This is to certify that the

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THE EFFECTIVENESS OF USING A HAND-HELD CALCULATOR
AS AN INSTRUCTIONAL AID IN TEACHING THE
BASIC MULTIPLICATION FACTS TO
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THE EFFECTIVENESS OF USING A HAND-HELD CALCULATOR AS AN INSTRUCTIONAL AID IN TEACHING THE BASIC MULTIPLICATION FACTS TO FOURTH GRADERS

By

David Keller Dean

A DISSERTATION

Submitted to
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ABSTRACT

THE EFFECTIVENESS OF USING A HAND-HELD CALCULATOR AS AN INSTRUCTIONAL AID IN TEACHING THE BASIC MULTIPLICATION FACTS TO FOURTH GRADERS

By

David Keller Dean

This experimental study was designed to compare the effectiveness of learning the basic multiplication facts with the aid of a hand-held calculator to the learning of the multiplication facts using the conventional paper and pencil approach. The experiment also examined the potential interaction between one's prior mathematics achievement and the influence of various degrees of calculator use on achievement.

The investigation included seven fourth grade classrooms (137 students) located in three elementary schools in a rural midwestern school district.

On the basis of a standardized mathematics achievement test administered five weeks prior to the treatment period, all students in the study were assigned one of three achievement levels; low, average, or high.

Each of the seven classrooms was randomly assigned to one of three treatment conditions:

1. Two intact classes were assigned to use the calculator for all computation.
2. Three classes were assigned to use the calculator for checking problems only. The calculator was used after the student had provided an initial answer.
3. Two classes were denied all calculator use.

Treatment for all three groups consisted of instruction over a six week unit on multiplication included in the students' regular fourth grade mathematics textbook. All instruction was provided by the regular classroom teachers. Individual classroom procedures varied only to the extent that the experimental groups were using calculators as prescribed in their treatment.

A pretest was given November 5, 1979. The treatment commenced the following day and ended December 14, 1979 with a posttest. A retention test was administered six weeks following the conclusion of the experiment. Throughout the investigation teachers recorded anecodotal accounts of how the calculators affected their classes.

The pretest, posttest and retention tests used in the study were three forms of the same instrument. The tests were randomly selected 50 item samples of the 100 basic multiplication facts. The pretest was used as the covariate in two computations of analysis of covariance.

The first analysis of covariance used the posttest scores as the criterion variable. The results showed no significant differences between the three treatment conditions. The analysis also produced no evidence of interaction effects.

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The second analysis of covariance used the retention test scores as the criterion variable, which was a measure of six week retention. There were no significant differences between the three treatment groups.

Teachers' attitudes toward the use of the calculator were varied. They viewed the calculator as worthwhile but with varying suitability for their classrooms. The more notable observed outcomes included:

1. All teachers found the calculator to be motivational to their students.
2. The teachers felt a loss of some control over the students' learning. This seemed to create some discomfort and a feeling of frustration.
3. The amount of time required to teach the multiplication facts did not seem to be affected by calculator use.

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It is also recognized that this study could never have been completed without the patience and loving support of the author's wife, Kathryn.

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CHAPTER I

THE PROBLEM

Introduction

Knowledge of the basic multiplication facts (0 X 0 through 9 X 9) is a competency that most educators expect from all students in the study of mathematics. It's an important objective of every elementary school mathematics program (Wilderman, 1976).

Youngsters are generally first exposed to the multiplication facts in the second and third grades. Instruction in these grades is usually introductory and consists of learning the "twos" and the "fives."

It is in the fourth grade that the student is generally expected to master all of the facts. Learning the essentials of multiplication is a basic component of the fourth grade mathematics curriculum and this is clearly evident when examining the content of most fourth grade mathematics textbooks (Freeman & Kuhs, 1979).

The availability of inexpensive, hand-held electronic calculators has been of interest and concern to all teachers of mathematics. Low cost and easy accessibility have made the application of calculators one of the most discussed topics in our schools today. Although opinions vary about how and when the calculator

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should be used in the classroom, it is generally recognized that pocket calculators are part of our lives and have a place in our schools.

The National Council of Teachers of Mathematics (NCTM, 1975) has taken the following position on the use of the calculator in the classroom:

> The NCTM encourages the use of calculators in the classroom as instructional aids and computational tools. Calculators give mathematics educators new opportunities to help students learn mathematics and solve contemporary problems. The use of calculators, however, will not replace the necessity for learning computational skills (p. 1).

According to Gibb (1975a), the multiplication facts can be handled quickly and easily on a calculator. Calculators provide the student with a quick response and immediate reinforcement. "Learners can engage in self-regulated exercises . . . teachers report that students who use hand-held calculators learn basic multiplication facts more quickly than their predecessors who used other devices" (p. 43).

It appears that the immediate feedback provided by hand-held calculators may play a role in helping youngsters learn the multiplication facts. Skinner and other behaviorists generally agree that for learning to occur, it is necessary that feedback be provided concerning the extent to which a behavior is correct. Skinner (1954) insisted that it is the confirmation of the correct response which is crucial to learning. In referring to teaching machines, Skinner (1968) says that the machine "reinforces the student for eve

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every correct response, using this immediate feedback not only to shape his behavior most efficiently but to maintain it in strength in a manner which the layman would describe as holding the student's interest" (p. 39).

Purpose

The purpose of this study was to investigate the effectiveness of using a hand-held calculator as an instructional aid in the learning of the basic multiplication facts. Five questions were posed:

1. Does the use of the hand-held calculator improve the learning of the basic multiplication facts in speed or understanding when compared with the conventional approach of using paper and pencil?
2. What degree of calculator use is most appropriate to the learner: Will more be learned through unlimited use of the machine, controlled use, or no use at all?
3. Which level of achiever, if any--low, average or high--is most apt to benefit from the use of the calculator?
4. Is there an interactive effect between the degree of use and the achievement level of the student?
5. What impact will the use of the hand-held calculator as an instructional aid have on the long term retention of the basic multiplication facts?

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Hypotheses

H_1 There will be significant differences in short-term retention among the two experimental groups using calculators and the control group which will not use calculators, where short-term retention is measured by a posttest of multiplication facts administered on the final day of instruction.

H_2 There will be significant differences in long-term retention among the two experimental groups using calculators and the control group which will not use calculators, where long-term retention is measured by a posttest of multiplication facts administered six weeks following the conclusion of instruction.

H_3 There will be a significant interaction in scores on the test of short-term retention, when degree of calculator use is crossed with previously demonstrated level of performance on a standardized test of mathematics achievement.

Importance of the Study

Hand-held calculators have become an integral part of our society. A 1977-78 study reported by the National Assessment of Educational Progress (Wyatt) found that more than 75% of 9 year olds, 80% of 13 year olds, and 85% of 17 year olds have access to calculators (p. 217). Their increasing availability in the student's world, at home and at school, forces educators to take a hard look to see what course the schools should take in regard to calculator use (Bell and Suydam, 1976, p. 1).

The calculator has the potential for replacing the paper and pencil calculations that have been the major (and often the sole) component of elementary school arithmetic. The widespread introduction of the calculator in the classroom may require the revision of the elementary school mathematics curriculum as we now know it.

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In this vein Max Bell (1974) of the University of Chicago stated, "Finally, I have become convinced during just this past year that the widespread availability of cheap electronic calculators will have profound effects and must move us very soon to reevaluate many of our current practices in the teaching of school mathematics" (p. 197).

Much of the previous research done on calculator use treated the machine and content studied as a supplement to the regular curriculum. This study investigated a basic curriculum component, multiplication, and dealt with it in a normal classroom setting using the content of the regular textbook as the focus of instruction. While it was a tightly controlled experiment, it was not conducted in an artificial or "laboratory" setting.

While many math educators are beginning to take the use of the calculator for granted, questions remain about how to make the best use of it. Little research has been devoted to studying the manner in which the calculator should be used.

Also, little has yet been discovered about the implications for calculator use among varying levels of achievers. Does calculator use have a greater impact upon one group than another?

Limitations

The following limitations must be considered in generalizing from the results:

1. Time: The study included twenty treatment sessions which took place over a period of six weeks.

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2. Population: The study included 137 youngsters in seven classes who were in the fourth grade in the Allegan, Michigan Public Schools in the fall of 1979.

3. Content: The study was limited to the learning of the basic multiplication facts.

Definitions of Terms

Hand-held calculator is defined to be an electronic device which displays the results of addition, subtraction, multiplication and division operations. Its features include the following: (1) algebraic logic; (2) floating decimal; (3) bright, easily readable eight digit display; (4) no keys with non-associated second functions; and (5) battery and AC adapter options. It is small enough to hold in the hand (mini-calculator, pocket calculator).

Basic multiplication facts are defined as the multiplication problems in which both factors are one digit numbers. Example: 4 X 6, 3 X 9, 0 X 5.

Degree of calculator use refers to the amount of use the student made of the calculator. The amount of use for each student falls into one of three categories: no use, limited use (checking problems only), and complete use (used for all calculations).

Low, average or high achiever refers to the student's achievement level as indicated on the Mathematics Computation and Mathematics Concepts and Applications subtest of the California Achievement Test administered one month prior to the study:

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Low = below 34 percentile
Average = 34-66 percentile
High = above 66 percentile

Control group refers to the students in the study who are taught the multiplication facts using conventional methods and do not use the calculator.

Experimental group #1 refers to all the students in the study who use the calculator only to check problems previously done without benefit of a calculator.

Experimental group #2 refers to all students in the study who were encouraged to use the calculator for all calculations.

Interaction refers to the effect on mathematics achievement due to the crossing of achievement levels with calculator-no calculator use.

Long term retention refers to achievement demonstrated on a posttest given six weeks following the conclusion of instruction on the multiplication facts.

Hawthorne effect refers to the stimulation or output that results from the mere fact of being under concerned observation.

Summary

There is much to be learned regarding the use of the calculator in the mathematics classroom. The evidence to date would seem to indicate that the calculator will continue to play an ever greater role in mathematics education. Knowledge of its most efficient use will lead to increased understanding and may affect the future of the mathematics curriculum.

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Previous research seems to suggest that the calculator has a positive influence in the areas of computation and attitude. The next chapter will examine earlier investigations regarding (1) the learning of the multiplication facts, and (2) the effects of calculator use.

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CHAPTER II

REVIEW OF LITERATURE

Literature relevant to the questions posed in this study are examined in three categories. The first section describes research relative to the teaching of multiplication. The second section reviews the debate for and against calculator use. Selected research on the calculator from 1937 to the present is reported in the third section.

The Teaching of the Basic Multiplication Facts

Previous research on multiplication covers a wide range of topics. This review will highlight studies relevant to the teaching of the basic multiplication facts. The first question examined concerns methods used to teach multiplication.

Tietz (1970) compared two methods of teaching multiplication to fourth graders. One approach used repeated addition with an array as a physical referent. The other used a ratio-to-one approach with a coordinate system and ordered pairs as a referent. No significant relationship was found. The data indicated that neither strategy was more effective than the other for the mastery of multiplication facts or understanding of math properties when the total group was compared.

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In research similar to Tietz, Hervey (1966) used the same two distinct definitions of multiplication, an equal addends definition and a Cartesian cross-product definition. Studying thirty-two second graders she found significant differences favoring the equal addends approach. Concept development was simplified through the use of the equal addends approach.

Nichols (1972) studied two other methods of teaching multiplication and division to third graders. She compared (1) the use of manipulative materials and pupil discovery with (2) abstract and semi-concrete materials with teacher explanation and exposition. She found significant differences favoring group one.

Gunderson (1955) made a similar discovery. She found that more time should be spent on the concrete and semi-concrete stages. She concluded that if the child is to see multiplication as a short cut for column addition of like numbers, he must have had sufficient experience with solving multiplication problems by addition and appreciate the value of multiplication.

F. T. Wilson (1931) presented multiplication problems to youngsters in two different forms, example 2 X 7 and $\begin{array}{r} 7 \\ \text{X}\,\underline{2} \end{array}$. He found that the form in which a multiplication combination is written is of no importance. "Grasping the plan of the task, the mind seems not to be disturbed by the arrangement of parts, but seeks to handle the material as a whole" (p. 536).

A second major issue covered in research on multiplication is an examination of the relationship between drill and meaning in learning how to multiply.

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Brownell and Chazel (1935) reviewed previous research on the effects of drill. Citing sixteen studies, they concluded that drill increases, fixes, maintains and rehabilitates efficiency. They then investigated the impact of drill on raising the level of children's performance in arithmetic. Skipping preliminary instruction and concept development, Brownell and Chazel taught sixty-three third graders exclusively by drill. They made the following discoveries:

1. Drill does not guarantee that children will be able immediately to recall combinations.
2. In spite of long-continued drill, children tend to maintain the use of whatever procedures they have found to satisfy their number needs.
3. Drill makes little, if any, contribution to growth in quantitative thinking by supplying maturer ways of dealing with numbers. (p. 28)

The authors concluded that this study in no way implies that drill has no place in arithmetic. It simply indicates that to be effective, drill must be preceded by sound instruction.

Howard (1950) did research on the learning of the multiplication facts and teaching methodology. He found children will retain learning longer when time spent developing meaning is followed by demonstration of how to work problems, then followed by drill exercises. More specifically, he found the relationship between time spent on developing meaning and the time spent on practicing computations should vary according to the grade level of the children and the step in arithmetic being learned.

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Glennon and Callahan (1968) found that youngsters should be taught the basic facts through the use of a variety of visual and manipulative devices. After meaning is achieved, then drill is still recommended. They found drill will consolidate the learning that has occurred.

McConnell (1934) compared pupils taught using the Gestalt idea of meaning with a group taught through the use of extensive drill. In a study of the 100 addition combinations, not multiplication, those taught with meaning excelled in tests of transfer to untaught combinations and on tests of maturity of manipulation of number facts. Those using the drill approach accomplished their goals faster, and the correlations between IQ and scores on final tests were uniformly higher for the drill taught group.

In other research by Brownell (1944), students' thought processes in dealing with multiplication combinations were classified. The researcher identified eleven categories of thought processes that best described a pupil's response to a given combination. It was discovered that each child used a variety of processes; and that fewer than 40% fit the rote memory, immediate recall model that would be associated with learning from drill. He also found a transition in thought processes from less mature to more mature as the children got older.

As far back as the 1920's researchers attempted to establish the relative difficulty of the 100 basic multiplication facts.

Investigating third graders, Fowlkes (1927) concluded that there seemed to be much less difference in the difficulty of the

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100 basic multiplication facts than had been concluded from studies of uncontrolled learning and practice conditions.

Similar research by Batson and Combellick (1925) provided much the same results. They concluded that the range of relative mental difficulty of the combinations is not so great as the range of relative physical difficulty of writing the results.

Smith (1921) studied the time it took a student to respond to a given combination. He discovered that focusing the drill on the more difficult facts was more effective for both short and long term retention than drilling all combinations equally.

Suppes (1966) measured response time using Computer Assisted Instruction equipment and called it response latency. He used a complex statistical procedure, linear regression equations, to identify problem related variables which could be used to predict problem difficulty. His findings indicated that the difficulty of a combination depended on the size of the smaller of the two factors much more than the size of the larger, and that these variables accounted for a very large part of the variance.

Brownell (1951) studied the readiness of 487 fifth graders who were to be taught division using two digit divisors. He concluded that the children find this topic hard because too many children have inadequate mastery of the prerequisite skills and facts, including the multiplication facts. Without these facts and skills children do not acquire the computation skills they need.

Clemens and Neubaurer (1928) investigated the major causes of errors in multiplication. Included in their findings was that

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5-15% of errors were the result of lack of mastery of the basic multiplication facts.

Summary

A variety of teaching methods have been examined for teaching the multiplication facts. The use of some drill is a widely recognized and accepted feature of most instruction on the facts. The learning of the multiplication facts is an important prerequisite to future mathematics achievement.

The Debate For and Against Calculator Use

The first battery operated hand-held electronic calculators were marketed in 1971 with prices in the hundreds of dollars. By 1975 one in ten Americans owned one (Schafer, Bell & Crown, 1976) and by 1978 over 80 million calculators had been sold (Suydam, 1978): one calculator for every three Americans.

These data reflect sales not only to individuals but to schools as well. The calculator has been readily accepted at the college level as an indispensible aid in higher mathematics, engineering, chemistry and other courses. At the secondary school level, there has also been a high degree of acceptance. The calculator has been recognized for its ability to reduce time spent on tedious computation and thus allow more time to be spent on mathematicsl ideas and higher order problems (Suydam, 1978).

From the junior high school years downward, hesitancy about using calculators increases (Suydam, 1978). The most obvious reason for this is the widespread belief, held by both parents and teachers, that children should master the basic facts and the procedures for addition, subtraction, multiplication and division before they use calculators.

Marilyn Suydam (1978), Director of the Calculator Information Center at Ohio State University, compiled a list in 1976 of reasons for using and not using calculators in schools. Other literature continues to make frequent reference to its pertinence.

The reasons for using calculators:

1. They aid in computation.
2. They facilitate concept development and understanding.
3. They lessen the need for memorization.
4. They help in problem solving.
5. They motivate.
6. They aid in exploring, understanding, and learning algorithmic processes.
7. They encourage discovery, exploration and creativity. and
8. They exist: this pragmatic fact is perhaps the most compelling, as they appear in the hands of increasing numbers of students.

The reasons for not using calculators:

1. They could be used as a substitute for developing computational skills.
2. They are not available to all.
3. They may give a false impression of mathematics--that it involves only computation and is largely mechanical.
4. There is insufficient research on their effects.
5. They lead to maintenance and security problems. (p. 5)

Concerns

A large number of mathematicians have tempered their enthusiasm for the calculator with words of caution and concern. Harrington (1976) noted that the calculator's potential to minimize the need for rote memory or computational skills might cause a deterioration of students' ability to compute without it, seriously handicapping future success in mathematics or everyday life. Feder (1975) contended that students should not use calculators until they have proven their ability to compute without it. Gibb (1975b) was more explicit. She believed that placing calculators in the hands of students simply because they're available would be disastrous. She stated that students should not use calculators until they have developed a concept of number, a system for naming numbers, and an understanding of the meaning and processes of the basic operations . . . that is until they understood what the calculator was doing for them.

Collins (1979) fears the negative side effects of poor teaching used in conjunction with the calculator. She cites several problems which may result from ineffectual calculator instruction: student dependency on machines; erosion of paper and pencil skills; lack of conceptual development; and blind acceptance of whatever answer the calculator produces.

Justifications

Joseph Caravella (1977), who authored one of the first books devoted entirely to calculators, notes that the calculator has become an integral part of our society, ". . . it is already making valuable contributions in the mathematics classroom. It is being used to save time, to reinforce learning, to develop concepts, to motivate the learner, and to apply mathematics in realistic, everyday situations" (p. 14).

In September 1974, the National Council of Teachers of Mathematics (NCTM) endorsed the minicalculator as a valuable instructional aid by issuing the following statement:

> 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. (p. 4)

Positive reactions were expressed by many: Gibb (1975a) believed they would help the learning and thinking of students. Elder (1975) added that the experiences would require and result in better understanding of mathematics; Spencer (1974) thought that slower students would profit most and Stultz (1975) noted the immediate reinforcement potential for drill practice; Quinn (1976a) believed that student interest, attitude, and computational skills were enhanced and Immeerzeel (1976) anticipated that students would undertake more "real life" problems.

Hopkins (1976) states that resistance to calculator use is "irrational." He views the calculator as simply the instrument of calculation and likens it to the paper and pencil. He states the aversion of many people to calculators in schools is simply resistance to a change in instruments in calculation brought about by advancing technology.

Shumway (1976) summarized the proponents arguments:

> The hand-held calculator is a tool used in society for calculations. Schools are "burying their heads in the sand" if hand-held calculators are not recognized and used as the calculational tool that they are. (p. 572)

The NCTM Board of Directors at its September 1975 meeting approved a report from the Council's Instructional Affairs Committee that identified nine ways in which the minicalculator can be used in the classroom.

1. To encourage students to be inquisitive and creative as they experiment with mathematical ideas.
2. To assist the individual to become a wiser consumer.
3. To reinforce the learning of the basic number facts and properties in addition, subtraction, multiplication, and division.
4. To develop the understanding of computational algorithms by repeated operations.
5. To serve as a flexible "answer key" to verify the results of computation.
6. To promote student independence in problem solving.
7. To solve problems that previously have been too time consuming or impractical to be solved with paper and pencil.
8. To formulate generalizations from patterns of numbers that are displayed.
9. To decrease the time needed to solve difficult computations. (p. 94)

Summary

In the literature reviewed it is clearly evident that the calculator is beginning to effect mathematics instruction and that its impact will continue to grow. All writers agreed that careful consideration should accompany its widespread use. In summarizing the debate surrounding calculator use, Suydam (1979a) concludes:

> Slowly but surely, the calculator is being incorporated into the school program at all levels. It is being recognized as an instructional tool which has certain capabilities. But it is not a panacea: it cannot resolve all of the difficulties in mathematics instruction. Moreover, it has certain limitations: teachers must accept responsibility for teaching children how and when to use calculators, and thus to be aware of its limitations. After all, students now in school will have calculators, or similar computational tools, to use for the rest of their lives. (p. 7)

Previous Studies on Calculator Use

The review of research on calculator use is organized into five categories: (1) General Calculator Use, (2) Calculators and the Teaching of Multiplication, (3) Calculators and Degree of Use, (4) Calculators and Mathematics Aptitude, and (5) Calculators and Retention.

General Calculator Use

The first reported study conducted on the effect of a calculating machine on arithmetic achievement took place in 1937. Betts (1937) experimented with calculating machines giving them to thirteen sixth graders for a six week treatment period. He compared gain scores on four tests and found improvement each time in favor of the calculating group. He also found that pupils were able to analyze more problems in the time available.

Fehr, McMeen and Sobel (1956) studied hard-operated computing machines with eight fifth grade classes, four experimental and four control. Their design included using alternate forms of the Stanford Achievement Test as a pre- and posttest. Treatment consisted of thirty-five to forty minutes a day of mathematics for four-and-a-half months. Fehr et al. found that students using the machine made significant gains in both computation and reasoning. Although their gains were greater than those of a control group, these differences were not statistically significant. Both students and teachers using calculators had a very positive attitude toward calculator use in the mathematics classroom.

Fourth, fifth and sixth graders were included in a study done by Beck (1960). Ms. Beck made the following observations: When used as a regular classroom tool, the calculator tended to motivate and reinforce understanding and achievement in the basic skills. Children seemed to enjoy using the calculators, and to exhibit better work habits while using them.

Lowerre, Scandura, Joseph and Alice, and Vaneski (1976) investigated a small sample (three students) of third and fourth graders. Their conclusions were: (1) use of the calculator is helpful in testing and practicing place value and metrics, primes and composites, and detecting pattern, (2) it enables the instructor to introduce "real world" problems, (3) they're motivational, and

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(4) the teacher gains more time to spend on concrete representations of concepts.

Nelson (1976) studied the impact of hand-held calculators on attitude and computational skills of fourth through seventh graders in a summer school program. One hundred ninety-six students were divided into four different curricular programs: the regular mathematics program, the regular program plus calculators, a commercial calculator involved curriculum, or a diagnosis-remediation calculator program. Treatment consisted of fifty minutes per class period for four weeks. Alternate forms of a standardized test were used as a pre- and posttest measure. Nelson concluded that: (1) gains in basic computational skills can be improved significantly with the introduction of calculators, (2) their planned use improves computational skills gains, and (3) attitudes are significantly improved through their use.

Jones (1976) studied the use of the calculator at the sixth grade. Her forty lessons covered computations and applications of decimal numbers and common fractions, with some attention to metric measures and percent. Two forms of a standardized achievement test were used to measure pre and post instruction achievement. Significant differences favoring the experimental group in total achievement, computation and concepts were discovered. The investigator also advanced the contention that the hand-held calculator reduces boring, tedious drill and serves as a motivational instrument.

Computational ability of elementary students using hand-held calculators was investigated by Schnur and Lang (1976). The sample consisted of sixty students enrolled in a compensatory summer program. Instruction focused on the four basic arithmetic operations. Separate forms of a standardized achievement test provided pre- and posttest data. The analysis of variance showed a significant gain favoring the calculator group.

Spencer (1975) investigated calculator use and the computational skills and reasoning ability of intermediate grade students. Eighty-four fifth and sixth graders divided equally among the experimental and control groups comprised the sample. The treatment consisted of instruction on the four basic operations plus fractions, decimals and percentages. No description was given of the length, frequency or nature of the instruction. Alternate forms of the Iowa Test of Basic Skills provided pre- and posttest data. At grade five significant differences were found favoring the experimental group on the gain scores of the reasoning test. At grade six significant differences favored the experimental group on both computation and total arithmetic.

Quinn (1976b), who studied calculator use with eighth and ninth graders, made the following discoveries: (1) students learn to operate calculators easily at almost any grade level, (2) students compute better with calculators than without, (3) students are able to tackle more "real life" problems, (4) students suffer no loss in paper and pencil computational ability, and (5) students enjoy using calculators.

Some experiments featuring intermediate grade students did not produce significant differences favoring the calculator group.

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Allen (1976) investigated sixth graders use of the calculator to learn decimals and the metric system. Treatment lasted for twenty-five days. A posttest was administered immediately following instruction and a retention test one month later. No significant differences were found between groups on the posttest. The retention test showed a significant difference favoring the control group on the metrics section.

Fourth, fifth and sixth graders were the subject of a study by Kobrin (1978). The six month investigation sought to determine the impact of calculator use on general mathematics achievement. Alternate forms of a standardized mathematics achievement test provided pre- and posttest measures. A statistical analysis revealed the following: (1) mathematics achievement of pupils in intermediate grades was not affected by the use of hand-held calculators, and (2) when grade level, sex, and level of achievement were considered, the mathematics achievement was not affected by the use of hand-held calculators.

Borden (1977) investigated the attitude and achievement of 126 sixth graders using calculators while studying decimal fractions. A standard pre/posttest design accompanied the four week unit. No significant differences were found on an immediate posttest or retention test given three weeks later. Attitudes were reported better among the experimental group.

A sixth grade unit on estimation was the focus on a study by Sutherlin (1977). A pretest was given at the beginning of week one and a posttest at the end of week three. A long term retention test was

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was given near week eight. Analysis of covariance followed all posttesting. No significant differences were found between the experimental and control group on the pretest, posttest or retention test.

Calculators and the Teaching of Multiplication

Hohlfeld (1973) studied the "effectiveness of an immediate feedback device for learning basic multiplication facts." His study, at the fifth grade level, compared the learning of students who were drilled on the multiplication facts while receiving immediate feedback from programmed electronic calculators to the learning of students who were drilled on the same facts using only paper and pencil. A third group which received no treatment other than their regular classroom activities was designated as the control group. All groups consisted of twenty-eight students, four from each of seven classrooms, which were randomly selected from a population of fifth graders who were identified as being weak in multiplication facts on the basis of a pretest. Both the calculator and the paper and pencil groups received eight minutes of drill per day for twenty-five days. Daily drill included a sequence of thirty exercises. The research design included a pretest, posttest and two retention tests which were administered one month and 3.5 months after the posttest. The tests consisted of four forms of the same instrument, which was an achievement test on 100 multiplication facts. Significant differences favored the electronic calculator practice group over the pencil and paper practice group on both acquisition and short term retention, but not on long term retention.

A. W. Wilson (1978) studied a wide range of multiplication topics at various grade levels. Topics selected were multiplication by six (grade three), multiplication by a two-digit number (grade four), and decimal multiplication (grade five). A Stanford Achievement Test was used for pre- and posttesting. The treatment lasted over seventeen weeks, however, it was not clearly defined. The calculators were used to check problems done by paper and pencil. Wilson concluded that calculators can be used as an instructional aid without adverse effects in the grades studied.

Calculators and Degree of Use

Research done by Anderson (1977) studied the effects of restricted and unrestricted use of calculators and their impact on achievement and attitude.

Anderson divided a sample of 376 seventh grade pupils into three groups: (1) an experimental group with unrestricted use of the calculator, (2) an experimental group that used calculators for checking previously completed problems, and (3) a control group which was not allowed to use calculators at all. He found that the calculator use in general led to improved attitudes toward mathematics but no change in achievement, understanding mathematical concepts, or computational skills. He also found that using calculators to check previously completed problems led to improved problem solving ability.

Hawthorne and Sullivan (1975), studying forty-eight sixth graders, also concluded that calculators were useful for checking answers.

Two Canadians, Campbell and Virgin (1976), compared the achievement, attitudes and teaching/learning experiences in the mathematics programs of two groups of approximately 150 fifth and sixth graders. A standardized mathematics test served as a pretest. In addition, a questionnaire regarding attitudes and the use of calculators was administered. For a seven month period, students in one school had calculators available in their classrooms for checking their work only, while at a second school no calculators were permitted. At the end of this time, the standardized test and the questionnaires were given as posttests. Results on the achievement test showed that for the computation subtest, there were no significant differences in the gain scores between the two schools. On both the mathematics concepts and the problem-solving subtests, however, fifth graders in the experimental group scored significantly higher than fifth graders in the comparison group.

Calculators and Mathematics Aptitude

Miller separated two heterogeneous fifth grade classes into a low and a high group on the basis of a readiness test. One class was then permitted to use calculators during a twelve day unit on division while the other was permitted the use of multiplication tables. The low calculator group scored significantly higher than the low control group on both division by two digit divisors and its prerequisite skills. No significant difference between high groups resulted.

Kasnic (1977) investigated the impact of calculator use on problem-solving ability. Using a standard achievement test he divided 200 sixth graders into groups of low, average and high achievers. The treatment covered only nine fifty minute sessions. He found that the calculator enabled the low-ability students to compete successfully. The calculator did not appear to significantly aid the average and high achiever.

Vaughn (1976) studied ninth graders in a Fundamental of Mathematics (FOM) program. FOM students are defined to be at least two years below grade level in mathematics achievement. Four classes used calculators and were taught from a curriculum designed by the investigator. The four comparison classes used the regular text and no calculators. Significant differences favored the experimental group on a posttest of mathematics achivement. A retention test, given two weeks later, produced no significant differences.

Jamski (1976) investigated calculator use with middle school students who were taught various rational number-decimal-percent conversion algorithms . . . and the interaction effect (if any) between student ability and calculator use. Jamski used an eight item pretest to assign students to a High, Middle and Low ability group. Instruction, based on the material in Holt School Mathematics, lasted three weeks. A posttest was given following the three week period and regiven five weeks later. The results led to the following conclusions: calculator use in general did not improve achievement, there was no significant interactive effect between calculator use and ability groups.

Eckmier (1978) investigated the use of the calculator with low-achieving fourth grade students in mathematics achievement and attitude. Six classes from four schools participated from September to June, with an experimental and a control classroom at each of three socio-economic levels. The three experimental classrooms used the traditional textbook approach. In addition, the experimental groups were assigned only 50% of the paper and pencil work completed by the control groups. The experimental students used calculators during the remaining class time to check math problems done by hand, as well as other calculator problems. All groups were pre- and posttested with the Metropolitan Achievement Test - Math Concepts, Math Computation and Problem Solving. No significant differences were found in achievement or attitude gains. There was no significant interaction between achievement and level of socio-economic status.

Calculators and Retention

The impact of calculator use on long-term retention is an important inquiry. Six of the studies previously cited (Allen, Borden, Sutherlin, Hohlfeld, Vaughn, and Jamski) include a retention test as a feature of their design. The administration of retention tests reviewed earlier varied in delay from two weeks to three-and-a-half months. In three cases the retention test results were different from the results of posttests which immediately followed instruction. Vaughn and Hohlfeld found that significant differences favoring the calculator group on a posttest were not evident on a retention test given later. In the other case, Allen found significant differences favoring the control group on a retention test given one month after instruction ceased. This difference was not evident on the posttest given immediately following instruction.

Suydam (1979b) sums up the status of calculator research in the introduction to Investigations with Calculators: "Almost all of the studies comparing achievement of groups using or not using calculators either favor the calculator group or (in about equal numbers) reflect no significant differences" (p. 1).

The review of literature has highlighted a number of significant findings. It has provided support for the hypotheses stated in Chapter I. It has also influenced the design of this study.

While conducting the review of previous research many features of research design were examined which have relevance to this study. In addition to the positive features suggested by previous research and incorporated in this investigation several shortcomings were also detected. In developing this study a deliberate effort was made to avoid the following methodological flaws:

1. Incorrect unit of analysis: In studies where intact classes receive the same treatment the unit of analysis should be the class mean. Some studies incorrectly designate the unit of analysis as the individual student.

2. Incomplete description of treatment: Information about how calculators were actually used is frequently left out. Also, observational data is often lacking. Descriptive information regarding what actually happens in the classroom is desperately needed in calculator research.

3. Brief treatments and/or duration of study: Some research is so brief that it cannot produce any substantive data. Ten of the studies reviewed lasted four weeks or less. Also, treatments often involved only minutes per week.

4. Hawthorne effect: The Hawthorne effect is often ignored in calculator research. However, something must be done with the control group to compensate for the novelty attached to calculator use in the experimental groups.

Summary

Research has been presented regarding multiplication and calculator use. Investigations relevant to this study have been highlighted in the summary of each review of literature.

The following conclusions are made:

1. Studies by Tietz, Hervey, Gunderson, Howard, Brownell, Cleamons and Neubauer indicated:

    a. multiplication is understood best when presented as repeated addition, and instruction should include the use of manipulatives.

    b. drill is most effective after meaning has been established.

c. knowledge of the basic multiplication facts is an important prerequisite for further math achievement.

2. Studies by Nelson, Jones, Spencer, Hohlfeld, Anderson, Jamski, Campbell and Virgin, Miller and Kasnic indicate:

a. use of the calculator in math classrooms leads to increased computational ability.

b. use of the calculator to check previously completed problems produces the best results.

c. use of the calculator tends to aid the low achiever more than the average or high achiever.

d. the retention of skills remains consistent with initial posttests among those who use the calculator.

CHAPTER III

METHOD AND PROCEDURE

This experimental study was designed to compare the effectiveness of learning the basic multiplication facts with the aid of a hand-held calculator to the learning of the basic multiplication facts using the conventional paper and pencil approach. It was also designed to examine the potential interaction effect between level of achiever and degree of calculator use.

Pilot Study

A pilot study was conducted in the fall of 1978 which served three distinct purposes: (1) to determine if it was practical to undertake the research, (2) to determine whether the methodology was adequate, and (3) to obtain additional information by which the major study could be improved.

The pilot study consisted of two fourth grade classes at one school. One classroom was assigned complete calculator use and the other was denied all calculator use. The instructional materials and the design of the pre- and posttests were the same as for the major study. The results of the pilot produced evidence favoring the calculator group though the findings were not statistically significant.

As a result of the pilot study it was decided to change the design of the major study in the following ways:

1. Include a "calculator for checking only" group. While observing the experimental class in the pilot study it was noted that some youngsters were using calculators to derive their initial answer while others were waiting to use the calculator to check problems which they had previously completed without the benefit of the calculator. To reduce this variable in the major study and to help establish which procedure might be more successful, it was decided to test both methods of calculator use.

2. Add a retention test at least five weeks after the treatment. After completing the pilot study with only posttest scores to analyze it was determined that a delayed posttest or retention test could provide additional and potentially valuable information.

3. Make observations with regard to the amount of time spent in each classroom teaching the basic multiplication facts. After observing multiplication lessons in the pilot classrooms it appeared that the time spent teaching the multiplication facts may be affected by calculator use.

The Population

The population for this study was fourth grade students of a small school district in a large midwestern state. The student population (K-12) of the school district was approximately 3,000. The school district can best be described as primarily rural middle-class Caucasian.

Sample

All seven fourth grade classrooms from the district's three elementary schools were selected to participate in the study. The classrooms were traditional self-contained units. Population ranged from twenty to twenty-five. Because the researcher was obliged to work with intact classrooms, the sample of students with individual classrooms was not a randomly selected and assigned one. However, the range of abilities of the youngsters in each class was similar. Special education students in the seven classes were excluded from the study. Scheduling problems prohibited their participation.

In early October, 1979, all fourth grade students (n = 151) were given a standardized mathematics achievement test. From the results of this test students were assigned to one of three achievement level groups: High Achievement, Average Achievement, or Low Achievement.

Further, based on a stratified random procedure, each of the seven classrooms was assigned to one of three treatment conditions:

1. Two classrooms (experimental group #2) were assigned to use the calculator for all calculations.

2. Three classrooms (experimental group #1) were assigned to use the calculator to check problems previously done without the benefit of a mechanical device.

3. Two classes (control group) were assigned to do all work by conventional means and were not allowed any calculator use.

The design may therefore be summarized in the following matrix of independent variables, where previously demonstrated level of achievement and degree of calculator use are crossed:

Achievement Level \ Classrooms Nested Within Treatments	Control (no use)		Experimental #1 (checking only)			Experimental #2 (everything)	
	1	2	3	4	5	6	7
High							
Average							
Low							

Instrumentation

The instrument used for initial assessment of mathematics achievement was the California Achievement Test, Level 14, Form C, Mathematics Computation and Mathematics Concepts and Applications subtests. This test spans grades 3.5 through 4.9. A brief description follows:

1. Computation: This section contains forty items which measure the students' ability to add, subtract, multiply and divide. The test has a twenty-five minute time limit.

2. Concepts and Applications: This section contains forty-five items which measure the students' understanding and use of

mathematical concepts in a variety of contexts. Among the basic concepts presented are those which involve place value, money, geometry, graphs, decimals, fractions and measurement. The test has a thirty-five minute time limit.

This test was chosen because of its potential as a predictor of acquisition and retention of the basic facts.

Results of the California Achievement Test are reported in a variety of ways. For this investigation assignment was made to an achievement group based on the student's national percentile score. Pupils scoring in the top one third (67th percentile and above) were assigned to the high achievement group; pupils in the middle (34-66th percentile) were assigned to the average group; and pupils in the bottom third (33rd percentile and below) were assigned to the low achievement group.

Support for this procedure is given by Feldt (1973):

> It is possible to improve the power of methods experiments by exerting some control over the assignment of subjects to treatment conditions. One of the recognized techniques is called "blocking," or the use of stratified samples in the formation of treatment groups. Under this approach one must obtain on each subject an initial measure of ability, such as intelligence quotient or pretest score, or a classification on some relevant variable. Several levels (score intervals) on this measure are arbitrarily established, usually dividing the entire group into thirds, quarters, or fifths. (p. 225)

Tests of achievement of the 100 basic multiplication facts were designed by the researcher. Three fifty item tests were generated (see Appendix A). Each question tested one basic multiplication fact.

The selection and order of questions for each test was established using a system based on a table of random numbers. Tests of this form were used for the pretest, posttest, and the retention test. There was no time limit for this test.

To control for variables in the testing situation, the investigator administered all tests.

Reliability of the tests was established using the Kudor-Richardson formula 20. Pretest reliability was .95, posttest .93, and retention test .88.

No calculator use was permitted in any testing situation.

Treatment

The seven classes were randomly assigned to a treatment group on a stratified schedule. Class means on a standardized mathematics achievement test provided the basis for the stratification. Five weeks prior to the experiment all students were administered the mathematics section of the California Achievement Test. The results of this test produced a mean grade equivalent score for each class. Mean grade equivalent scores for the seven classes ranged from 3.5 to 4.5. Table 1 presents the mean grade equivalent scores by class.

From the group of classes with the three lowest class means one class was randomly assigned to each of the three treatment groups. A similar technique was employed with the classes achieving the three highest class means. The remaining class was also randomly assigned to a group.

Table 1

Mean Grade Equivalent Scores

Class Number	Mean Grade Equivalent Score	Group Assigned
1	3.8	Control
2	4.4	Control
3	3.5	Experimental No. 1
4	3.9	Experimental No. 1
5	4.0	Experimental No. 1
6	3.6	Experimental No. 2
7	4.5	Experimental No. 2

To examine for differences in mathematics teaching ability, a comparison was made of the growth shown by youngsters in each teacher's two previous classes. The growth indicated by mean class averages from one year to the next on the mathematics section of the California Achievement Test served as the basis for this comparison. Difference between mean grade equivalent scores ranged from .62 to 1.5 in an individual year but were largely equal when both years were examined and compared (see Appendix B). This led to the experimental assumption that the teachers were of comparable competence.

Demographic data on the participating teachers is featured in Table 2.

Two months prior to the experiment the researcher met with all teachers involved and described the intent of the research proposal. The specific demands of the project were also discussed. These included: (1) that anyone starting the project would be expected to complete it, (2) that a specific instructional sequence and schedule must be followed, and (3) that the class would adhere at all times to the treatment conditions.

Another meeting was held in late October at which time the instructional sequence and procedures were outlined. Also, the logistics of delivery, security, and maintenance of the classroom sets of calculators that each classroom would be using was reviewed. The calculators and a supply of batteries were delivered to the school at the time of the first testing session.

Table 2

Demographic Data on Teachers

Teacher	Age	Number of Years Teaching	Highest Degree	College Major
1	62	41	BS	Science
2	32	8	BS	Social Studies
3	42	3	BS	Psychology
4	59	21	BS	Social Science
5	25	2	BS	Art, Group Science
6	58	24	MA	Social Studies
7	28	6	BA	Psychology

Teachers were provided no special training or materials before and/or during the study. The material in the textbook needed no alteration to accommodate the treatment assigned.

Prior to the treatment period teachers were given explicit instructions with regard to the degree of calculator use permitted within their classrooms (see Appendix C).

The treatment conditions were defined as follows:

Experimental group number 2: Youngsters were to use calculators to do all of their computation. Its use was required for any multiplication activity demanding a written answer. This included all assigned tasks in the textbook, dittoed materials, board work, etc. A calculator was provided for each student in this treatment group.

Experimental group number 1: Youngsters used calculators to check problems on which they had already provided an answer. The student did the initial computation and used the calculator to verify it. One calculator was provided for every two youngsters in this group. The treatment condition, "calculators for checking only," called for fewer calculators.

Control group: Youngsters were permitted no calculator use. They computed their answers and checked their problems using conventional means.

Students who were selected for calculator use were given twenty to thirty minutes the first day of the treatment to familiarize themselves with its use. The youngsters' previous exposure to the calculator combined with the relatively simple nature of its operation enabled the students to master its use quickly.

The calculators used in the experiment were Texas Instrument 1000's and 1025's. They are standard, battery operated, four function calculators with eight places and a floating decimal. They use standard algebraic logic which enables the user to punch in a problem just as he sees it. In other words, to use the calculator to figure the problem 4 X 6 the student would punch

$\boxed{4}$ $\boxed{X}$ $\boxed{6}$ $\boxed{=}$ __ and receive the answer.

Immediately prior to the treatment period all students were given a pretest composed of 50 of the 100 basic multiplication facts. This provided data from which to establish group means for each cell within the variable matrix presented on page 35.

The treatment consisted of all groups undertaking a series of multiplication activities. The activities were contained in the student's regular fourth grade mathematics textbook, <u>Mathematics Around Us</u>, published by Scott-Foresman. A thirty-two page multiplication unit begins on page 84. It requires approximately twenty instructional sessions. The instructional sequence is outlined in Appendix D.

The general instruction on the multiplication unit consisted of the regular classroom teachers teaching the material from the book using a traditional textbook approach. A typical day was ten to fifteen minutes of teacher exposition followed by thirty minutes of some form of drill on the multiplication facts.

Instruction followed the pre-determined schedule which generally included one or two pages from the textbook each day. Appendix E details the schedule of instruction.

For the most part teachers taught their entire class as one group. There was little grouping within classes or individualization of instruction.

To supplement the materials presented in the book teachers were instructed to use whatever additional materials and techniques that they had relied upon in the past. This most often took the form of additional dittoed material common to the teaching of the multiplication facts. Teachers were discouraged from requiring homework.

Teachers were further instructed to keep the student's degree of calculator use consistent whenever working on supplemental material.

Throughout the treatment period this researcher made frequent observations in the experimental and control classrooms. This was for the purpose of monitoring the activity to assure that there was adherence to instructional procedures and assigned treatment conditions. In every instance, teachers and students were following prescribed behaviors with regard to calculator use.

In addition, to supplement the observations, teachers were required to maintain a daily log of their multiplication activities. Selected calculator related comments from the logs are included in Appendix F. The logs included a record of the time spent teaching the facts each day, opinions of the youngsters' attitudes and work habits, and any other general information and impressions the teacher viewed as noteworthy.

To control for the Hawthorne effect control classes participating in the experiment were made aware that they were part of an investigation on the effectiveness of the use of the calculator. Letters were sent home to advise parents of the experiment (see Appendix G). The researcher's presence during observations helped keep the students aware of their participation in the experiment. Also, the control classes were promised the use of calculators after the experiment.

Prior to the experiment youngsters were asked to refrain from using the calculator at home. At the conclusion of the experiment students were asked to report whether they had used the calculator at home. There was no reported use.

The pretest was administered on November 5, 1979 to 145 students. For posttesting six weeks later, 139 of the original subjects were tested. Six weeks after the posttest 137 students took retention tests. The attrition is the result of absences caused by moving and illness.

Analysis of Data

The data was analyzed using an analysis of covariance test with pretest scores serving as the covariate. By using this statistical procedure it was possible to examine the effects of degree of calculator use on short and long term retention. It was also possible to examine the interaction between prior achievement (CAT) and degree of calculator use. Because classrooms rather than individuals serve as the unit of analysis, adjusted mean scores were computed for each cell in the table and served as the primary data source. The three hypotheses were tested at the .05 level of significance.

The following hypotheses, stated in null form, were tested:

H_1 There will be no significant differences in short-term retention among the two experimental groups using calculators and the control group which will not use calculators, where short-term retention is measured by a posttest of multiplication facts administered on the final day of instruction.

H_2 There will be no significant differences in long-term retention among the two experimental groups using calculators and the control group which will not use calculators, where long-term retention is measured by a posttest of multiplication facts administered six weeks following the conclusion of instruction.

H_3 The interaction between achievement level and degree of calculator use will not be statistically significant when a posttest of multiplication facts administered on the final day of instruction serves as the dependent variable.

Limitations

The results of the study are subject to the following design limitations:

1. The researcher exerted neither direct nor full control over the teaching methods within any of the classrooms.

2. The supplementary materials, used in conjunction with the students' regular mathematics textbook, were selected by the individual teacher. These materials were neither determined nor prescribed by the researcher.

Summary

A sample was selected from the population of a small rural school district. Students from fourth grade undertook a six week unit on multiplication. An experimental group used calculators for everything, another used calculators for checking problems only, and a control group did not use calculators. Additionally, students were assigned to an achievement level.

Students were pretested and posttested for short and long term retention. Data were analyzed to determine if the use of the calculator enhanced the learning of the multiplication facts. Also of special interest was the interaction effect, if any, between the three achievement levels and the varying degrees of calculator use.

CHAPTER IV

ANALYSIS OF DATA

Statistical Findings

The purpose of this study was to compare the achievement of fourth grade youngsters who were taught the basic multiplication facts with the aid of a hand-held calculator to the achievement of youngsters who were taught the basic multiplication facts while using the conventional paper and pencil approach. Comparisons were made between treatment groups which varied as to the extent to which they used calculators as well as the interaction between one's prior achievement and degree of calculator use.

As previously stated, the pretest (Appendix A) was designed by the researcher. It was a 50 item test, the items being randomly selected from the 100 basic multiplication facts. It was administered to 145 students on November 5, 1979, the day before the instruction period commenced.

The pretest scores were later used as covariates in two computations of analysis of covariance; the first computation used the posttest as the criterion variable, the second used the retention test as criterion variable.

The posttest and retention tests (Appendix A) were designed by the researcher in the same manner as the pretest. They were 50 item tests, the items being randomly selected from the 100 basic multiplication facts.

The posttest was administered to 139 students on December 12, 1979 and the retention test was administered to 137 students on January 23, 1980.

Table 3 presents means scores for each classroom on the pretest, posttest, and retention test. The columns in Table 3 have been organized by classrooms and treatments; the rows represent achievement levels.

Table 4 presents the data at a higher level of aggregation than that in Table 3. The nesting of classrooms within treatments is removed. Table 4 presents raw mean scores on the pretest, posttest, and retention test by achievement level and treatment.

Tables 3 and 4 suggest the following observations of the basic data:

1. The pattern of scores on the pretest, posttest, and retention test is consistent across classrooms. The means of retention test scores were equal to or higher than the posttest scores. With only one exception, the means of the posttest scores were higher than the pretest scores. (The pretest scores were higher for low achievers in experimental class #7.)

2. As would be expected there is also consistency across achievement levels; the high group outscoring the average group which outscored the low group. The only exception to this pattern also occurs in class #7, among average and low achievers.

Table 3

Raw Mean Scores on the Pretest, Posttest and Retention Test with Nesting Within Classrooms

		Control (No Use)		Experimental Group #1 (Checking Only)			Experimental Group #2 (Everything)		
		1	2	3	4	5	6	7	Totals
High:	Pretest	45.7	45.9	48.0	48.0	47.6	45.2	43.8	45.6
	Posttest	49.3	49.3	50.0	50.0	48.4	47.2	44.8	47.9
	Retention	49.6	49.7	50.0	50.0	50.0	49.2	47.9	49.2
		(n=6)	(n=12)	(n=1)	(n=2)	(n=5)	(n=5)	(n=10)	(n=41)
Average:	Pretest	41.9	44.5	41.7	43.7	39.3	40.2	31.0	41.3
	Posttest	48.1	49.2	48.2	47.6	49.7	46.0	31.5	46.7
	Retention	49.9	49.2	49.2	48.1	49.7	48.7	36.7	48.1
		(n=10)	(n=6)	(n=12)	(n=8)	(n=3)	(n=4)	(n=4)	(n=47)
Low:	Pretest	28.3	33.0	38.6	38.3	30.2	25.2	38.6	33.4
	Posttest	48.7	46.5	47.7	42.9	43.8	40.4	38.4	43.5
	Retention	49.0	48.0	49.3	46.0	46.4	45.9	46.0	47.0
		(n=3)	(n=4)	(n=9)	(n=11)	(n=6)	(n=11)	(n=5)	(n=49)
Totals:	Pretest	40.9	43.2	40.7	41.3	38.3	33.2	39.7	39.7
	Posttest	48.6	48.8	48.1	45.4	46.7	43.2	40.3	45.9
	Retention	49.6	49.3	49.3	47.2	48.4	47.2	45.3	48.1
		(n=19)	(n=22)	(n=22)	(n=21)	(n=14)	(n=20)	(n=19)	(n=137)

Note: Maximum Score = 50.0.

Table 4

Raw Mean Scores on the Pretest, Posttest and Retention Test

		Control (No Use)	Experimental Group #1 (Checking Only)	Experimental Group #2 (Everything)	Totals
High:	Pretest	45.8	47.8	44.3	45.6
	Posttest	49.3	49.0	45.6	47.9
	Retention	49.7	50.0	48.3	49.2
		(n=18)	(n= 8)	(n= 15)	(n=41)
Average:	Pretest	42.9	42.1	35.6	41.3
	Posttest	48.6	48.2	38.8	46.7
	Retention	49.6	48.9	42.7	48.1
		(n=16)	(n=23)	(n= 8)	(n=47)
Low:	Pretest	31.0	36.5	29.4	33.4
	Posttest	47.4	44.8	39.8	43.5
	Retention	48.4	47.2	45.9	47.0
		(n= 7)	(n=26)	(n=16)	(n=49)
Totals:	Pretest	42.1	40.3	36.4	39.7
	Posttest	48.7	46.7	41.8	45.9
	Retention	49.4	48.2	46.3	48.1
		(n=41)	(n=57)	(n=39)	(n=137)

3. Even on the pretest, the mean scores within some cells approach 50 which is the highest possible score on each of the three tests. These high mean scores suggest that all three tests have a "low ceiling." Because the low ceiling effectively prevents some groups from achieving as much growth as others, it has had a decisive influence on the results that were obtained in this investigation.

Hypothesis H_1

The primary question posed in this study is: Does the use of the hand-held calculator as an instructional aide enhance the learning of basic multiplication facts. Hypothesis H_1 stated in the null form is:

> There will be no significant difference in short-term retention among the two experimental groups using calculators and the control group which will not use calculators, where short-term retention is measured by a posttest of multiplication facts administered on the final day of instruction.

Hypothesis H_3

The second major question examined in this study relates to the interaction between the students' achievement level and degree of calculator use. Stated in the null form, H_3 is:

> The interaction between achievement level and degree of calculator use will not be statistically significant when a posttest of multiplication facts administered on the final day of instruction serves as the dependent variable.

The dependent variable in H_1 and H_3 is adjusted mean posttest scores. Table 5 presents the adjusted mean scores on the posttest by achievement level and treatment.

The data summarized in Table 5 suggests that the adjusted mean scores for the low achievement group were higher than for the average and high achievement groups. This pattern may be a function of the low ceiling effect. With lower pretest scores the lower groups had greater opportunity for improvement.

The adjusted posttest means for treatment groups reveal a considerable range. The control group outscored experimental group #1 by over two points and experimental group #2 by over eight points. It should be noted, however, that even these results were influenced by the low ceiling effect. Because of this phenomenon, there was a negative correlation between pre- and posttest scores which resulted in increases in adjusted mean scores beyond the range of differences in actual posttest means. This was true despite the fact that the control group had the highest pretest scores.

When checking for interactions the adjusted means also indicate a consistent pattern across treatment conditions. The control group outscored the experimental groups at all three achievement levels. Experimental group #1 outscored experimental group #2 at all achievement levels.

Even though the findings are not in the predicted direction there is some difference in the observed adjusted means by treatments. Analysis of covariance tests were therefore computed to

Table 5

Adjusted Mean Posttest Scores

	Control (No Use)	Experimental Group #1 (Checking Only)	Experimental Group #2 (Everything)	Totals
High	46.8 (n=18)	46.2 (n= 8)	44.1 (n=15)	45.8 (n=41)
Average	47.2 (n=16)	47.7 (n=23)	40.5 (n= 8)	45.5 (n=47)
Low	51.3 (n= 7)	46.4 (n=26)	42.5 (n=16)	46.7 (n=49)
Totals	49.2 (n=41)	46.8 (n=57)	41.2 (n=39)	

determine whether or not the observed differences were statistically significant. The results are summarized in Table 6.

Hypotheses numbers are listed in the source column of the table beside the test with which the hypothesis was associated.

The data summarized in Table 6 shows that observed differences among treatment groups were not statistically significant. Thus the hypothesis that no statistically significant differences exist in adjusted posttest scores across the three treatment conditions, namely Hypothesis H_1, was not rejected.

Table 6 also shows that the interaction between treatments and ability levels was not significant. Thus, the third null hypothesis, H_3, which suggests that the overall impact of the treatments does not vary as a function of existing achievement levels, was not rejected.

In summary, the analysis of covariance of the adjusted posttest scores produced evidence relating to the acquisition of multiplication facts across treatments and ability levels. The first and third hypotheses were tested and neither was rejected.

<u>Hypothesis H_2</u>

The final question posed in this study related to the retention of basic multiplication facts. Hypothesis H_2 stated in the null form is:

> There will be no significant differences in long-term retention among the two experimental groups using calculators and the control group which will not use calculators, where long-term retention is measured by a posttest of multiplication facts administered six weeks following the conclusion of instruction.

Table 6

Analysis of Covariance: Posttest

Source	df	ms	F
H_1 Treatments	2	60.24	2.85
None vs. Checking	1	49.38	2.34
Checking vs. Everything	1	68.86	3.26
Classroom: Treatment (Error Term for Testing Treatment Effects)	3	21.14	
Ability	2	1.42	.25
H_3 Treatment x Ability	4	8.93	1.59
A x C : T (Error Term for Testing T x A, A, C:T)	7	5.61	

Table 7 presents the adjusted mean scores for the retention test by achievement levels and treatments. Data summarized in Table 7 support the following observations:

1. Adjusted retention scores for the low achievers were higher than those for average or high achievers. The average achievers slightly outscored the high achievers. However, the low ceiling effect may account for these results.

2. Of the three treatment conditions, adjusted mean scores for the control group were slightly higher than those for experimental group #1 which were higher than those for experimental group #2.

The adjusted retention test scores among the treatment groups seemed to indicate that the degree of calculator use did influence the results. An analysis of covariance test was therefore computed to determine whether or not the differences were statistically significant. The results of this test are summarized in Table 8.

Adjusted retention test scores did not differ significantly among treatment groups. Thus the null hypothesis that predicts that there will be no statistically significant differences in adjusted retention test scores across the three treatment conditions, namely Hypothesis H_3, was not rejected.

Summary

The purpose of this study was to determine if significant differences in mathematics achievement scores could be found between students who used calculators while learning the basic

Table 7

Adjusted Mean Retention Test Scores

	Control (No Use)	Experimental Group #1 (Checking Only)	Experimental Group #2 (Everything)	Totals
High	47.1 (n=18)	46.6 (n= 8)	46.6 (n=15)	46.8 (n=41)
Average	48.1 (n=16)	48.3 (n=23)	44.4 (n= 8)	47.1 (n=47)
Low	52.3 (n= 7)	48.9 (n=26)	49.2 (n=16)	49.9 (n=49)
Totals	49.9 (n=41)	48.3 (n=57)	45.3 (n=49)	

Table 8

Analysis of Covariance: Retention Test

Source	df	ms	F
H_2 Treatments	2	16.94	1.65
None vs. Checking	1	12.06	1.17
Checking vs. Everything	1	21.21	2.06
Classroom: Treatment	3	10.30	
Ability	2	6.74	2.23
Treatment x Ability	4	4.5	1.50
A x C : T	7	3.02	

multiplication facts and students who did not use calculators. Three hypotheses were tested.

The data were gathered and analyzed by analysis of covariance tests for treatment and treatment by achievement group interaction on a posttest and a test of long term retention. Because there were no significant differences between the adjusted means of the two experimental groups and the control group and the interaction between treatments and ability levels were not significant, the three null hypotheses were not rejected.

Anecodotal Findings

In addition to the data gathered through testing and presented in the first part of this chapter, there were various other outcomes which were gleaned from teacher logs, observations, and interviews. These outcomes, while not based on statistical data, are important nonetheless and make a significant contribution to the findings of this investigation.

All of the teachers in the experimental classrooms reported an enthusiasm among their youngsters for the use of calculators. They found the students very excited about using the machines. This enthusiasm seemed to sustain itself throughout the six week treatment period. This finding is consistent with much of the earlier research on calculator use.

Teachers in both experimental groups reported a certain discomfort in not knowing how well their youngsters were progressing. Relieved of the need to check all papers, teachers found that they did not have as great an understanding of their students' learning. By eliminating their most frequent form of feedback, the teachers felt the calculator was interfering somewhat with their teaching. One teacher considered dropping out of the experiment for this reason.

The teachers appear to have a need to feel in greater control of the students' learning. Turning the checking over to a mechanical device proved discomforting. Frequent teacher checks appear necessary to keep the teacher informed of the class' progress.

The teachers' feeling of exercising less control over the students' learning may have serious implications for calculator use and the use of other teaching devices as well. It would appear that it will be necessary to overcome this feeling among teachers in order for the calculator to gain acceptance. This conclusion actually suggests a larger philosophical question related to how teachers view teaching. This study would indicate that the use of the calculator may require the teacher to redefine their perception of their own role.

The teachers of the experimental groups viewed the calculator as worthwhile but with varying suitability for their classrooms. Most felt it would be more effective if it were used more selectively. Several noted that small group use would be more appropriate. They felt small group use relieved problems associated with use by entire classes.

Time spent teaching the multiplication facts did not vary a significant amount when compared across treatments. Table 9 summarizes the time spent as reported in the teachers' daily logs.

Table 9

Time Spent Teaching Multiplication

Classroom	Time Spent	Treatment Condition
1	21 hrs	Control
2	20 hrs 30 min	Control
3	18 hrs 30 min	Experimental Group #1
4	20 hrs	Experimental Group #1
5	21 hrs 15 min	Experimental Group #1
6	18 hrs 45 min	Experimental Group #2
7	16 hrs 30 min	Experimental Group #2

These times reflect the time the class spent studying the facts over the entire six week unit on multiplication.

As is evident from the data presented in this table, all seven classes spent a similar amount of time working on the facts.

Teachers of the experimental groups also reported spending similar periods of time teaching the facts in previous years. They did not view the calculator as having an appreciative impact on the time they spent teaching the basic multiplication facts from this unit.

Youngsters quickly stopped using the calculator once they mastered the facts. Button pushing proved too time consuming to those who knew their facts.

The teachers reported that the daily logistics involved in distributing and collecting the calculators was a negative factor. Teachers felt uncomfortable with the responsibility for the safe-keeping of the calculators. They would prefer not to have to concern themselves with security measures. This feeling of added responsibility was cited as a disadvantage of calculator use. Movement to and from the collection point was a minor disturbance.

All participants in the experiment, teachers and students, experimental and control, seemed to make a concerted effort to satisfy the conditions of this study. This effort is reflected in the posttest and retention test results. An overall average of 92% on the posttest and 96% on the retention test is indicative of the hard work on the part of both teachers and students which was evident throughout the course of the study.

It appears that participation in a study of this nature may have had the overall impact of increasing attention span, and thereby increasing the achievement, of the pupils involved. It is assumed all seven teachers worked harder as a result of the fact that this was an experiment and that attention would be focused upon the test results.

Summary

To summarize, the major anecdotal findings of this experiment support the following generalizations:

1. The use of calculators appears to heighten student interest.
2. Teachers must find a way to adequately monitor student progress where calculators are being used.
3. The use of calculators by small groups of students may be more effective.
4. The use of calculators does not differentially affect the time spent teaching the multiplication facts.
5. Students apparently stop using calculators once they have "mastered" the facts.
6. Distribution, maintenance and the security of the calculators in the classroom are a minor nuisance.
7. The Hawthorne effect appeared to be operating with all participants in this experiment.

CHAPTER V

SUMMARY, CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

Summary

This experimental study was designed to compare the effectiveness of learning the basic multiplication facts with the aid of a hand-held calculator to the learning of the multiplication facts using the conventional paper and pencil approach. The experiment also examined the potential interaction between one's prior achievement and the influence of various degrees of calculator use on achievement.

The investigation included seven fourth grade classrooms located in three schools from a rural midwestern school district. All regular education students in the seven classes participated.

Each of the seven classrooms was randomly assigned to one of three treatment conditions:

1. Two intact classes were assigned to use the calculator for all computation.
2. Three classes were assigned calculator use for "checking problems only." The calculator was used only after the student had provided an initial answer.
3. Two classes were denied all calculator use.

On the basis of a standardized mathematics achievement test administered five weeks prior to the treatment period all students in the study were partitioned into one of three achievement levels; high, average, or low.

Treatment for all three groups consisted of instruction over a six week unit on multiplication included in the students' regular fourth grade mathematics textbook. All instruction was provided by the regular classroom teachers. They varied their instruction only to the extent that the experimental groups were using calculators as prescribed in their treatment.

Treatment started the first week of November and ended just before Christmas with a posttest. A retention test was administered six weeks following the conclusion of the experiment. Throughout the study teachers recorded anecdotal accounts of how calculators were used, accepted, and might benefit students.

The pretest, posttest, and retention tests used were three forms of the same instrument, which was a randomly selected 50 item sample of the 100 basic multiplication facts. The pretest was used as the covariate in the two analysis of covariance tests that examined mean scores on the posttest and the test of retention.

The results of the ANCOVA test of posttest scores showed no significant differences between the three treatment conditions. Thus, the experimental groups using calculators did not gain significantly more in learning the multiplication facts than did the control group. This analysis also produced no evidence of significant interaction effects between treatment and ability levels.

The second analysis of covariance test used the retention test scores as the criterion variable. Again, there were no significant differences between treatment groups.

There were two major problems in the conduct of this investigation that may have had a considerable influence on the results. First, scores on the pretest were substantially higher than anticipated. This phenomenon suggests that most youngsters had already spent considerable time studying multiplication facts under instructional conditions other than those prescribed by the study. The low ceiling on the pretest also gave rise to a number of statistical phenomena that made it difficult to interpret the results. A negative correlation between pre- and posttest scores is illustrative of problems that may be traced to the low ceiling on the pretest.

Second, the observed mean on the retention test was higher than the corresponding mean for the posttest (across all seven classrooms). This increase implies that learning occurred in the time between the conclusion of the treatment and the administration of the retention test. The design of the experiment did not specify procedures for determining the origin of such learning. Therefore learning of an undetermined origin, or contamination, probably affected the variance in the second analysis.

Such contamination is not surprising. The fact that the learning of the multiplication facts is crucial to success in the fourth grade is one of the reasons for selecting it for the investigation. That the facts would continue to be studied following the completion of the treatment is therefore understandable.

Conclusions

Despite the problems cited above, the results of this investigation warrant several conclusions regarding the use of calculators as an instructional aid in teaching the multiplication facts to fourth graders.

First, as used in the two experimental groups in this study, the calculators did not contribute to improved achievement. By the same token, the calculators did not appear to be a significant detriment to the learning of the facts. The experimental students were not at a significant disadvantage as a result of calculator use.

Second, there appeared to be no interactive effect between degree of calculator use and level of achiever. In other words, gains in achievement did not appear to be a function of a youngsters' prior achievement level. Youngsters at low achievement levels gained as much or more than youngsters at higher achievement levels.

Third, the use of calculators had little impact on the ability of the students to retain the learning that had occurred. The use of calculators did not significantly affect retention.

Perhaps the most definitive results of the investigation were derived from an analysis of informal sources of data.

All teachers found the calculator to be motivational to their students. Students who had been in the habit of doing their arithmetic with paper and pencil caused teachers to comment about their enthusiasm when they were permitted to use the calculators.

The feeling of giving up some control of the students' learning bothered most teachers in the experimental groups. Calculators seemed to replace something the teacher formerly provided and this contributed to teacher discomfort. Teachers expressed a need to feel in greater command of what the student was learning.

The amount of time required to teach the multiplication facts did not seem to be affected by calculator use. Teachers reported similar periods across treatments and also from last year to this.

Concern for the maintenance and durability of calculators proved to be a minor problem. Also, security was not a problem.

Implications

The most telling point related to calculators may well concern motivation, and the present study supported much of the earlier research on calculator use and motivation. The use of a new learning device in a traditional subject area, frequently characterized by laborious drill and memorization, may indeed have a stimulating or motivating effect on student learning. The fact that calculator use did not significantly diminish achievement and is more enjoyable than the conventional approach would suggest that calculator use certainly merits further exploration and consideration.

Recommendations

The following recommendations for further research are based on the findings and conclusions of this study:

1. An investigation of the learning of the multiplication facts begun earlier in the youngsters' school career may provide significant results. The relatively high pretest scores evident in this study would seem to indicate that considerable learning

had already occurred prior to the fourth grade unit on multiplication.

2. A study of longer duration may produce results with significant achievement differences. This study indicated that although differences did occur between and among groups, these differences were not statistically significant. Similar methodology should be undertaken over a longer treatment period.

3. Research should be done on the effectiveness of hand-held calculators on different types of learning outcomes. Possible topics to be studied in conjunction with multiplication would be in the areas of problem-solving and applications.

APPENDICES

APPENDIX A

COPIES OF THE THREE TESTS

Name ______________________

Date ______________________

MULTIPLICATION PRETEST

2X1= ____	3X7= ____	4x5= ____	6X1= ____	2X8= ____
3X3= ____	8X8= ____	0X9= ____	9X0= ____	7X1= ____
1X6= ____	2X0= ____	6X9= ____	4X6= ____	1X3= ____
9X7= ____	4X4= ____	4X8= ____	9X2= ____	3X2= ____
3X1= ____	8X2= ____	8X9= ____	7X2= ____	0X6= ____
5X7= ____	5X2= ____	5X3= ____	9X4= ____	5X6= ____
9X8= ____	1X5= ____	8X3= ____	7X8= ____	7X9= ____
3X0= ____	4X9= ____	4X3= ____	7X6= ____	9X9= ____
5X5= ____	6X3= ____	8X6= ____	4X7= ____	2X2= ____
3X6= ____	0X4= ____	8X7= ____	7X0= ____	9X6= ____

Name ____________________

Date ____________________

MULTIPLICATION POSTTEST

9X6= ____	2X0= ____	8X7= ____	0X4= ____	3X6= ____
2X2= ____	4X7= ____	8X6= ____	6X3= ____	5X5= ____
9X9= ____	7X6= ____	4X3= ____	4X9= ____	3X0= ____
7X9= ____	7X8= ____	8X3= ____	1X5= ____	9X8= ____
5X6= ____	9X4= ____	5X3= ____	6X2= ____	5X7= ____
0X6= ____	7X2= ____	8X9= ____	8X2= ____	3X1= ____
3X2= ____	9X2= ____	4X8= ____	4X4= ____	9X7= ____
1X3= ____	4X6= ____	6X9= ____	2X0= ____	1X6= ____
7X1= ____	9X0= ____	0X9= ____	8X8= ____	3X3= ____
2X8= ____	6X1= ____	4X5= ____	3X7= ____	2X1= ____

Name ______________________

Date ______________________

RETENTION TEST

4X7= ____	3X1= ____	7X6= ____	0X7= ____	8X2= ____
3X9= ____	0X6= ____	5X4= ____	9X2= ____	6X3= ____
2X6= ____	5X6= ____	8X6= ____	5X0= ____	6X6= ____
6X8= ____	7X5= ____	9X0- ____	7X3= ____	7X4= ____
3X2= ____	5X9= ____	6X5= ____	0X4= ____	9X7= ____
7X9= ____	5X2= ____	3X7= ____	1X3= ____	8X9= ____
7X2= ____	2X4= ____	1X9= ____	2X8= ____	2X0= ____
2X7= ____	9X3= ____	8X5= ____	6X7= ____	5X1= ____
0X9= ____	2X2= ____	3x0= ____	6X1= ____	1X4= ____
8X3= ____	5X3= ____	8X1= ____	9X6= ____	0X3= ____

APPENDIX B

AVERAGE GROWTH DEMONSTRATED BY EACH TEACHER'S PREVIOUS TWO CLASSES

AVERAGE GROWTH DEMONSTRATED

Teacher	2 Years Ago	1 Year Ago
#1	1.5	1.0
#2	1.2	1.2
#3	1.4	.92
#4	1.1	1.45
#5	1.0	.77
#6	Maternity Leave	.62
#7	Not Employed	Fifth Grade Teacher

APPENDIX C

EXPLICIT INSTRUCTIONS TO TEACHERS

EXPLICIT INSTRUCTIONS TO TEACHERS

Calculators for everything: Have the youngsters do all of their computation on a calculator. This means that they are to use it to get their initial answers. Require its use on all activities that require written answers. This includes all work in the textbook, dittoed materials, board work, etc.

Calculators for 'Checking Only': Have the youngsters use their calculators to check all compuation on which they've already provided an answer. They are to check their answers immediately after completing their assignment.

No calculators: Permit no use whatsoever.

APPENDIX D

INSTRUCTIONAL SEQUENCE

Items Covered in Pages 84-115

	Concept	Page(s)
1.	Meaning of multiplication	84-85
2.	Relating multiplication and addition	86
3.	Products through 36	87
4.	Missing factors	88
5.	Computation thru 36	89
6.	Meaning of division	90
7.	Dividends thru 36	91
8.	Relating multiplication and division	92-93
9.	Division	94
10.	Products and dividends 40-56	96-97
11.	Using multiplication and division	98-99
12.	Products and dividends 63-81	104
13.	Finding products and quotients	105
14.	Multiplication and division facts	106-107
15.	Products and dividents 40-81	109
16.	Multiples	110
17.	Finding multiples	111
18.	Common multiples	112
19.	More than two factors	114
20.	Multiplication and division facts	115

APPENDIX E

SCHEDULE OF INSTRUCTION

Schedule of Instruction

November 5 1977	Everyone pretested (D. Dean)
November 6-9	Pages 84-85 86-87 88
November 12-14	Pages 89 90
November 19-21	Pages 91 92-93
November 26-30	Pages 94 96-97 98-99 100 (102)
December 3-7	Pages 101 (103) 104-105 106 (107) 108-109
December 10-14	Pages 110, 111, 112 (113), 114 115
December 14	Everyone posttested (D. Dean)

The assignments in the schedule of instruction are grouped according to the minimum standards as established by the textbook publisher (page 65 in teacher's edition).

There is a free day each week for you to do as you choose. Also, I encourage you to use whatever additional materials and techniques you have relied upon in the past.

APPENDIX F

CALCULATOR RELATED COMMENTS

CALCULATOR RELATED COMMENTS

Experimental Group Two

Takes longer to do easy problems than if you did in your head.
Real enthusiasm for math.
Don't have to think with the calculator.
Some students don't want to use calculators.

Experimental Group One

Need more calculators.
Not learning facts without other drill too.
Tests necessary for more accurate measurement, reassurance by teacher.
Small group work would be helpful - with use of calculator.
Calculators are not infallible - minds sometimes are more dependable.
Too much time spent checking out large numbers.

APPENDIX G

LETTER TO PARENTS

November 5, 1979

Dear Parents:

For the next six weeks your child will be participating in an experiment on the use of the hand-held calculator as an aid in the learning of the basic multiplication facts.

Your child will be using a calculator to help him/her learn the multiplication facts. At the conclusion of the experiment the growth demonstrated by your child's class will be compared against the gains made in other fourth grades, some of whom will be using a calculator and others who will not.

Let me assure you that the use of the calculator will not hinder your child's progress. Many studies on the use of the calculator have already been done. Almost all of the studies comparing achievement groups using or not using calculators either favor the calculator group or (in about equal numbers) reflect no significant differences.

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

> "The NCTM encourages the use of calculators in the classroom as instructional aids and computational tools. Calculators give mathematic educators new opportunities to help students learn mathematics and solve contemporary problems."

The purpose of this study is to provide teachers with more information about how to make the best use of the calculator in their classrooms.

If you have any questions regarding the project please feel free to contact me.

Sincerely,

David K. Dean

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