).

The calculators used were hand-operated with a sixteen place answer dial. A student turned the operating handle forward to add or multiply and backward to subtract or divide.

The lack of a control group eliminated any significant observations, but results of the pre- and posttest raw score means on the Compass Diagnostic Test showed an average gain of 10.1. Betts found that normal sixth grade students found calculating machines interesting and that there was probably no loss in the students' computational ability as a result of the machines.

In 1956, Fehr, McMeen, and Sobel conducted a controlled experiment with fifth grade students using hand-operated calculators. The experiment tested the following hypothesis: "Pupils who use computing machines to learn arithmetic will gain significantly in paper and pencil computations, and in arithmetic reasoning over those who do not use the computing machines" (Fehr, McMeen, Sobel, 1956).

The experimental and control groups were pretested and posttested with parallel forms of the Intermediate Arithmetic Stanford Achievement Test. Gains were greatly in favor of the experimental
group; however, no statistical test was performed to test the significance of the gain. Scores of twenty-five matched pairs of students were analyzed and results indicated a significant gain at the .95 level of confidence.

Durrance (1963) conducted a nine-week study on the effect of the rotary calculator on arithmetic achievement in grades six, seven, and eight. Results revealed that the calculator had no effect on computation, reasoning, and concept except in the seventh grade where there was an effect on reasoning. Data presented in the study indicated that the calculator had no effect in any other area or grade.

Learning difficulties were identified as errors in addition, subtraction, multiplication, and division of whole numbers, fractions, and decimals. The data presented in the study indicated that the calculator had no effect on the correction of learning difficulties in any of the three grade levels.

Longstaff (1968) investigated the use of desk calculators in mathematics classes in Canada. The sample for the study included two groups of ninth grade students and one group of fifth grade students in three different instructional settings. Results revealed no significant difference in improvement in mathematics skills between the experimental, control, and Hawthorne groups. The experimental students used the calculator as part of the curriculum, control students did not have access to the calculator, and the Hawthorne students could use the calculator to check work after class.
Keough and Burke (1969) investigated the use of an electronic calculator to facilitate instruction in mathematics for eleventh and twelfth grade students in two New York State high schools. Students in the experimental group were taken to a laboratory where they used electronic calculators whenever a new unit of instruction began. They used the calculators to solve problems related to classwork and homework. The Sequential Test of Educational Progress was used as pre- and posttest. Results indicated that the use of the electronic calculator can facilitate mathematics instruction in the eleventh and twelfth grades.

Studies have been made concerning the use of calculating devices with low achievers. In 1964, a junior high school in Des Moines, Iowa conducted a pilot project using nineteen calculators with ninth grade students. Evidence indicated that use of the calculators resulted in motivation in mathematics for formerly disinterested students. Use of the calculators reduced computational drudgery and increased the success factor for the students. Some students found for the first time that they could obtain the correct answer to a problem. It was concluded that the success of the project could not be accredited to the singular usage of the calculators. The machine was a motivational tool like the pencil and protractor (Secondary Mathematics, 1965).

Mastbaum (1969) reported the results of a study in which he compared the effectiveness of the electric calculator and computational skills kits in teaching mathematics to slow learners in the seventh and eighth grades. Students were randomly placed into one of four treatment
groups as follows: basic text and calculator; basic text and skills kits; basic text, calculator, and skills kits; and basic text only. It was concluded that the ability to solve problems with the calculators did not transfer to non-calculator situations. It was also concluded that when used as a teaching aid with slow learners in mathematics in the seventh and eighth grades, the calculator does not significantly improve attitude, increase mathematical ability, non-calculator computation skill, mastery of mathematical concepts or ability to solve mathematical problems. There was no significant difference with respect to the above areas between classes which used the skills kits and those who did not.

Ellis and Corum (1969) conducted an investigation to determine the effects of calculators on the attitude, achievement, and academic motivation of low achievers in a Miami high school. Results revealed no statistically significant gains in mathematical achievement by the experimental group. However, the control group did realize a significant gain in several areas being taught. A more favorable attitude toward mathematics, as measured by the attitude scale, was recorded and a weaker degree of academic motivation, as measured by the Motivation Inventory, was reported by both groups at the conclusion of the study. The authors suggested that loss in motivation probably resulted from negative influences outside of the mathematics laboratory environment.

Cech (1972) conducted a study of the effect of the desk calculator on motivation and achievement of low achieving ninth grade students.
Results failed to support the hypothesis that the use of calculators improved attitudes or computational skills of low-achievers. Results did support the hypothesis that ninth grade, low-achieving mathematics students can compute better with calculators than without them. This experiment indicated that the use of the calculator as a means to improve computational skills through reinforcement was not effective when so used for less than a year. Cech suggested that though the calculators may be of little value in improving computational skills, this does not preclude its desirability when seeking other objectives such as the ability to solve meaningful problems.

Advani (1972) conducted a study of eighteen twelve to fifteen year old children with learning disabilities and behavioral problems to determine the effect of desk calculators on student achievement, attitude, and behavior. Four calculators were placed in a corner of the classroom and students were encouraged to check their answers to mathematics problems. The teacher also used the machines as tools for the enrichment and reinforcement of a new unit. Comparison of the pre- and post- scores showed a significant difference at the .01 level and an analysis of the questionnaire data indicated marked increases in student interest and positive attitudes toward mathematics. Advani (1972) concluded that the use of calculators can facilitate mathematics instruction in a special class and help teachers in individualizing mathematics instruction.

Another study aimed at the low achievers was conducted by Ladd (1973) who investigated the effects of desk calculators on attitudes.
and achievement of ninth grade low achievers in mathematics. It was revealed that there was a significant improvement in mathematics attitudes and achievement of students enrolled in the course which utilized realistic problems obtained from local businesses, was taught by experienced teachers, and was organized in a sequence of short lessons. Based upon the posttest, there was no significant increase or decrease in attitude or achievement of students using the calculators in the same course of instruction.

A mobile computer mathematics laboratory traveled to five schools in Los Angeles and served twenty-three classrooms of grades five through twelve. It was a van equipped with calculating devices from minicalculators to programmable calculators. Evaluations indicated that students learned more mathematics better and calculators took the drudgery out of computing. Students had a great respect for the calculator's capabilities and the enthusiasm was high among students using them (Skoll, 1974).

Investigations using the hand-held calculator have been few. Mathematics and science professors at Menlo College in California equipped a classroom with minicalculators, revamped teaching methods, and altered subject matter to match the capability of a sophisticated $325 scientific calculator. Although no formal study was made at Menlo, the professors were convinced that students actually learned more mathematics and science with the calculators in daily classroom use (Menlo, 1974).

During 1973-74 minicalculators were employed in an experimental project with two sixth grade classes, one in South Colonie Village
School and the other in Citizen Genet Middle School in East Greenbush, New York. This program aimed at reinforcing basic mathematical skills. According to state officials and teachers in the project, there were better test scores, higher student interest, and greater comprehension. Two parallel forms of the New York State Mathematics Test for Beginning Grade Six were used as pretest and posttest. One form was used in October as the pretest and the other form was used in May as the posttest. The mean scores of the group of students who used the calculators were higher on the concepts and computations sections of the test than were the corresponding scores for students not using calculators. These differences in mean scores were significant at the .02 level, but not at the .01 level. The two groups performed about the same on the problem solving section of the test (Hawthorne, 1975).

As a result of the New York experiment, Hawthorne (1975) reported that the outstanding impact of the calculator may have been its power to motivate increased attention to decimal fractions. Barrett, teacher in charge of the project at Citizen Genet, employed the calculators for an experiment in exploration and discovery of the rule for placement of the decimal point in multiplication. Barrett stated that most students learned the rule in less than a half hour with the calculator wherein it usually took two or three days to get this lesson across. Barrett stated that the presence of the calculators was almost like having another person working with him.
Spencer (1975) investigated the effect of the hand-held calculator on computational skills, reasoning ability, and total arithmetic achievement of fifth and sixth grade students in an open-concept school. Results revealed significant difference in favor of the experimental group on gain scores of the reasoning test for the fifth graders. There was a significant difference in favor of the experimental group on computation and total arithmetic for the sixth graders; the difference between the treatments approached significance on reasoning ability in favor of the experimental group.

The National Council of Teachers of Mathematics (1974) supported the use of minicalculators in schools to motivate students and to reinforce learning. The Council suggested that the calculator be used to reinforce skills, save time, and check solutions. The following should substantiate the position that the hand-held calculator is a useful tool in every classroom.

1. To encourage the students to explore and to be creative as they experiment with mathematical ideas.
2. To reinforce the learning of the basic facts in addition, subtraction, multiplication and division.
3. To develop the understanding of computational algorithms by repeated operations.
4. To verify the results of computation.
5. To assist in finding errors in problems.
6. To solve problems that previously have been too time consuming or impractical to be done with paper and pencil.
7. To formulate generalizations from patterns of numbers which are displayed (Gibb, 1975).

Elementary and secondary schools in New York, Philadelphia, Washington, Chicago, Denver, Seattle, San Francisco and Berkeley have started
experimenting with hand-held calculators. The hand-held calculator has invaded new territories, promising to eventually change the teaching of the mathematics curriculum.

SUMMARY

This review of research leads the writer to conclude that education in metric principles is imperative and present methods of instruction are inadequate. Since the metric system is a decimal system, instruction in decimals is imperative. There is a need for investigation into the most efficient and effective methods for teaching decimals and the metric system.

Scientific studies on the effects of calculating devices and the study of metric units are few. Most of the research on the effects of calculating devices is concerned with the low achiever. Some studies indicate that calculating devices have no effect on mathematics achievement, but recent investigators contend that the hand-held calculator can serve as a useful mathematics tool. The few studies which exist are either descriptive in nature or lacking in controls. With the availability of hand-held calculators, investigation into the effects of calculating devices on mathematics achievement of elementary and secondary students is needed.
Chapter 3

METHODOLOGY

This experimental study was designed to investigate the effectiveness of an instructional program utilizing hand-held calculators for improving the abilities of students in working with decimals and metric measures. The methodology and procedures used in this investigation are discussed in seven sections within this chapter. The seven sections include: (1) the sample in the study; (2) mathematics content; (3) treatments; (4) instruments; (5) control of extraneous variables; (6) procedure; and (7) treatment of data.

SAMPLE

The sample for this experimental study was six intact sixth grade classes. Three classes were located at Lindenwood Elementary School in Norfolk, Virginia and three classes were located at Cavalier Manor Elementary School in Portsmouth, Virginia. Both schools house students from low to middle socio-economic areas and from multi-ethnic backgrounds. Lindenwood School houses approximately 649 pupils who are in kindergarten through grade six and Cavalier Manor School houses approximately 456 pupils who are in grades five and six.

Review of curriculum outlines and consultation with mathematics educators indicated that many schools teach decimal quantities at the sixth grade level. The sample was defined to be the set of pupils assigned to average sixth grade classrooms and who had no apparent
learning disability. Fifty-three boys and sixty girls made up the experimental classes. Twenty-nine boys and thirty-three girls were included in the control classes.

The six teachers involved in this study were experienced, competent and were judged by the principals as having good discipline in their classes. None was new to the schools. Appendix A denotes their experience and training.

MATHEMATICS CONTENT

The content taught during the experiment included the following concepts: place value; addition, subtraction, multiplication, and division of decimals; metric measures; and verbal problems involving decimal fractions and metric measures. The experimental group and the control group covered the same content.

Learning objectives covered in this study appear in Appendix B. The textbook used by the experimental and control groups was Heath Elementary Mathematics, level six. The objectives for the study were based on the textbook objectives but were sequenced differently in that decimals were taught before fractions.

TREATMENTS

There were two groups involved in this experimental study. Classes were assigned to treatments within school by pulling slips from a bag. Since there were only thirty calculators in each school, principals were asked not to assign additional students to the
experimental classes if it would make the class enrollment exceed thirty. Table 1 indicates the resulting student distribution. There were two experimental classes and one control class in each of the two schools.

Students in the experimental group were given one day of instruction on use and care of the calculators before beginning the selected mathematics lessons. Students in this group completed lessons based on the learning objectives with no additional content taught other than that which normally arises in classroom discussion. The calculators were used each day in either of the following ways: to encourage inquisitiveness and creativity in experimenting with mathematical ideas; to develop the understanding of computational algorithms by repeated operations; to check pencil and paper calculations; to find errors in problems; or to decrease the time needed to solve difficult computations. A calculator was provided for each student. Each school was equipped with thirty calculators which were used by each experimental class at different class periods of the day.

The Monroe 30 was the calculator used in the experiment. The Monroe 30 is a full function hand-held calculator with an eight-digit capacity, automatic constant multiplication and division, sequential and percent calculations, floating and + (Add Mode) decimal selection (See Appendix C), zero suppression for longer operating time, overflow, underflow, and a bright, large, glare-free planar display. The spacious keyboard and the angle of the display facilitate desk-top as well as hand-held operation. The dimensions of the calculator were as follows:
Table 1
Control and Experimental Group Membership

<table>
<thead>
<tr>
<th>Class</th>
<th>Treatment</th>
<th>Boys</th>
<th>Girls</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Experimental</td>
<td>14</td>
<td>11</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>Experimental</td>
<td>14</td>
<td>15</td>
<td>29</td>
</tr>
<tr>
<td>3</td>
<td>Experimental</td>
<td>13</td>
<td>16</td>
<td>29</td>
</tr>
<tr>
<td>4</td>
<td>Experimental</td>
<td>12</td>
<td>18</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>Control</td>
<td>17</td>
<td>14</td>
<td>31</td>
</tr>
<tr>
<td>6</td>
<td>Control</td>
<td>12</td>
<td>19</td>
<td>31</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>82</td>
<td>93</td>
<td>175</td>
</tr>
</tbody>
</table>

Experimental Total: **113**  Control Total: **62**
Length 15.2 cm, Width 8.9 cm, and Height 5.1 cm. The calculator weighed 312 g. The calculator operated off alkaline batteries with average operating time of twenty hours, nickel cadmium rechargeable batteries with operating time eleven hours on a full charge, or AC operation with or without batteries.

For purposes of this experiment, the classrooms were equipped with horizontal extension outlets to accommodate thirty calculators. In order to cut the cost, the calculators operated on AC current without batteries. A locked facility for storage was made available by the principal of each school since the use of calculators was restricted to the experimental study. Monroe, The Calculator Company, furnished the hand-held calculators for this study without charge.

Students in the control group completed lessons based on the same objectives as did the experimental group. Again, no additional content was taught other than that which normally arises in classroom discussions. In this control group all calculations were performed with pencil and paper alone. At the conclusion of the study, experimental and control students answered questionnaires concerning school and home use of calculators (See Appendix H).

All groups met each day, five times per week, with each math class fifty-five to sixty minutes in length. Calculators were used from thirty to fifty minutes daily. The treatment lasted twenty-five math class days beginning October 15, 1975 through November 21, 1975.
INSTRUMENTS

The instruments used in the study were the Science Research Associates Assessment Survey Test, The Criterion Referenced Test in Metrics Measurement, and a test on decimals which was developed by the researcher.

The Science Research Associates Test (SRA), Green Level, Form E of the Achievement Series was used as a standardized measure of academic development in mathematics because it is given to all sixth grade students by the schools. The multilevel edition consists of three separate but overlapping tests of graduated difficulty designed for use in grades four through nine. The blue level is the easiest, the red level the most difficult. The green level overlaps the upper end of the blue level and the lower end of the red level. The math section consisted of eighty items. Kuder-Richardson 20 reliability estimates for the Green Level total mathematics test was .94 for grades six, seven, and eight.

The Criterion Referenced Test in Metrics Measurement was a fifty-item four-choice test of knowledge of the metric units and applications of these units. It was used experimentally with pre-service and in-service teachers. Reliability was estimated for this population as .84 using the Kuder-Richardson 20.

The twenty-item subtest developed by Dr. L. J. Weber for use with elementary students was utilized in this study (See Appendix D). This subtest was administered to students in grades four through nine. Esham (1974) reported a KR-20 index of .67 for 134 sixth and seventh
grade students. For comparative purposes KR-20 coefficients for the same group on two sections of twenty items each of the McFee (1967) test were .51 for the general proficiency subtest and .64 for the intuitive subtest. Other studies by Esham produced KR-20 coefficients of .64 and .67 for 117 fifth grade students and 88 sixth grade students respectively for the Criterion Referenced Test (Weber, 1975).

A test of achievement, designed by the researcher, was an instrument consisting of twenty multiple-choice questions. Test items were based on the concepts of decimal quantities covered by the learning objectives for the study. After items were constructed and assembled, the instrument was mailed to sixteen mathematics education and/or test construction experts for validation (See Appendix E). An evaluation sheet was completed and returned by the validators (See Appendix F); modifications were made to include their applicable suggestions.

The instrument was administered to 135 seventh and eighth grade students in Virginia in September, 1975 (See Appendix G). These students were used to establish test reliability and did not participate in the experiment. Test data were processed by Virginia Polytechnic Institute and State University's Test Scoring and Analysis Program; it was found that the instrument possessed a reliability coefficient of .83.

The SRA test was administered by the schools prior to the experiment. The teachers administered the metric test and the decimal test as pretests prior to the experiment. The posttests were given November 21 and 24, 1975 and retention tests were given one month later. The posttests and retention tests were the same as the pretests, and were administered in an identical manner.
Two separate questionnaires, developed by the researcher, were administered to experimental and control students at the conclusion of the experiment to determine possible contamination of the groups (See Appendix H).

CONTROL OF EXTRANEOUS VARIABLES

Since there were six teachers involved in this study, it was decided to minimize the possible effect of teacher difference by having a teacher orientation session. The session was conducted by the researcher prior to the start of the experiment. Lessons, based on the learning objectives, were prepared by the researcher so that any topic presented by a teacher of one experimental section was presented by teachers of all experimental sections. A schedule for the experiment was given to all teachers (See Appendix I). In addition, weekly conferences were held between the participating teachers during the experiment. Teachers of the experimental sections were given instructions on the use of the calculators in the classrooms. Experimental teachers maintained a log of calculator usage during the experiment.

Students in the experimental group were given one day of calculator instruction before beginning the selected mathematics lessons. The control group started the lessons immediately, therefore, they were one day ahead during the experiment. However, each group was tested after spending twenty-five math class days on an identical number of lessons. The experimental group actually had one more day in the study, but this day was not spent on formal mathematics nor on the selected mathematics content of this study.
Sections were taught during different hours of the school day; but since the assignment of sections was random, the hour assignment was also random.

PROCEDURE

The Science Research Associates Assessment Survey Test was administered to all sections two days prior to the beginning of the experiment.

The next day, the decimal test and The Criterion Referenced Test in Metrics Measurement were given to all sections. Directions used were at the beginning of each test booklet. Students worked the problems using pencil and paper and recorded their answers on a separate answer sheet.

On the day following the pretests, the control group began studying the mathematics content described in lesson one (See Appendix B). The experimental group completed its one day of calculator orientation and on the second day after pretests, started studying the content described for lesson one. Each group then moved through the lessons at an identical pace. To ensure common procedure, pace, and testing, each teacher received a schedule at the start of the study. In addition, weekly conferences were held between the participating teachers to discuss the project.

Students in the control group worked all problems using pencil and paper. Students in the experimental group either worked problems on the hand-held calculator or worked problems using pencil and paper followed
by a check of their results on the calculator. No calculators were allowed during testing. The experimental design was planned so that homework would be assigned to neither experimental nor control groups, but because of parental objection to not having homework, teachers assigned study of and practice concerning work done in class.

The experimental group and the control group spent twenty-five days covering the lessons; the experimental group finished one day later than the control group.

The questionnaires on calculator usage were administered to the groups and the decimal test and the Criterion Referenced Test in Metrics Measurement were re-administered as each group completed the lessons. Procedure for the posttests were identical to that for the pretests. The same two tests were re-administered one month after the posttests to measure for retention. The calculators were used in the experimental classes between posttests and retention tests. During this time, experimental and control classes were taught a unit on fractions.

TREATMENT OF DATA

Science Research Associates total mathematics test (SRA) scores were obtained from the schools. The Criterion Referenced Test in Metrics Measurement and the decimal test were machine scored by Virginia Polytechnic Institute and State University's Test Scoring and Analysis Program.
The method of data analysis was multivariate analysis of covariance. "Analysis of covariance represents an extension of analysis of variance to allow for the correlation between initial and final scores. Through covariance analysis one is able to effect adjustments in final or terminal scores which will allow for differences in some initial variable" (Garrett, 1964).

The SRA scores, the metric pretest scores, and the decimal pretest scores were used as covariates in the multivariate analysis of covariance with the posttest scores as criterion variables. The SRA scores, the metric pretest scores, the decimal pretest scores, the metric posttest scores, and the decimal posttest scores were used as covariates in the multivariate analysis of covariance with the retention scores as criterion variables. The computer program Multivariate Analysis of Variance was chosen to compute the multivariate analysis of covariance (Multivariate Analysis of Variance, 1975).
Chapter 4

FINDINGS

The purpose of this study was to determine the effectiveness of an instructional program utilizing hand-held calculators for improving the abilities of students in working with decimals and metric measures. The following hypotheses were tested:

$H_1$ There will be no difference between the adjusted mean post-test score of the experimental group and the adjusted mean posttest score of the control group on the decimal test.

$H_2$ There will be no difference between the adjusted mean post-test score of the experimental group and the adjusted mean posttest score of the control group on the metric test.

$H_3$ There will be no difference between the adjusted mean retention test score of the experimental group and the adjusted mean retention test score of the control group on the decimal test.

$H_4$ There will be no difference between the adjusted mean retention score of the experimental group and the adjusted mean retention test score of the control group on the metric test.

The sample for this study was six intact sixth grade classes. The sample was defined to be the set of pupils assigned to average sixth grade classrooms and who had no apparent learning disability. The sample consisted of eighty-two boys and ninety-three girls.
Science Research Associates total mathematics test scores were obtained from the schools. The findings reported in this chapter are based on data collected from the SRA scores and pretest, posttest, and retention test scores of The Criterion Referenced Test in Metrics Measurement by Weber and a decimal test by the researcher. The Kuder-Richardson formula 20 is a measure of the internal consistency of the test materials. Table 2 shows reliability coefficients which indicate that if items on the test have high intercorrelations with each other and are measures of much the same attributes, then the reliability coefficient is high (Ferguson, 1971). KR-20 reliability estimates for the metric and decimal pretests, posttests, and retention tests are found in Table 2. The reliability estimates increased after instruction was given on the content covered by the tests.

The SRA scores, the metric pretest scores, and the decimal pretest scores were used as covariates in multivariate analysis of covariance. The first analysis used the metric posttest and the decimal posttest as criterion variables and the second used the metric retention test and the decimal retention test as criterion variables. Additional analyses were used to determine possible contamination of the control group. The third and fourth analyses were the same as the first two, but were done using the students in the control group who admitted using calculators at home during the experiment as one treatment group and the remaining control students as the other treatment group. The fifth and sixth analyses were the same as the first and second excluding the students in the control group who admitted using calculators at home during the experiment.
Table 2
KR-20: Pretests, Posttests, Retention Tests

<table>
<thead>
<tr>
<th></th>
<th>Decimal</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>.47</td>
<td>.51</td>
</tr>
<tr>
<td>Posttest</td>
<td>.78</td>
<td>.67</td>
</tr>
<tr>
<td>Retention Test</td>
<td>.77</td>
<td>.71</td>
</tr>
</tbody>
</table>
Table 3 presents the means of the raw scores and the adjusted means on the posttests for the experimental and the control groups. This table shows that the SRA and pretest mean scores for the control group were higher than those for the experimental group. The means of the posttests raw scores tended to be higher for the control group than for the experimental group. The adjusted means for the control group were also greater than the adjusted means for the experimental group. The difference in pretests and SRA scores has been removed through the covariance analysis.

Results from the multivariate analysis of covariance indicated that the posttest scores, adjusted for the three covariates, did not differ significantly between the experimental group and the control group ($F = 0.974$, $p < 0.380$). The results did not provide sufficient evidence to reject the hypotheses that no statistically significant differences exist among the adjusted mean posttest scores of the experimental group and the adjusted mean posttest scores of the control group on the metric test and the decimal test. Hypotheses $H_1$ and $H_2$ were not rejected.

The retention test scores were treated statistically in exactly the same way that the posttest scores were treated. Table 4 presents the means of raw scores and adjusted means on the retention tests for each treatment group.

Table 4 shows that the means of retention test raw scores were higher for the control group than for the experimental group. The adjusted means were also higher for the control group. The difference
<table>
<thead>
<tr>
<th></th>
<th>Pretest Dec</th>
<th>Posttest Met</th>
<th>Adjusted Posttest Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>32.802</td>
<td>10.514</td>
<td>9.652</td>
</tr>
<tr>
<td>Experimental</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>32.831</td>
<td>10.119</td>
<td>11.288</td>
</tr>
<tr>
<td>Control Group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>32.802</td>
<td>10.514</td>
<td>9.652</td>
</tr>
<tr>
<td></td>
<td>32.831</td>
<td>10.119</td>
<td>11.288</td>
</tr>
</tbody>
</table>
### Table 4

**Means and Adjusted Means on Retention Tests**

<table>
<thead>
<tr>
<th></th>
<th>Pretest</th>
<th></th>
<th></th>
<th>Retention</th>
<th></th>
<th></th>
<th>Adjusted</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SRA</td>
<td>Met</td>
<td>Dec</td>
<td>Met</td>
<td>Dec</td>
<td>Met</td>
<td>Dec</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
in pretest and SRA scores has been removed through the covariance analysis.

Results of the multivariate analysis of covariance indicated that the retention test scores, adjusted for the covariates, differed significantly between the treatment groups in favor of the control group ($F = 9.312, p \leq .001$). Based upon simultaneous confidence intervals, the difference was attributed to the metric test. The 95 percent confidence interval was $(0.9346, 3.2774)$. Thus the hypothesis that no difference exists between the adjusted mean retention test score of the experimental group and the adjusted mean retention test score of the control group on the metric test, namely Hypothesis $H_4$, was rejected. The procedure did not provide sufficient evidence to reject the hypothesis that there exists no difference between the adjusted mean retention test score of the experimental group and the adjusted mean retention test score of the control group on the decimal test, namely Hypothesis $H_3$.

Experimental student responses to the questionnaire on calculator usage (See Appendix H) indicated that, out of 113 students, 108 liked using the calculator and five did not. Ninety-two students believed that the calculator helped them to understand better and twenty-one did not. One-hundred ten said that the calculator gave the correct answer when they were wrong. There were 103 "yes" answers to whether the calculator was fun. Eighty students, out of the 113, would like to use the calculators all the time. Seventeen of the 113 used calculators at home for the following reasons during the experiment:
To do homework - one student (five times), to have fun - seventeen students, to show others at home what they were doing in school - six students, and to figure cost of Christmas items - one student.

Forty-two of the 113 students had received some help at home during the experiment. Only eight students discussed usage of the calculators with other sixth grade students, but none of those eight students were in the control group. Table 5 presents data obtained from the questionnaires answered by the experimental students.

Control student responses to the questionnaire indicated that twenty-eight of the sixty-two students received help at home during the experiment. Ten of the students admitted that they had used calculators at home during the experiment. The following reasons were given for the usage: To do homework - two students (three times and one time) and to have fun - eight students. Separate multivariate analyses of covariance were used to test if significant differences exist between the adjusted mean posttest and retention test scores of the ten students who used calculators at home and the adjusted mean posttest and retention test scores of the remaining control students.

Table 6 presents data obtained from the questionnaires answered by the control students.

Table 7 presents the means of the raw scores and the adjusted means on the posttests for the ten-student group and the remaining control group.

Table 7 shows that mean scores were higher on the SRA and metric pretest for the ten-student group, but higher on the decimal
Table 5
Results of Questionnaire: Experimental Group

<table>
<thead>
<tr>
<th>Question</th>
<th>Number of &quot;Yes&quot; Answers</th>
<th>Number of &quot;No&quot; Answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Like using calculators</td>
<td>108</td>
<td>5</td>
</tr>
<tr>
<td>2. Calculator helps you understand better</td>
<td>92</td>
<td>21</td>
</tr>
<tr>
<td>3. Calculator gives correct answer when you are wrong</td>
<td>110</td>
<td>3</td>
</tr>
<tr>
<td>4. Calculator is fun</td>
<td>103</td>
<td>10</td>
</tr>
<tr>
<td>5. Would like to use calculator all the time</td>
<td>80</td>
<td>33</td>
</tr>
<tr>
<td>6. Used calculator at home during experiment</td>
<td>17</td>
<td>96</td>
</tr>
<tr>
<td>7. Received help in math at home during experiment</td>
<td>42</td>
<td>71</td>
</tr>
<tr>
<td>8. Discussed use of calculator with control students</td>
<td>0</td>
<td>113</td>
</tr>
</tbody>
</table>
Table 6

Results of Questionnaire: Control Group

<table>
<thead>
<tr>
<th>Question</th>
<th>Number of &quot;Yes&quot; Answers</th>
<th>Number of &quot;No&quot; Answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Used calculator at home during experiment</td>
<td>10</td>
<td>52</td>
</tr>
<tr>
<td>2. Received help in math at home during experiment</td>
<td>28</td>
<td>34</td>
</tr>
<tr>
<td>3. Discussed use of calculators with experimental students</td>
<td>0</td>
<td>62</td>
</tr>
</tbody>
</table>
Table 7
Means and Adjusted Means on Posttest: Control

<table>
<thead>
<tr>
<th></th>
<th>Pretest</th>
<th></th>
<th>Posttest</th>
<th></th>
<th>Adjusted Posttest</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SRA</td>
<td>Met</td>
<td>Dec</td>
<td>Met</td>
<td>Dec</td>
<td>Met</td>
</tr>
</tbody>
</table>
test for the remaining control group. The means of the posttest raw scores were higher for the ten-student group than the remaining control group. The adjusted means for the ten-student group were also greater than the adjusted means for the remaining control group. The difference in pretests and SRA scores has been removed through covariance analysis.

Results of the multivariate analysis of covariance, relative to possible contamination of the control group by home usage of calculators, indicated that the posttest scores, adjusted for the covariates, differed significantly between the ten-student group and the remaining control group in favor of the ten-student group ($F = 4.506, p \leq .016$). Based upon simultaneous confidence intervals, the difference was attributed to the decimal test. The 95 percent confidence interval was (.97462, 3.69138).

The retention test scores were treated statistically in exactly the same way that the posttest scores were treated. Table 8 presents the means of raw scores and adjusted means on the retention tests for the ten-student group and the remaining control group.

Table 8 shows that the means of retention test raw scores tended to be higher for the ten-student group than the remaining control group. The adjusted mean for the metric test was higher for the ten-student group, but the adjusted mean for the decimal test was higher for the remaining control group. The difference in pretest and SRA scores has been removed through the covariance analysis.
<table>
<thead>
<tr>
<th></th>
<th>Pretest</th>
<th>Retention</th>
<th>Adjusted Retention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SRA</td>
<td>Met</td>
<td>Dec</td>
</tr>
<tr>
<td>Ten-student Group</td>
<td>38.125</td>
<td>8.125</td>
<td>7.500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14.375</td>
<td>12.250</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12.829</td>
<td>10.540</td>
</tr>
<tr>
<td>Remaining Control Group</td>
<td>32.000</td>
<td>7.373</td>
<td>8.333</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11.333</td>
<td>11.706</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11.576</td>
<td>11.974</td>
</tr>
</tbody>
</table>
Results of the multivariate analysis of covariance, relative to possible contamination of the control group by home usage of calculators, indicated that the retention test scores, adjusted for the covariates, did not differ significantly between the ten-student group and the remaining control group ($F = 1.213, p \geq .306$).

The fifth and sixth analyses using multivariate analysis of covariance were to test if significant differences exist between the adjusted mean posttest and retention test scores of the experimental group and the adjusted mean posttest and retention test scores of the control group minus the ten students who admitted using calculators at home during the experiment.

Table 9 presents the means of the raw scores and the adjusted means on the posttests for the experimental group and the control group minus the ten students.

Table 9 shows that the mean of the SRA scores is higher for the experimental group than for the control group minus the ten students. The means of the pretest scores are higher in favor of the control group. The means of the posttest raw scores tended to be slightly higher for the control group minus the ten than for the experimental group. The adjusted mean for the decimal test was a little greater for the control group minus ten, but the adjusted mean for the metric test was higher for the experimental group.

Results of the multivariate analysis of covariance showed no difference between the adjusted mean posttest scores of the experimental group and the adjusted mean posttest scores of the control group.
Table 9
Means and Adjusted Means on Posttests: Minus Ten Controls

<table>
<thead>
<tr>
<th></th>
<th>Pretest</th>
<th></th>
<th>Posttest</th>
<th>Adjusted Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SRA</td>
<td>Met</td>
<td>Dec</td>
<td>Met</td>
</tr>
</tbody>
</table>
minus the ten students who used calculators at home ($F = .075$, $p \leq .928$).

Table 10 presents the means of the raw scores and the adjusted means on the retention tests for the experimental group and the control group minus the ten students.

Table 10 shows that the means of retention test raw scores and the adjusted means tended to be higher for the control group minus the ten than the experimental group.

Results of the multivariate analysis of covariance showed that the retention test scores, adjusted for the covariates, differed significantly between the experimental group and the control group minus the ten students who used calculators at home during the experiment in favor of the control group ($F = 7.495$, $p \leq .001$). Based upon simultaneous confidence intervals, the difference was attributed to both the metric and the decimal tests. The 95 percent confidence intervals were (0.6514, 3.1146) and (0.0291, 2.4649) for the metric test and decimal test respectively.

Table 11 presents the adjusted means for the experimental group and the control group minus the ten students on the posttests and retention tests.

Table 11 shows that the adjusted means for the experimental group decreased from the posttest to the retention test while the adjusted means for the control group minus the ten students increased. Figures 1 and 2 present graphic representations of the adjusted mean scores on the posttests and retention tests.
<table>
<thead>
<tr>
<th></th>
<th>Pretest</th>
<th>Retention</th>
<th>Adjusted Retention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SRA</td>
<td>Met</td>
<td>Dec</td>
</tr>
</tbody>
</table>
Table 11
Adjusted Means on Posttest and Retention Tests: Experimental and Control Minus Ten

<table>
<thead>
<tr>
<th></th>
<th>Pretest</th>
<th></th>
<th>Adjusted Posttest</th>
<th></th>
<th>Adjusted Retention</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>SRA</td>
<td>Met</td>
<td>Dec</td>
<td>Met</td>
<td>Dec</td>
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</tr>
<tr>
<td>Experimental</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Control Group</td>
<td></td>
<td></td>
<td></td>
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</tr>
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<td></td>
<td></td>
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<td></td>
<td></td>
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</tbody>
</table>
Figure 1. Graphic Representation of Adjusted Mean Scores on the Metric Test of the Experimental Group vs. the Control Group - 10
Figure 2. Graphic Representation of Adjusted Mean Scores on the Decimal Test of the Experimental Group vs. the Control Group - 10
SUMMARY OF FINDINGS

The purpose of this problem was to compare the effectiveness of an instructional program utilizing hand-held calculators for the acquisition and retention of concepts and skills on decimal algorithms and metric units with the use of pencil and paper computation only for the same purpose. Hypotheses $H_1$ and $H_2$ related directly to the acquisition part of the comparison and were not rejected. Hypotheses $H_3$ and $H_4$ related to the retention part of the comparison. Hypothesis $H_3$, on the decimal test, was not rejected and hypothesis $H_4$, on the metric test, was rejected.

Answers to the questionnaires indicated that ten students in the control group had used calculators at home during the experiment. There was a significant difference between the mean adjusted posttest scores of these ten students and the remaining control group. This difference was attributed to the decimal test in favor of the ten-student group. There was no difference between these same groups on the retention tests.

There was a significant difference on the retention tests between the experimental group and the control group minus the ten students who used calculators at home in favor of the control group. The difference was attributed to both the metric test and the decimal test. There were no significant differences on the posttests between these same two groups.
Chapter 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY

Recent research has shown that a certain amount of thought is given to the decrease in the emphasis on pencil and paper computation and to a greater use of calculators in mathematics instruction. The literature indicated that the calculator could be used as a mathematics tool to achieve the following:

1. To encourage the students to explore and to be creative as they experiment with mathematical ideas.

2. To reinforce the learning of the basis facts in addition, subtraction, multiplication, and division.

3. To develop the understanding of computational algorithms by repeated operations.

4. To verify the results of computation.

5. To assist in finding errors in problems.

6. To solve problems that previously have been too time consuming or impractical to be done with pencil and paper.

7. To formulate generalizations from patterns of numbers which are displayed (Gibb, 1975).

The purpose of this study was to determine the effectiveness of utilizing hand-held calculators for improving the abilities of students in working with decimals and metric measures. This experimental study was designed to compare the learning of students who used hand-held calculators to the learning of students who used pencil and paper only.
Those students using calculators were called experimental students and those who used pencil and paper only were called control students. The study included 113 experimental students and 62 control students. The six intact sixth grade classes were assigned randomly to treatment.

Delimitations placed on the study included: (1) students enrolled in sixth grade in one school in Norfolk, Virginia and one school in Portsmouth, Virginia and (2) study of decimal quantities and the metric system.

Identical learning objectives were used with the experimental and control classes. The instructional periods were held for 50-60 minutes daily for a total of twenty-five periods. Treatment started in October and ended in November with a metric posttest and a decimal posttest. The same two tests were readministered one month later to test for retention. The pretests, posttests, and retention tests used the same instruments. No calculators were allowed during testing. The math section of the SRA was used as one covariate, with the pretests as the other covariates in multivariate analyses of covariance.

The first multivariate analysis of covariance used the posttest scores as criterion variables, which was interpreted as measures of the acquisition of decimal and metric concepts. There were no significant differences on the acquisition.

The second multivariate analysis of covariance used the retention test scores as criterion variables, which was interpreted as a measure of retention. Significant differences (p < .001) favored the control group over the experimental group which was attributed to the metric test.
The third and fourth multivariate analyses of covariance were the same as the first two, but used the ten students in the control group who admitted using calculators at home during the experiment as one treatment group and used the remaining control students as the other treatment group. Difference between these groups was significant \( (p < .016) \) on the posttest in favor of the ten students who used calculators at home over the remaining control group. This difference was attributable to the decimal test. There were no significant differences on the retention tests.

The fifth and sixth multivariate analyses of covariance were the same as the first and second excluding the ten students in the control group who admitted using calculators at home during the experiment. There was no significant difference on the posttest between the experimental group and the control group minus the ten students. There were significant differences \( (p < .001) \) on the retention tests between the two groups in favor of the control group. These differences were attributed to both the metric and decimal tests.

**CONCLUSIONS**

Within the limitations of the study, sixth grade students and two urban schools located in two separate school districts in Virginia, the conclusions supported by the findings of this study are the following:

1. There was no significant difference between scores of students who used hand-held calculators and those who used
pencil and paper only for the acquisition of concepts and skills on decimal algorithms and metric units.

2. Using pencil and paper only was more effective than using hand-held calculators for the retention of concepts and skills of decimal algorithms and of metric units.

Adjusted mean scores increased for the control group between posttests and retention tests, an indication of continued learning. In contrast, the adjusted mean scores decreased for the experimental group between posttests and retention tests. The calculators were used in the experimental classes between posttest and retention tests. During this time, experimental and control classes were taught a unit on fractions.

The literature (Spencer, Hawthorne, 1975) reported that calculators were more effective than paper and pencil in teaching computation for sixth graders. This study, which adjusted for initial differences and outside use of calculators, did not find the same results and found that paper and pencil computation produced higher retention scores based on paper and pencil tests.

The question of whether the experimental group would get higher scores using the calculators than the control group using paper and pencil was not part of this study. One would surmise that calculators would improve the scores.

The literature indicated that emphasis should be placed on practical, realistic, and significant problems.
RECOMMENDATIONS

Further research is needed to ascertain the effectiveness of using the hand-held calculator for learning decimals and the metric system. The following recommendations are based on the findings and conclusions of this study.

1. The study should be repeated allowing use of calculators on the posttests and retention tests by the experimental group.

2. The study should be repeated allowing use of calculators on the posttests and retention tests by both experimental and control groups. Prior to taking the tests, the control group should be given a day of calculator instruction.

3. The study should be repeated at other grade levels and other geographical areas.

4. Research using such variables as I.Q., social and cultural background, and academic grades should determine their effects, if any, on a student's ability to work with decimals and metric measures using the calculator.

5. Investigations in the area of attitude and self-concept in relation to using the hand-held calculator are needed.

6. There is a need to determine the kind of materials and teaching strategies which would be appropriate for a hand-held calculator program.

7. There is a need to determine the percent of students using calculators at home and the effects, if any, on achievement.
REFERENCES

BOOKS


ARTICLES AND PERIODICALS


REPORTS, UNPUBLISHED, AND MISCELLANEOUS MATERIALS


Odom, Jeffrey V. A History and Overview of Metrication and Its Impact on Education. ERIC Document ED 068330, 1972.


APPENDIXES
APPENDIX A

Participating Teacher Characteristics
<table>
<thead>
<tr>
<th>Age</th>
<th>Sex</th>
<th>Marital Status</th>
<th>Degree Held</th>
<th>Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>Female</td>
<td>Married</td>
<td>B.S.</td>
<td>15 years</td>
</tr>
<tr>
<td>51</td>
<td>Female</td>
<td>Single</td>
<td>M.A.</td>
<td>29 years</td>
</tr>
<tr>
<td>50</td>
<td>Female</td>
<td>Married</td>
<td>M.A.</td>
<td>27 years</td>
</tr>
<tr>
<td>35</td>
<td>Male</td>
<td>Married</td>
<td>M.A.</td>
<td>11 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Male</td>
<td>Married</td>
<td>B.A.</td>
<td>19 years</td>
</tr>
<tr>
<td>34</td>
<td>Female</td>
<td>Widowed</td>
<td>B.S.</td>
<td>12 years</td>
</tr>
</tbody>
</table>

Participating Teacher Characteristics
APPENDIX B

Learning Objectives
LEARNING OBJECTIVES

Lesson 1

1. The student will be able to use decimal notation for tenths, hundredths, thousandths, and ten-thousandths.
2. The student will be able to read decimals with at most four digits to the right of the decimal point.
3. The student will be able to tell which number in decimal form is the greater when two numbers have at most four digits to the right of the decimal point.

Lesson 2

4. The student will be able to add decimal numbers.

Lesson 3

5. The student will be able to subtract a decimal number from a decimal number.

Lesson 4

6. The student will be able to solve simple verbal problems involving addition or subtraction of decimal numbers.

Lesson 5

7. The student will be able to multiply any number in decimal form by a one-digit whole number.
8. The student will be able to multiply any number in decimal form by 10 and by 100.
Lesson 6

9. The student will be able to multiply any decimal number by a two-digit multiple of 10 and by a three-digit multiple of 100.

10. The student will be able to multiply a decimal number by a two-digit or three-digit whole number.

Lesson 7

11. The student will be able to divide a decimal number by a one-digit whole number.

12. The student will be able to divide a decimal number by a two- or three-digit whole number.

Lesson 8

13. The student will be able to compute averages.

14. The student will be able to solve word problems about averages.

Lesson 9

15. The student will be able to solve word problems involving multiplication or division of decimals by whole numbers.

Lesson 10

16. The student will be able to tell whether a given quantity relates to length, area, or volume using metric units.

17. The student will be able to measure various lengths correct to the nearest millimeter.
Lesson 11

18. The student will be able to make conversions among metric units for measuring length.

Lesson 12

19. The student will be able to express one metric unit in terms of another, using decimals.

Lesson 13

20. The student will be able to compute, in metric units, perimeters of polygons.

Lesson 14

21. The student will be able to compute, in metric units, areas of parallelograms and triangles.

Lesson 15

22. The student will be able to compute, in metric units, the volume of solid figures composed of rectangular solids.

Lesson 16

23. The student will be able to solve word problems involving applications of length, area, or volume in the metric system.

Lesson 17

24. The student will be able to make conversions among metric units for measuring liquid volume and for measuring weight.
Lesson 18

25. The student will be able to multiply a number in decimal form by .1 or .01.

Lessons 19 and 20

26. The student will be able to multiply a number in decimal form by a number in decimal form.

Lesson 21

27. The student will be able to divide a number in decimal form by .1 or .01.

Lesson 22 and 23

28. The student will be able to divide a number in decimal form by a number in decimal form.

Lessons 24 and 25

29. The student will be able to solve word problems involving multiplication or division of decimals.
APPENDIX C

Operating Controls of Calculator
Operating Controls

**ON/OFF**
When Model 30 is turned on, it is automatically cleared and ready for use. Decimal positions are F (full floating) and + (add-mode).

**CLEAR AND CLEAR ENTRY KEY**
Clears incorrect entries; a pending multiplication or division operation or an overflow condition.

**NUMERIC ENTRY KEYS**
Enter numbers and decimal point exactly as you would write them.

**PLUS KEY**
Adds entry to the add register and displays the sum. Repetitive depressions cause repeat addition. If depressed after a multiplication percentage operation, it adds the result to the multiplicand.

**PERCENT KEY**
Calculates percentages. Has add-on and discount capabilities.

**MULTIPLY KEY**
Enter number in display as a multiplicand (first number in a multiplication sequence) or completes a calculation and sets up result as a multiplicand.

**EQUALS KEY**
Completes a multiplication or division operation.

**DIVIDE KEY**
Enter number in display as a dividend (first number in a division sequence) or completes a calculation and sets up result as a dividend.

**MINUS KEY**
Subtracts entry from add register, displays the difference. Repetitive depressions cause repeat subtraction. If depressed after a multiplication percentage operation, it subtracts result from multiplicand.

---

Taken from *Model 30 Operating Instructions*, handbook by Monroe, The Calculator Company.
APPENDIX D

The Criterion Referenced Test in Metrics Measurement
CRITERION REFERENCED METRIC TEST

Instructions:
1. Select the choice which represents the best answer.
2. Mark the number of the choice on the answer sheet.
3. Answer all questions; there is no penalty for guessing.
4. Do not mark on the test "booklet."

1. A metre is equal to
   a. 10 centimetres
   b. 100 centimetres
   c. 1000 millimetres
   d. both b and c

2. A kilogram is equal to
   a. 100 grams
   b. 1000 grams
   c. 100 centimetres
   d. 1000 centimetres

3. The temperature at which water freezes is
   a. 0°C
   b. 32°F C
   c. 100° C
   d. 212° C

4. The temperature at which water boils is
   a. 0°C
   b. 32°F
   c. 100° C
   d. 212° C

5. What is the distance in centimetres from point A to point B?
   A __________________________ B
   a. 1.2
   b. 12
   c. 120
   d. 1200

6. What is the precision of the ruler below?

   0 1 2 3 4 5 6 7 8

   centimetres (cm)
   a. 1 centimetre
   b. 5 centimetres
   c. 1 millimetre
   d. 8 centimetres

7. What is the length of the pencil?

   a. 1 metre
   b. 1 kilometre
   c. 1 centimetre
   d. 10 centimetres
8. 2 centimetres and 40 millimetres equal ___ centimetres.
   a. 260
   b. 24
   c. 6
   d. 50

9. Add the following lengths:
   1 metre + 20 centimetres + 40 millimetres
   a. 1.24 centimetres
   b. 1 metre plus 260 centimetres
   c. 1.24 metres
   d. 124 millimetres

10. Subtract the following lengths:
   20.762 metres - 3.824 metres
   a. 6.938 metres
   b. 7.948 metres
   c. 6.940 centimetres
   d. 7.940 centimetres

11. Subtract the following lengths:
   147.0612 metres - 164.9887 metres
   a. 1.0755 metres
   b. 0.0755 centimetres
   c. 72.9 millimetres
   d. 7.25 millimetres

12. What is the temperature of the thermometer below?
   a. 20° C
   b. 30° C
   c. 25° C
   d. 85° C

13. What is the perimeter of the following figure?

   a. 18 centimetres
   b. 9 centimetres
   c. 12 centimetres
   d. 6 centimetres

14. What is the perimeter of the following figure?

   a. 7 centimetres
   b. 160 millimetres
   c. 14 metres
   d. 1.4 metres

15. What is the area of the following figure?

   a. 8 square centimetres
   b. 16 square centimetres
   c. 15 square centimetres
   d. 15 square millimetres
16. What is the volume of the box below?

- a. 7 cubic centimeters
- b. 12 cubic centimeters
- c. 14 cubic centimeters
- d. 24 cubic centimeters

For Questions 17 through 20 refer to the following information regarding the weight of two students, Tom and Sally.

17. How much does Tom weigh?

- a. 40 kilograms
- b. 40.5 kilograms
- c. 45 kilograms
- d. 50 kilograms

18. How much does Sally weigh?

- a. 28 kilograms
- b. 35 kilograms
- c. 36 kilograms
- d. 36.5 kilograms

19. What is the combined weight of Sally and Tom?

- a. 68 kilograms
- b. 75 kilograms
- c. 80 kilograms
- d. 81 kilograms

20. What is the difference in weight between Tom and Sally?

- a. 4 kilograms
- b. 5 kilograms
- c. 9 kilograms
- d. 14 kilograms
APPENDIX E

Names of Validators
NAMES OF VALIDATORS

1. Edna F. Atkins, Sixth grade teacher, Portsmouth, Virginia.

2. Gerald D. Brazier, Assistant professor mathematics education, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.


4. H. Copley, Mathematics supervisor, Virginia Beach City Schools, Virginia Beach, Virginia.


6. Evelyne M. Graham, Supervisor of mathematics, Chesapeake City Schools, Chesapeake, Virginia.

7. Lucien T. Hall, Jr., Mathematics-Science specialist, Richmond City Schools, Richmond, Virginia.

8. M. Boyd Jones, Professor of mathematics, Norfolk State College, Norfolk, Virginia.

9. Virgie I. Keith, Coordinator of mathematics and science, Pulaski County Schools, Pulaski, Virginia.


APPENDIX F

Evaluation Sheet for Securing Information for Validation
Dear

I am preparing to conduct a study on the effectiveness of using the hand-held calculator for learning decimal quantities and the metric system with sixth grade students, it is necessary that the test items are validated. You may help in this study by completing the enclosed validation form and return in the self-addressed envelope by September 8, 1975.

Your assistance will be greatly appreciated.

Sincerely,

Maxine B. Allen
205 Lane Hall
VPI & SU
Blacksburg, Virginia 24061

MBA/spw
Evaluator ____________________________________________________________

Position and School ____________________________________________________

1. Please read each item for ambiguity and/or proper wording.

2. Verify each answer. Answers are noted with asterisks.

3. Please check the appropriate grade level for which you think students can properly work each test item. Grades 1 and 2 are represented by level 1, grades 3 and 4 are represented by level 2, and grades 5 and 6 are represented by level 3.

<table>
<thead>
<tr>
<th>Item</th>
<th>Grade Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Express in decimal form the value &quot;six hundredths.&quot;</td>
<td>1 2 3</td>
</tr>
<tr>
<td><em>(1)</em> .06</td>
<td>1</td>
</tr>
<tr>
<td><em>(2)</em> 6</td>
<td>2</td>
</tr>
<tr>
<td><em>(3)</em> 6</td>
<td>3</td>
</tr>
<tr>
<td><em>(4)</em> 600</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Grade Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Give the correct sign: .9 ≠ 1.0</td>
<td>1 2 3</td>
</tr>
<tr>
<td><em>(1)</em> &lt;</td>
<td>1</td>
</tr>
<tr>
<td><em>(2)</em> &gt;</td>
<td>2</td>
</tr>
<tr>
<td><em>(3)</em> =</td>
<td>3</td>
</tr>
<tr>
<td><em>(4)</em> =</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Grade Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Give the correct sign: .04 ≠ .003</td>
<td>1 2 3</td>
</tr>
<tr>
<td><em>(1)</em> &gt;</td>
<td>1</td>
</tr>
<tr>
<td><em>(2)</em> &lt;</td>
<td>2</td>
</tr>
<tr>
<td><em>(3)</em> =</td>
<td>3</td>
</tr>
<tr>
<td><em>(4)</em> =</td>
<td>3</td>
</tr>
</tbody>
</table>

Comments:
4. Add: 0.8
   \[+ 0.6\]
   \[
   \begin{array}{l}
   (1) 0.14 \\
   (2) .14 \\
   *(3) 1.4 \\
   (4) 14
   \end{array}
   \]

5. Add: 48.96 + 1.67

   \[
   \begin{array}{l}
   (1) 0.5063 \\
   (2) 50.53 \\
   *(3) 50.63 \\
   (4) 5063
   \end{array}
   \]

6. Subtract: 8.54 - 2.47

   \[
   \begin{array}{l}
   (1) 5.07 \\
   *(2) 6.07 \\
   (3) 6.7 \\
   (4) 67
   \end{array}
   \]

7. Subtract: 0.546 - 0.167

   \[
   \begin{array}{l}
   (1) 0.0379 \\
   *(2) 0.379 \\
   (3) 3.79 \\
   (4) 379
   \end{array}
   \]

8. Multiply: 59.14 \[\times 100\

   \[
   \begin{array}{l}
   (1) 59.14 \\
   (2) 591.4 \\
   *(3) 5914 \\
   (4) 591400
   \end{array}
   \]

9. Multiply: 6.7 \[\times 20\

   \[
   \begin{array}{l}
   (1) 1.34 \\
   (2) 13.40 \\
   *(3) 134 \\
   (4) 1340
   \end{array}
   \]
10. Multiply: \[ 20.6 \times 0.01 \]
   
   (1) 0.026
   (2) 0.206
   (3) 2.06
   (4) 206

11. Multiply: \[ 4.5 \times 0.7 \]
   
   (1) 3.015
   (2) 3.15
   (3) 31.5
   (4) 315

12. Multiply: \[ 1.24 \times 2.15 \]
   
   (1) 0.26660
   (2) 2.666
   (3) 266.60
   (4) 26660

13. Divide: \[ 8 \div 49.6 \]
   
   (1) 0.62
   (2) 6.2
   (3) 62
   (4) 620

14. Divide: \[ 73 \div 76.65 \]
   
   (1) 0.105
   (2) 1.05
   (3) 105
   (4) 1050

15. Divide: \[ \frac{1}{63.48} \]
   
   (1) 6.348
   (2) 63.48
   (3) 634.8
   (4) 6348
16. Divide: \( 12.4 \div .4 \)
   \[
   \begin{array}{l}
   (1) \ 0.31 \\
   (2) \ 3.1 \\
   * (3) \ 31 \\
   (4) \ 310
   \end{array}
   \]

17. Divide: \( .94 \overline{488.8} \)
   \[
   \begin{array}{l}
   (1) \ 0.52 \\
   (2) \ 5.2 \\
   (3) \ 5.20 \\
   * (4) \ 520
   \end{array}
   \]

WORD PROBLEMS

18. George ran the 100-meter dash in 12.31 seconds. Reggie ran it in 12.17 seconds. How many seconds more did it take George?
   \[
   \begin{array}{l}
   (1) \ 0.18 \text{ seconds} \\
   * (2) \ 0.18 \text{ seconds} \\
   (3) \ 1.08 \text{ seconds} \\
   (4) \ 18 \text{ seconds}
   \end{array}
   \]

19. A small car averages 12.3 kilometers per liter of gasoline. How far can the car travel on 0.9 liters of gasoline?
   \[
   \begin{array}{l}
   * (1) \ 11.07 \text{ kilometers} \\
   (2) \ 11.7 \text{ kilometers} \\
   (3) \ 117 \text{ kilometers} \\
   (4) \ 1107 \text{ kilometers}
   \end{array}
   \]

20. If one bar of candy costs $0.09, how many pieces of candy can you buy with $1.35?
   \[
   \begin{array}{l}
   (1) \ 1 \\
   (2) \ 1.5 \\
   * (3) \ 15 \\
   (4) \ 150
   \end{array}
   \]
APPENDIX G

Decimal Test
**DECIMAL TEST**

**Instructions:**
1. Select the choice which represents the best **answer**.
2. Mark the number of the choice on the answer sheet.
3. Answer all questions; there is no penalty for guessing.
4. Do not mark on the test booklet.

<table>
<thead>
<tr>
<th>1. Express in decimal form the value &quot;six hundredths.&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) .06</td>
</tr>
<tr>
<td>(2) .5</td>
</tr>
<tr>
<td>(3) .6</td>
</tr>
<tr>
<td>(4) .006</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. Give the correct sign: .9 &lt; 1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) &lt;</td>
</tr>
<tr>
<td>(2) &gt;</td>
</tr>
<tr>
<td>(3) ≥</td>
</tr>
<tr>
<td>(4) =</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. Give the correct sign: .06 X .003</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) &lt;</td>
</tr>
<tr>
<td>(2) ≤</td>
</tr>
<tr>
<td>(3) ≥</td>
</tr>
<tr>
<td>(4) =</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4. Add: 0.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Add: 0.6</td>
</tr>
<tr>
<td>(1) 0.14</td>
</tr>
<tr>
<td>(2) .14</td>
</tr>
<tr>
<td>(3) 1.4</td>
</tr>
<tr>
<td>(4) 14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5. Add: 48.96 + 1.67</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) 50.53</td>
</tr>
<tr>
<td>(2) 50.53</td>
</tr>
<tr>
<td>(3) 50.63</td>
</tr>
<tr>
<td>(4) 5063</td>
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</table>

<table>
<thead>
<tr>
<th>6. Subtract: 5.94 - 2.67</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) 5.07</td>
</tr>
<tr>
<td>(2) 6.07</td>
</tr>
<tr>
<td>(3) 6.7</td>
</tr>
<tr>
<td>(4) 67</td>
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</table>

<table>
<thead>
<tr>
<th>7. Subtract: 0.546 - 0.187</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) 0.379</td>
</tr>
<tr>
<td>(2) 0.379</td>
</tr>
<tr>
<td>(3) 3.79</td>
</tr>
<tr>
<td>(4) 379</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>8. Multiply: 59.14 X 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) 59.14</td>
</tr>
<tr>
<td>(2) 591.4</td>
</tr>
<tr>
<td>(3) 5914</td>
</tr>
<tr>
<td>(4) 591400</td>
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</table>

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<thead>
<tr>
<th>9. Multiply: 6.7 X 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) 134</td>
</tr>
<tr>
<td>(2) 134</td>
</tr>
<tr>
<td>(3) 134</td>
</tr>
<tr>
<td>(4) 1340</td>
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</table>

<table>
<thead>
<tr>
<th>10. Multiply: 20.6 X .01</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) 0.206</td>
</tr>
<tr>
<td>(2) 0.206</td>
</tr>
<tr>
<td>(3) 2.06</td>
</tr>
<tr>
<td>(4) 206</td>
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<table>
<thead>
<tr>
<th>11. Multiply: 4.5 X .7</th>
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<tbody>
<tr>
<td>(1) 3.015</td>
</tr>
<tr>
<td>(2) 3.15</td>
</tr>
<tr>
<td>(3) 31.5</td>
</tr>
<tr>
<td>(4) 315</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>12. Multiply: 1.24 X 7.15</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) 0.26660</td>
</tr>
<tr>
<td>(2) 2.6660</td>
</tr>
<tr>
<td>(3) 266.60</td>
</tr>
<tr>
<td>(4) 26660</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>13. Divide: 649.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) 62</td>
</tr>
<tr>
<td>(2) 62</td>
</tr>
<tr>
<td>(3) 62</td>
</tr>
<tr>
<td>(4) 620</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>14. Divide: 73 X 78.65</th>
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</thead>
<tbody>
<tr>
<td>(1) 0.105</td>
</tr>
<tr>
<td>(2) 1.05</td>
</tr>
<tr>
<td>(3) 105</td>
</tr>
<tr>
<td>(4) 1050</td>
</tr>
</tbody>
</table>
### Word Problems

18. George ran the 100-metre dash in 12.25 seconds. Hangie ran it in 12.17 seconds. How many more seconds did it take George to run the dash than Hangie?

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<tr>
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<tbody>
<tr>
<td>(1)</td>
<td>0.018</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2)</td>
<td>0.18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3)</td>
<td>1.08</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4)</td>
<td>18</td>
<td></td>
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19. A small car averages 12.3 kilometres per litre of gasoline. How far can the car travel on .9 litres of gasoline?

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</thead>
<tbody>
<tr>
<td>(1)</td>
<td>11.07 kilometres</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2)</td>
<td>11.7 kilometres</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3)</td>
<td>117 kilometres</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4)</td>
<td>1107 kilometres</td>
<td></td>
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20. If one bar of candy costs $0.09, how many pieces of candy at the same price can you buy with $1.35?

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<tbody>
<tr>
<td>(1)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2)</td>
<td>1.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3)</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4)</td>
<td>150</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
APPENDIX H

Questionnaires on Use of Calculators
Directions: Check the appropriate answer.

1. Do you like using the calculator?
   ___ yes
   ___ no

2. Does the calculator help you understand better?
   ___ yes
   ___ no

3. Does the calculator give you the correct answer when you are wrong?
   ___ yes
   ___ no

4. Is the calculator fun?
   ___ yes
   ___ no

5. Would you like to use the calculator all the time?
   ___ yes
   ___ no

6. Have you used the calculator at home since you started using them in school in October?
   ___ yes
   ___ no
   If your answer is yes, check the following reason(s) for your using the calculator at home.
   (a) To do homework for math class.   _______
       How many times did you use it to do homework?   _______
   (b) To do homework for another class.   _______
       How many times?   _______
   (c) To have fun.   _______
       How many times?   _______
   (d) To show those at home what you were doing in school.   _______
   (e) Other (please state what)   _______

7. Since you started using calculators in school in October, have you received help in math at home from
   (a) Parent   _______
   (b) Brother or Sister   _______
   (c) Other Students   _______
   (d) No Help   _______
8. Have you discussed your classroom usage of the calculator with other sixth-grade students who do not use calculators in their classrooms?

   ___ yes
   ___ no

   If yes, give the students' names.

   ____________________________________________________________

   Did you explain to them how to use the calculator?

   ___ yes
   ___ no

   Did you help them with their math?

   ___ yes
   ___ no

   Did they help you?

   ___ yes
   ___ no

9. Have you had any homework in math since October when you started using the calculator in class?

   ___ yes
   ___ no
CONTROL
  Name
  School
  Teacher
  Date

Directions: Check the appropriate answer.

1. Have you used a calculator at home since October when you started working with decimals in math class?
   Yes
   No

   If your answer is yes, check the following reason(s) for your using the calculator.
   (a) To do homework for math class. ______
       How many times did you use it to do homework? ______
   (b) To do homework for another class. ______
       How many times? ______
   (c) To have fun. ______
   (d) To try what other students in the sixth grade who use calculators in school are doing. ______
   (e) Other (please state what) ______

2. Since you started working with decimals in October, have you received help in math at home from
   (a) Parents ______
   (b) Brother or sister ______
   (c) Other Students ______
   (d) No Help ______

3. Have you discussed using calculators with sixth grade students who use them in school?
   Yes
   No

   If yes, give the students' names.

   ______

   Did these students explain how to use the calculator?
   Yes
   No

   Did they help you with your math?
   Yes
   No

   Did you help them?
   Yes
   No

4. Have you had any homework in math since October when you started working with decimals?
   Yes
   No
APPENDIX I

Schedule for the Experiment
SCHEDULE FOR THE EXPERIMENT

Day 1  Teacher Orientation
Day 2  All students - SRA
Day 3  All students - Pretests, decimal test and The Criterion Referenced Test in Metrics Measurement
Day 4  Experimental Group - Instruction, Use of the Calculator Control Group - Lesson 1 (See Learning Objectives)
Day 5  Experimental Group - Lesson 1  Control Group - Lesson 2
Day 6  Experimental Group - Lesson 2  Control Group - Lesson 3
Day 7  Experimental Group - Lesson 3  Control Group - Lesson 4
Day 8  Experimental Group - Lesson 4  Control Group - Lesson 5
Day 9  Experimental Group - Lesson 5  Control Group - Lesson 6
Day 10 Experimental Group - Lesson 6  Control Group - Lesson 7
Day 11 Experimental Group - Lesson 7  Control Group - Lesson 8
Day 12 Experimental Group - Lesson 8  Control Group - Lesson 9
Day 13 Experimental Group - Lesson 9  Control Group - Lesson 10
Day 14 Experimental Group - Lesson 10  Control Group - Lesson 11
Day 15 Experimental Group - Lesson 11  Control Group - Lesson 12
Day 16 Experimental Group - Lesson 12  Control Group - Lesson 13
Day 17
Experimental Group - Lesson 13
Control Group - Lesson 14

Day 18
Experimental Group - Lesson 14
Control Group - Lesson 15

Day 19
Experimental Group - Lesson 15
Control Group - Lesson 16

Day 20
Experimental Group - Lesson 16
Control Group - Lesson 17

Day 21
Experimental Group - Lesson 17
Control Group - Lesson 18

Day 22
Experimental Group - Lesson 18
Control Group - Lesson 19

Day 23
Experimental Group - Lesson 19
Control Group - Lesson 20

Day 24
Experimental Group - Lesson 20
Control Group - Lesson 21

Day 25
Experimental Group - Lesson 21
Control Group - Lesson 22

Day 26
Experimental Group - Lesson 22
Control Group - Lesson 23

Day 27
Experimental Group - Lesson 23
Control Group - Lesson 24

Day 28
Experimental Group - Lesson 24
Control Group - Lesson 25

Day 29
Experimental Group - Lesson 25
Control Group - Posttests, decimal test and metric test

Day 30
Experimental Group - Posttests, decimal test and metric test

One month after
Day 30
All students - Retention tests, decimal test and metric test
VITA

Maxine Bogues Allen was born in Portsmouth, Virginia on July 31, 1942. She attended the public schools in Portsmouth and was graduated from I. C. Norcom High School in 1960.

She received the Bachelor of Science degree in mathematics education from Norfolk State College, a Master of Arts degree in mathematics education from Hampton Institute, and the Doctor of Education degree in supervision from Virginia Polytechnic Institute and State University.

Her work experience in mathematics education includes: teacher and department chairman in the Portsmouth, Virginia school system, teacher in upward bound projects at Norfolk State College and Virginia Polytechnic Institute and State University, and supervisor of student teachers under a graduate teaching assistantship at Virginia Polytechnic Institute and State University.

Maxine B. Allen
EFFECTIVENESS OF USING HAND-HELD CALCULATORS FOR LEARNING DECIMAL QUANTITIES AND THE METRIC SYSTEM

by

Maxine B. Allen

(ABSTRACT)

The problem of this research was to determine whether using hand-held calculators was more effective for the acquisition and retention of concepts and skills on decimal algorithms and metric units than the use of pencil and paper computation only.

The sample consisted of six intact sixth grade classes (175 students). Two classes using hand-held calculators (the experimental group) and one class using pencil and paper only (the control group) were located in each of two schools in separate school districts. The classes were assigned randomly as either experimental or control. Each treatment period was 30-50 minutes daily for the duration of the twenty-five day study. Both groups studied the same content based on designated learning objectives.

Test scores of the Criterion Referenced Test in Metrics Measurement by Weber and a decimal test, developed by the researcher, were used as dependent variables. Both tests were used as pretests, posttests, and retention tests. The multivariate analysis of covariance technique was used to test the hypotheses.

The results of the study showed no significant differences on the posttests. There was a significant difference (p < .001) on the
linear combination of the decimal and metric retention tests in favor of the control group. The difference was attributable to the metric test.

Ten students in the control group admitted that they had used calculators at home during the experiment. Separate multivariate analyses of covariance were used to determine if differences existed between the ten students and the other members of the control group. There was a significant difference on the linear combination of the posttests between the ten students and the other control students \( (p \leq .016) \). This difference was attributed to the decimal test in favor of the ten-student group.

Multivariate analyses of covariance were used to test if significant differences existed between the experimental group and the control group minus the ten students who admitted using calculators at home during the experiment. There were significant differences on the retention tests in favor of the control group minus the ten students who used calculators at home \( (p \leq .001) \). The differences were attributable to both the metric and the decimal tests.

From the findings, the following conclusions were drawn. Using pencil and paper only was more effective than using hand-held calculators for the retention of concepts and skills of decimal algorithms and metric units.