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CALCULATOR USE IN GRADE SIX

A THESIS PRESENTED TO THE FACULTY OF EDUCATION IN PARTIAL
FULFILMENT OF THE REQUIREMENTS FOR THE MASTER OF
EDUCATION DEGREEE

By
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WINNIPEG, MANITOBA
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CALCULATOR USE IN GRADE SIX

BY

ANNE NEUFELD

A thesis submitted to the Faculty of Graduate Studies of
the University of Manitoba in partial fulfillment of the requirements
of the degree of

MASTER OF EDUCATION

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ABSTRACT

The purpose of this study was to test the null hypothesis which stated that, "there will be no significant difference in achievement between the group of students who use the Calculator Package and the group of students who use the Non Calculator Package". Four grade six classes, a total of one hundred and two students, and five teachers from the River East School Division in Winnipeg, Manitoba were involved in the study.

Data was collected, a two tailed t test was conducted and the results of this study were noted. As a result of this test the researcher came to the conclusion that the null hypothesis must be accepted.

The study included a review of the relevant literature, a survey of the grade six Manitoba mathematics curriculum, the development of an introductory unit for the correct use of the calculator, as well a Calculator Study Packet.

On the basis of the literature review and the results of the study several recommendations for the effective use of the hand-held calculator in the grade six classroom were made.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS.....	v
CHAPTER 1. PRELIMINARY CONSIDERATIONS.....	1
Purpose and Scope.....	1
Rationale and Hypothesis.....	2
Rationale.....	2
Hypothesis.....	3
Limitations.....	3
Definition of Terms.....	4
Conclusion.....	6
CHAPTER 2. REVIEW OF LITERATURE.....	7
Introduction.....	7
Points of View.....	7
Results of Other Studies.....	14
Effective Ways of Using the Calculator..	15
Suitable Topics.....	19
Summary.....	19
Conclusion.....	20
CHAPTER 3. STUDY DESIGN.....	21
Introduction.....	21
Calculator Study Packet.....	22
Selection of Teachers and Classes.....	23
Directions for the Implementation of the Study.....	24
CHAPTER 4. RAW DATA.....	29
Introduction.....	29
Data Collected.....	29
Procedures Used to Conduct t Test.....	30
Results of t Test.....	31
Formulae.....	33
Basic Information.....	34
Table I.....	35
Table II.....	36
CHAPTER 5. RESULTS, CONCLUSIONS AND RECOMMENDATIONS	37
Introduction.....	37
Review of Project.....	37
Observations and Conclusions.....	44
Recommendations.....	49
Summary.....	51
NOTES.....	52
SELECTED BIBLIOGRAPHY.....	57
APPENDICES.....	62

APPENDIX A:	CALCULATOR STUDY PACKET.....	63
	Directions for Implementation.....	64
	Contents of Packet.....	65
	Diagnostic Test.....	66
	Pre and Post Math Facts Tests.....	68
	Calculator Package and Non Calculator Package.....	69
	Color Coded Key.....	239
APPENDIX B:	TEST SCORES (X) AND (X ²).....	294
	Experimental Group Test Scores (X).....	295
	Control Group Test Scores (X).....	298
	Experimental Group Test Scores (X ²).....	301
	Control Group Test Scores (X ²).....	304

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Anne Neufeld
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CHAPTER ONE

PRELIMINARY CONSIDERATION

Purpose and Scope

The purpose of this study was to determine whether there was a difference in achievement between a randomly selected group of students who used the Calculator Package and a similar group of students who used the Non Calculator Package.

Questions considered by this study relative to the problem were: 1) When, where and how can calculators be used most effectively in the classroom? 2) What topics in the mathematics curriculum are most suitable for calculator use? 3) Do problem solving skills improve with calculator use? 4) How does the availability of the calculator influence performance in testing situations? 5) Are there other studies which have attempted to measure the difference in achievement between students using the calculator and students not using the calculator?

From a practical point of view a supplementary question to be considered was whether there were materials available to measure the difference in achievement between students using calculator materials and students using non calculator materials?

Rationale and Hypothesis

Rationale

Due to the availability and wide spread use of the hand held calculators in our society, questions have been raised by educators and parents as to the advisability of using calculators in the elementary schools. Will the use of calculator have a detrimental effect on the students' learning of concepts and the basic mathematical facts? Will calculator use have an adverse effect upon the students' computational skills development? Further, what effect, if any, will the use of the calculator have on the students' problem solving abilities? The intent of this study was to explore these questions and if possible come to some definitive conclusions. Several steps were undertaken to achieve this purpose: 1) research literature related to this topic was reviewed; 2) the grade six mathematics curriculum of the Province of Manitoba was surveyed for possibilities for calculator use; 3) an introductory mathematics unit for the correct use of the calculator was developed; and 4) A Calculator Study Packet which included both a Calculator Package and a Non Calculator Package was developed.

Hypothesis

This study was designed in order to test whether there is a significant difference in achievement between the group of students who use the Calculator Package and the group of students who use the Non Calculator Package.

The null hypothesis of this study is that: there will be no significant difference in achievement between the group of students who use the Calculator Package and the group of students who use the Non Calculator Package.

Limitations

In view of the fact, that a study of this nature could not be undertaken in ideal and completely regulated circumstances, several limitations needed to be identified. These limitations may have affected both the control and experimental groups to an unpredictable extent. The limitations fall into two categories: Those factors related to the students and those related to the experimenters.

In relation to the students, the following limitations were identified: 1) all the students involved in the Calculator Study were grade six students. Due to this limitation generalizations of findings to other grade levels will be limited; 2) calculators were not equally accessible at all times, to all students in the calculator group since the calculators may or may not

have been available to the students' outside regular classroom hours; 3) the possibility of the students in the non calculator group using the calculator at home was not controlled; 4) no effort was made to administer the pre and post test at the same time of day.

In reference to the experimenters, the following limitations needed to be noted: the quality of the relationship between individual experimenters and students within the groups as well as the specific approach employed by the experimenter with his/her group may have influenced the outcome of the study.

Definition of Terms

Achievement:

The difference in results as measured by means of a test prior to and at the end of a designated time period.

Basic Math Facts:

Knowledge of the single digit number facts (namely addition, subtraction, multiplication and division) and the use of the same in mental arithmetic activities.

Calculator Package:

A package of activities designed to teach and develop number theory concepts, reinforce the basic math facts and problem solving skills as well as motivate students, through the use of the hand-held calculator.

Computational Skills:

The application of the number facts involving the four operations.

Critical T:

The t found on page 270 of Exploring Statistics by Sarah M. Durham.

Curriculum:

The grade six Province of Manitoba Mathematics Curriculum.

Hand-Held Calculators:

An electronic instrument, small enough to be held in one's hand, with the capability of performing arithmetic computations at high speed.

Heterogeneous Grouping:

The placing of students with varied mental and performance ability into a designated group.

Non Calculator Package:

A package of activities designed to teach and develop number theory concepts, reinforce the basic math facts and problem solving skills as well as motivate students, without the use of the hand-held calculator.

Number Theory Concepts:

The ideas related to notation, place value, rounding, divisibility, factors, multiples, prime and composite numbers.

Problem Solving Skills:

Is the process of applying previously acquired knowledge to the new and unfamiliar situation. Problem solving strategies involve posing questions, analyzing situations, translating results, illustrating results, drawing diagrams and using trial and error.

Conclusion

In conclusion then, the purpose of this study was to examine the effect of calculator use among a randomly selected group of grade six elementary pupils. The study will test the hypothesis as stated above by using both experimental and control groups in four different grade six classrooms. Several limitations in relation to both the students and experimenters were listed. Terms used frequently throughout the study were carefully defined. The results of the study may be useful in answering the questions posed both by educators and parents in reference to the use of the calculator in the elementary grades.

CHAPTER TWO

REVIEW OF LITERATURE

Introduction

Numerous articles related to the use of the hand-held calculator have been published since 1973. These articles deal with a number of key topics: various points of view; results of studies on the effects of calculator use; effective ways of using the calculator in the classroom and suitable topics for such use.

Points of View

The use of the hand-held calculator has been the focus of a great deal of discussion, controversy and research since its use became a financial possibility for the home and school. The 1977-78 Mathematics Assessment of Educational Progress (NAEP) revealed that in North America over seventy-five percent of the nine year olds and eighty-five percent of the seventeen year olds had access to at least one hand-held calculator.¹

In a survey conducted in 1979, a random sample of one hundred and ninety-four classroom teachers in Missouri showed that although eighty-four percent of the teachers said that calculators should be available to

children in school, only thirty-four percent had actually used hand-held calculators in the mathematics' classes.² This statistic indicates that at that time teachers felt that calculators would be useful.

One of the first articles written on the use of the calculator in the classroom was published in 1973. This study conducted by James Frances Shea was entitled, "The Effects of Achievement and Attitude Among Fourth Graders Using the Calculator Flow Charting vs. Conventional Instruction in Arithmetic." The results indicated that flow charting as a teaching media is superior to conventional instruction in improving arithmetic computation but not superior for affecting gains in concept development.³

In 1976 the Arithmetic Teacher devoted its entire November publication to discussion on the hand-held calculator. Articles such as "Let's Do It: Taking Advantage of the Hand-Held Calculator" by Bruni and Silverman; "Instructional Games with Calculators" by Judd Wallace; and "Hand-Held Calculators: Where Do You Stand?" by Shumway are but samples of many articles disclosing ideas and feelings about calculator use in the classroom.

From the conclusions expressed in these articles it seems that parents, teachers, and administrators were divided on the desirability of the general use of the

calculator in school. This is evident in the articles, by Shumway, Reys and Schmalz, in which they present several sides of the issue dealing with arguments for and against calculator use. One group, as pointed out by Robert E. Reys, in his article "Calculators in The Elementary Classroom: How Can we go Wrong" felt that banning the use of the calculator in mathematics classes was the answer.⁴ Reys however, feels that we can go wrong by using that approach; he is not a supporter of this concept. Another group, mentioned in the above article, held the position that selected use of the calculator would be beneficial to the students but calculator use on tests should not be allowed. Some of the educators in this group also stipulated that the calculator is not to be used until students have to some degree mastered the four mathematical operations.⁵ Jesse A. Rudnick and Stephen Krulik in their article, "The Mini Calculator, Friend or Foe?" stated that some educators are covering their tracks by taking the above position. The third group held that calculator use should be allowed in all situations without limitations. Etlinger's position on the issue is cited in the article by Jane Donnelly Gawrowski and Dwight Coblentz, "Calculators and the Mathematics Curriculum". He holds the position that the calculator should not replace something but should be used to facilitate learning.⁶

Shumway also gives arguments in favor of calculator use but he does not state his own position. Paula M. Drake, a supporter of this third group, found that among other things, calculator use gives students an immediate sense of accomplishment as a result of immediate feedback.⁷ In the article, "Calculators: What Difference Will They Make?" Rosemary Schmalz, a strong supporter of this third group, makes the point that calculators can be integrated into the body of Mathematics instruction at all levels. She feels that teachers should develop or adapt a curriculum that uses calculators to teach concepts. Everything taught in mathematics should be looked at in the light of the availability of the calculator and the best interest of the students' future.⁸

Those who were against all hand-held calculator use stated that such use would: 1) adversely affect the development of computational skills; 2) stifle creativity; 3) result in cheating on assignments; 4) dehumanize education; 5) promote overdependence on machines; 6) result in the erosion of the teachers role;⁹ 7) destroy all motivation for learning the basic facts; 8) discourage mathematical thinking; 9) change the child's notion of the nature of mathematics; 10) ensure that poorly motivated students would not learn their basic math facts; 11) destroy the basic mainstream of the

elementary school curriculum.¹⁰ This group was in favor of banning the calculator from the classroom.

The essential argument presented by this group was:

"The principal objectives of mathematic instruction, at least in kindergarten to grade nine, are that children learn the basic facts and the paper and pencil algorithm. Such learning will not occur if hand-held calculators are made available in the schools."¹¹

The group that was in favor of calculator use in all situations without limitations argued that using the hand-held calculator in the classroom would: 1) free students from the tediousness of computations; 2) help prepare students for the real world; 3) increase the time available for teaching and practicing problem solving skills; 4) furnish faster and more efficient ways of solving problems; 5) allow for problems of greater intricacy to be attempted; 6) contribute to further application and exploration of related topics;¹² 7) increase enthusiasm for mathematics; 8) eliminate extensive drill and practice exercises; 9) allow for more realistic mathematical exercises; 10) make calculations easy and practical for all children; 11) place emphasis on which operation to use rather than how to perform the paper and pencil algorithm correctly;¹³ 12) facilitate understanding and concept development; 13) encourage estimation, approximation, and verification; 14) encourage

discovery, exploration, and creativity; and 15) encourage curiosity, positive attitudes, and independence.¹⁴

Shumway summarizes the proponents' argument in the following statement:

"The hand-held calculator is the tool used in society today for calculations. Schools are "burying their heads in the sand" if hand held calculators are not recognized and used as the calculational tools that they are."¹⁵

Hopkins, a member of the proponent group; introduced the somewhat radical proposal mentioned in point eleven above, when he suggested that students should no longer be expected to do sums and products using algorithms with paper and pencil. Most students, he feels, possess merely the mechanical skills with no idea what lies behind them. By using the calculator one is merely changing the choice of instrument to be used; the hand-held calculator rather than paper and pencil. "They will lose the ability to do sums and products on paper but at a very early age they will gain the ability of doing products with very large numbers," says Hopkins.¹⁶ The widespread teaching of paper and pencil algorithms in the schools started in the late eighteenth to early nineteenth century depending on the country and so is less than two hundred years old. The history of mathematics education is far older than that. Replacing

paper and pencil algorithms by some other method of calculation does not seem as radical when viewed in this perspective.

John J. Sullivan would agree with many of the arguments for using the calculator in the classroom. In a classroom trial which he conducted with two sixth grade classes in New York during the 1973-74 school year, he found that many of the proponent's arguments were valid. The major goal had been to try to discover how (and if) the calculators could enrich, supplement, and support the regular mathematics program. He states that to the mathematics specialist the most heartening thing was to see how the calculators seemed to encourage children to explore topics not usually studied extensively in the sixth grade, such as probability, exponents, and negative numbers.¹⁷

Although Eleanor Machlowitz concurs that the calculator eliminates time consuming computations, she argues that there is the need for repetitive drills to ensure that the retention of the skill or concept is not eliminated.¹⁸ She would fit nicely into the proponent's group, which held that the selected use of the calculator would be beneficial to students. Within this group there were educators who believed that students should be allowed to use the calculator in a problem solving situation on assignments and on tests involving problem

solving skills but not when computational skills were being tested.

Results of Other Studies

Many studies have been conducted since 1973 when Francis Shea conducted his study. In 1974 Taverre, et al. conducted experiments exploring ways to use hand-held calculators with children ages five to seven.¹⁹ They found that not only did these students respond enthusiastically to the calculator, but they also showed considerable gains in mathematical achievement.

In Marilyn N. Suydam's August 1982 article "Using Calculators in Pre-College Education," (August 1982) she reports that the data continues to support the idea that students who use calculators for instruction achieve at least as high or higher scores on tests than students not using the calculators, even though the calculator is not used when writing tests. This conclusion was reached from two-thirds of the studies that were conducted in which the question asked was, "Does use of the hand-held calculator hurt achievement scores?" In the majority of the studies conducted in 1982, no significant difference was reported.²⁰ In a total of seventy-five studies in which comparisons were made of achievement of groups using and not using calculators, which spanned all grades, the results varied. In nineteen percent of the studies, mixed findings, some supporting and some not

supporting hand-held calculators were reported. Thirty-five percent of the studies provided evidence that students score higher when hand-held calculators are used. Forty-four percent indicate that there is no significant difference and three percent report that using the calculator resulted in lower scores than when using pencil and paper.²¹

Effective Ways of Using the Calculator

The question no longer seems to be whether calculators should be used, but rather how they should be used in the mathematic's program.

Researchers such as Eli Teitelbaum have assumed that the mathematics program can be broken down into several distinct categories namely basic computational skills, applied mathematics and verbal problem solving.²² This distinction is fundamental to Teitelbaum's analysis of the value of the hand-held calculator. He states that learning basic computational skills is mainly a matter of memorizing tables and rules. Problem solving however, requires the ability to reason analytically, clearly understand what is wanted and analyze that problem in order to arrive at how the problem is to be solved.²³ When applying problem solving skills, the students should not be penalized (or tested) for poor computational skills. Allowing the students to use the calculator on assignments and tests in a problem solving situation

relieves the students of the tedious computation factor in the problem and allows them to concentrate on how the problem should be attacked. C. Wheatly (1980) found that grade six students who had used the calculators in their instruction used more problem solving processes and made fewer errors.²⁴ G. Wheatly, Shumway, Coburn, Reys, Schoen, C. Wheatly, and White (1979) encourage the use of the calculator as an excellent aid for developing skills in problem solving (p. 21).²⁵

Carpenter has come to the conclusion that calculators do not solve problems, people do. He states that although students perform routine computations better with the aid of the calculator, the percentage of students using the calculator who failed to answer problems correctly was consistently high on all problem solving examples.²⁶

Phillis I. Meyer, however, has found that the most valuable benefit to most students using the calculator was learning to reason logically through a problem. He states that "When you use a calculator you have to think."²⁷

In the article "Calculators In Elementary Schools," Bell encourages teachers to use calculators as an instructional aid, exploring ways of using them as an integral part of the teaching learning process.²⁸

Barbara J. Bestgen concludes her article "Calculators

Taking the First Step," by stating that the calculator is a powerful instructional tool that should be viewed as such.²⁹

Another dimension of using the calculator effectively is the understanding and use of its language. Several researchers have also done work in this area. In the article, "The Language of the Calculator," Williams states that teaching the language of the calculator is a must before using it effectively in the mathematics program.³⁰ Max S. Bell however, feels very little explicit instruction in the use of the calculator is necessary. He emphasizes that children learn to use the hand-held calculator very quickly, usually within an hour.³¹ Williams, on the other hand, feels that we can not assume that children will be able to operate a calculator efficiently without formal instruction. Learning and using the language of the calculator allows the students to take full advantage of this instructional tool.

The first and foremost step in learning the language of the hand-held calculator or a set of hand-held calculators is to become familiar with the booklet of instructions that comes with the calculator. It is best to work through examples in the booklet with a calculator in hand to verify resulting displays.³² The student should be made aware, briefly and informally of

all key functions as well as of any special features of the calculator being used.

Many articles in which suggestions and ideas for calculator use are given have been written. "Calculator Games Combining Skills and Problem Solving: by Bill Fisher;³³ "Count on the Calculator" by Garry Bitter,³⁴ "Minicalculators in the Schools" by the National Board of Directors;³⁵ "Problem Solving with Calculators" by Janet Barber Morris³⁶ are but a few examples of such articles. Numerous books giving ideas on how to use the calculator have also been published. This material however, did not seem to be organized or related to the Manitoba curriculum. Since this study was begun the Manitoba Department of Education has developed a Calculator handbook³⁷ which combines the curriculum with some of the available materials.

The review of literature has reinforced this researcher's belief that the hand-held calculator could be used effectively for: 1) teaching and developing concepts; 2) promoting realistic problem solving; 3) drill with the calculator used as a basic "flash card" 4) practicing facts and increasing speed on basic math facts 5) calculator games used to reinforce computational skills and problem solving skills; 6) word games and crossword puzzles; 7) calculator check out centre; 8) calculator club; and 9) practicing estimation skills.

Suitable Topics

A survey of the grade six curriculum³⁸ guide together with a review of available literature has convinced the researcher that the following topics would be suitable for the use of the hand-held calculator in the classroom: 1) place value; 2) and estimation-rounding; 3) number patterns; 4) negative numbers; 5) scientific notation; 6) prime and composite numbers; 7) decimals; 8) metric measurement; 9) geometry; 10) multiplication and division of whole numbers; 11) averaging; 12) percent and 13) problem solving using word problems.

Summary

In summary, the review of literature, on Calculator use In The Classroom, indicates that: 1) the mathematics program can be broken down into several distinct categories namely basic computational skills, applied mathematics and verbal problem solving; 2) the hand-held calculator will not prevent students from learning the basic facts but rather its use could be beneficial in learning these skills, 3) with the use of the hand-held calculator problem solving skills would receive greater emphasis in the mathematics curriculum; 4) the hand-held calculator should be used in imaginative ways to reinforce learning and to motivate learners to

become proficient in mathematics, 5) incorporating the hand-held calculator into the standard mathematics curriculum is a must if we wish to prepare our students for the real world.

Conclusion

This review of literature has shown that there are a variety of opinions about the value of calculator use in the classroom. Further it is evident that some studies indicate that there is a significant difference in achievement when calculators are used in the classroom whereas other studies indicate that there is no significant difference in achievement. This literature also suggests a number of factors which will contribute to the most effective ways of using the calculator in the classroom. Finally this survey has also led to the identification of topics in the curriculum suitable for calculator use.

CHAPTER THREE

STUDY DESIGN

Introduction

In preparation for this study the researcher developed pre and post tests for the following topics in the grade six mathematics program: 1) Numbers, Numerals and Number Theory; 2) Decimals; 3) Problem Solving; 4) Ratio and Percent; and 5) Fractions.

Prior to conducting the study these tests as well as sample materials were piloted in order to determine which materials would be most suitable for the Calculator Package and which would be most suitable for the Non Calculator Package. The prepared tests were piloted for feasibility of use in the study project.

In light of the pilot results and other considerations, the conclusion was reached to limit this study to two units, namely Numbers, Numerals, Number Theory and Problem Solving. A Diagnostic Test was to be administered before the implementation of the study and again upon the completion of the study. This Diagnostic Test covering these two units as well as pre and post math fact tests were also developed by the researcher.

Calculator Study Packet

A Calculator Study Packet, containing the Diagnostic Test, the pre and post math facts tests as well as a Calculator Package to be used by the experimental group and a Non Calculator Package to be used by the control group was also developed. The same format was used for both the Calculator Package and the Non Calculator Package. Each package provided unit materials in labelled folders covering the same topics. Most of the materials in these folders were different. The materials to be used with both groups were: 1) Introduction to the Calculator; 2) Games and 3) Problem Solving A (without the use of the four operations). It was felt that since the students in both groups would be using the calculator with materials from the "Games" folder they should know how to use the calculator correctly. The remaining materials covered the following topics: 1) Basic Math Facts, 2) Rounding and Estimation; 3) Primes and Composites; 4) Factors and Multiples; and 5) Patterns, Divisibility and Comparisons. Puzzles, Tricks, Magic Squares and Reviews were prepared for each group as well. The above mentioned folders of materials were prepared for Unit I which covered the topic Numbers, Numerals and Number Theory. For Unit II which dealt with Problem Solving Skills, a separate folder of materials, in which the four

operations to solve problems was employed, was prepared for the Calculator Package to be used by the experimental group and for the Non Calculator Package to be used by the control group. One folder, as mentioned earlier, in which the problems were solved without the use of the mathematical operations, was designed to be used by both groups.

A duotang folder containing color-coded keys for both packages was also included in the Calculator Packet.

Selection of Teachers and Classes

Four grade six classes, a total of one hundred and two students from the River East School Division in Winnipeg, Manitoba were chosen to take part in the study. The teachers who participated were asked to do so approximately one year before the study was conducted. All the teachers chosen were or had been the researcher's colleagues. Since one of the classrooms chosen was a classroom in which two teachers were teaching on alternate days, five teachers rather than four were involved in the study, although only four grade six classes were involved in the study. Although the principals from these two schools did not supervise the study, they were asked in advance for permission to conduct the study in their schools. They were also shown the contents of the Calculator Packet and informed as to

the purpose of the study. The participating teachers were asked to complete the study in four months, beginning in September and completing by the end of December.

Directions for the Implementation of the Study

The teachers were given the Calculator Packet which contained the Diagnostic Test, Pre and Post Math Fact Tests, Calculator Package and Non Calculator Package, a Color Coded key as well as step by step instructions for the implementation of the Calculator Study. The researcher then explained the expected procedures to each of the piloting teachers. A discussion of the contents of the Calculator Study and the implementation of the study followed.

The teachers were asked to administer the Diagnostic Test to all the students in the four classes. They were instructed to do this before the actual teaching of the lessons. The approximate time allotted for this test was two hours. The teachers were asked to give the test in two sittings. Following each sitting the teachers were instructed to place the tests into the enclosed envelopes in the students' presence, and asked not to mark the Diagnostic Test themselves after the final sitting.

Then the teachers were asked to administer the math facts pretest giving the students exactly eight minutes to do so. The teacher was given the choice to mark the tests and record the marks for his/her own evaluation purposes or place the tests into the envelope unmarked. After sealing the envelope the researcher was to be notified that the envelopes containing the tests were ready for pick up.

The next step for the piloting teachers was to divide their classes into two groups. Group I would be referred to as the experimental group and Group II would be called the control group. In order to divide each class into these two groups two options were given. In the first option the teacher would be allowed to make a random selection within each ability level in order to form these groups. This could be done in the following manner. The students in each of the four classrooms would be asked to write their names on a slip of paper. These slips of paper would then be grouped into three ability levels. From each of these three groups of names, half of the names drawn would belong to the experimental group and the other half of the names drawn would belong to the control group.

In the second option given the students would be asked to write their names on slips of paper. Then all these slips of paper would be placed into a hat. Half of

the names drawn would then form the experimental group and the remaining names would form the control group.

Following either option one or option two procedure the teachers were instructed to discuss with their classes the reason for having divided the students in this way. They were also asked to mention to the students that their co-operation and understanding would be very much appreciated.

The teachers involved in the study were instructed to familiarize the students with the Calculator Study Packet, pointing out that each group would have a package of materials to be used. The teachers were also asked to give the students the following guidelines. The experimental group would be allowed to use the calculator when using materials from the Calculator Package as well as on the work assigned by the piloting teacher from the textbook or other sources. The control group however, would use the calculator with materials from the "Introduction to the Calculator" folder and the "Games" folder but not with any activities from the other folders in the Non Calculator Package. Math fact tests, math fact reviews, "Learn-o-Math" cards and work assigned from textbooks or other sources by the classroom teacher should be completed without the use of the calculator.

The materials from the folder entitled "Introduction to the Calculator" was designed to be used

by the entire class. This folder should be used to introduce all the students to the calculator. Since all members of the four classes would be using the calculator with materials from the "Games" folder, it was felt that the students should be taught how to use the calculator correctly before playing the games from the "Games" folder.

The piloting teacher would now be ready to teach the concepts in Unit I and Unit II. Each teacher was instructed to teach these concepts in the regular manner and then incorporate the materials provided in this study as a supplement to the mathematics curriculum. Although all the topics outlined in this study were to be taught the teachers were informed that it was not necessary to teach the concepts in the sequence outlined in the study.

It was also not necessary to use all the materials provided in the Calculator Packet. The piloting teacher was asked to choose materials from the folders which were best suited for the students in each class since the difficulty level of the materials varied somewhat or use all the materials making copies available for each student.

The students were to be instructed to place all materials handed to them during the course of the study into a duotang folder labelled with their name and the group to which they belong. The above method was the

piloting teachers' first option. For option two the piloting teacher would duplicate only a few copies of the selected materials. The students would then be asked to answer the questions on lined paper which had been placed in their labelled duotang folders. If the activity sheet was designed in such a way that the work must be completed directly on it, then the teacher was asked to follow option one mentioned above.

The teachers were also instructed to ask the students to use the color-coded answer keys to check their own or each other's work.

Upon completion of the study the teachers were directed to administer the Diagnostic Test and the Math Facts Post Test following the same instructions as the Pre Test except that the experimental group must use the calculator on the Diagnostic test.

Finally the teachers were asked to write a brief, narrative evaluation of the study for the researcher.

CHAPTER FOUR

RAW DATA

Introduction

The Calculator Study was conducted by the five piloting teachers in the manner set out by the researcher. The students in three of the classrooms were chosen randomly within ability groups, in other words using option one as outlined in the directions for implementation of the study included in the Calculator Study Packet. In the other classroom the students were chosen randomly without ability group considerations.

Data Collected

Pre and post diagnostic tests were administered to all the students in the experimental and control groups. These tests were marked by the researcher in order that the marking would be uniform. The test scores for the experimental and control groups are listed in separate charts in Appendix B of this thesis. In order that the student's identity be kept confidential, each student was given an identification number and his/her scores were listed under that number. In tabulating the scores, the

students from the four experimental groups became one group; the students from the four control groups also became one group.

The Diagnostic Test was divided into Part I and Part II. Part I covered Unit I which was entitled Numbers, Numerals and Number Theory, and Part II covered Unit II which was entitled Problem Solving. The scores in the charts are listed as follows: Unit I Pretest, Unit I Post Test, Unit II Pretest, Unit II Post Test, Combined Unit I and II Pretest, and Combined Unit I and II Post Test. The combined scores refer to the average mark obtained by each student in Part I and Part II.

Pre and post math fact tests were also given to all of the students in the four classrooms. The piloting teachers marked these tests. The pre and post math fact scores for both groups are also listed in Appendix B.

Procedures Used to Conduct t Test

In order to ascertain whether there was any significant difference between the academic progress made by the students in the experimental group and the control group an independent sample t test had to be conducted. The t test is designed to determine whether the null hypothesis would be sustained by the research. The null hypothesis stated earlier said that "there will be no significant difference in achievement between the group

of students who use the Calculator Package and the group of students who use the Non Calculator Package". The formula used for the t test is found on page 33.

In order to conduct the independent sample t test the researcher had to find the mean of the test scores. The mean is found by dividing the sum of all the scores by the number of participants. This was done for the experimental group scores as well as for the control group scores. It was also necessary to calculate the standard deviation and the variance; to do this the sum of each score squared as well as the total of all the scores squared had to be found. This information is listed in a basic information chart on page 34. The mean, standard deviation, and variance for the above listed tests are included in Table I.

Using the basic information chart and the results found in the mean, standard deviation, and variance table, the researcher was able to perform an independent two-tail t test with $d=.01$ on all experimental and control group pre, post, and combined test scores. These results are tabulated in Table II.

Result of t Test

As a result of the independent two-tail t test with $d=.01$ it was noted that there was no significant difference between the experimental and the control

groups' pre and post test scores for Unit I, Unit II, Unit I and II Combined, and Math Facts Test. In order for a significant difference to be observed, the calculated t would need to be greater than the critical t . As recorded in Table II of this thesis this is not the case on any of the scores.

The null hypothesis that there would be no significant difference between the group of students who use the Calculator Package and the group of students who use the Non Calculator Package was accepted.

Formulae

$$M = \frac{\sum X}{N}$$

$$S.D. = \sqrt{\frac{N\sum X^2 - (\sum X)^2}{N^2}}$$

$$\text{Var} = \frac{N\sum X^2 - (\sum X)^2}{N^2} \text{ or } S^2$$

$$t = \frac{\text{Mean}_1 - \text{Mean}_2}{\sqrt{\frac{\text{Var}_1}{N_1} + \frac{\text{Var}_2}{N_2}}}$$

$$df = \left(\frac{\frac{\text{Var}_1}{N_1} + \frac{\text{Var}_2}{N_2}}{\frac{(\text{Var}_1)^2}{(N_1)^2(N_1-1)} + \frac{(\text{Var}_2)^2}{(N_2)^2(N_2-1)}} \right)^2$$

Key

M = Mean

S.D. = Standard Deviation

Var. or V = Variance

t = t test

N = Number in sample

d.f. = Degrees of Freedom

$\sum X$ = Sum of scores

$\sum X^2$ = Sum of squared scores

$(\sum X)^2$ = Sum of scores squared

Basic Information

<u>Unit I: Numbers, Numerals, Number Theory</u>			
<u>Pretest</u>		<u>Post Test</u>	
<u>Group I</u>	<u>Group II</u>	<u>Group I</u>	<u>Group II</u>
X = 1744	X = 1476	X = 3329	X = 2843
X ² = 66484	X ² = 53076	X ² = 228873	X ² = 183131
(X) ² = 3041536	(X) ² = 2178576	(X) ² = 11082241	(X) ² = 8082649
N=51	N=45	N=53	N=48
<u>Unit II: Problem Solving</u>			
<u>Pretest</u>		<u>Post Test</u>	
<u>Group I</u>	<u>Group II</u>	<u>Group I</u>	<u>Group II</u>
X = 1266	X = 1008	X = 3218	X = 2871
X ² = 45912	X ² = 33438	X ² = 213376	X ² = 195598
(X) ² = 1602756	(X) ² = 1016064	(X) ² = 10355524	(X) ² = 8242641
N=51	N=45	N=52	N=48
<u>Unit I and Unit II Combined</u>			
<u>Pretest</u>		<u>Post Test</u>	
<u>Group I</u>	<u>Group II</u>	<u>Group I</u>	<u>Group II</u>
X = 1515	X = 1230	X = 3049	X = 2881
X ² = 53279	X ² = 39714	X ² = 221474	X ² = 189685
(X) ² = 2295225	(X) ² = 1512900	(X) ² = 9296401	(X) ² = 8300161
N=51	N=44	N=53	N=48
<u>Basic Math Facts</u>			
<u>Pretest</u>		<u>Post Test</u>	
<u>Group I</u>	<u>Group II</u>	<u>Group I</u>	<u>Group II</u>
X = 3212	X = 2822	X = 3791	X = 3180
X ² = 210570	X ² = 178585	X ² = 308811	X ² = 251792
(X) ² = 10316944	(X) ² = 7963684	(X) ² = 14371681	(X) ² = 10112400
N=51	N=47	N=48	N=42

TABLE I

	PRETEST UNIT I	POST TEST UNIT I	PRETEST UNIT II	POST TEST UNIT II	PRETEST COMBINED	POST TEST COMBINED	PRETEST MATH FACTS	POST TEST MATH FACTS	
GROUP I EXPERIMENTAL	M	34.20	62.81	24.82	61.88	29.71	57.53	62.9	78.98
	S.D.	11.59	19.32	16.85	16.54	12.74	29.48	12.74	13.99
	VAR.	134.33	373.26	283.92	273.57	162.28	869.07	162.31	195.72
GROUP II CONTROL	M.	32.8	58.02	22.40	59.81	27.95	60.02	60.04	75.71
	S.D.	10.18	17.53	15.53	22.30	10.01	18.69	13.95	16.2
	VAR.	103.63	307.30	241.18	497.29	100.20	349.32	194.6	262.44

Key: Unit I: Numbers, Numerals
Number Theory

Unit II: Problem Solving
M: Mean
S.D.: Standard Deviation
Var.: Variance

TABLE II

2 tailed t tests at $\alpha=.01$		PRETEST UNIT I	POST TEST UNIT I	PRETEST UNIT II	POST TEST UNIT II	PRETEST COMBINED	POST TEST COMBINED	PRETEST BASIC FACTS	POST TEST BASIC FACTS
GROUP I	Cal. t	0.63	0.98	2.21	0.66	0.74	70.588	1.055	1.018
	df.	93.48	99.24	93.89	86.43	90.56	88.98	93.13	81.64
GROUP II	Crit. t	$t_{93}=2.63$	$t_{99}=2.63$	$t_{94}=2.63$	$t_{86}=2.64$	$t_{91}=2.63$	$t_{89}=2.63$	$t_{93}=2.63$	$t_{82}=2.64$
		$t_{93} =$ 2.63 \rightarrow nt. sgn.	$t_{99} =$ 2.63 \rightarrow nt. sgn.	$t_{94} =$ 2.63 \rightarrow nt. sgn.	$t_{86} =$ 2.64 \rightarrow nt. sgn.	$t_{91} =$ 2.63 \rightarrow nt. sgn.	$t_{89} =$ 2.63 \rightarrow nt. sgn.	$t_{93} =$ 2.63 \rightarrow nt. sgn.	$t_{82} =$ 2.64 \rightarrow nt. sgn.

Key: nt. sgn. - not significant
- if calculated $t >$ critical t
then significant.

CHAPTER FIVE

RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

The intent of this chapter is three fold: Firstly, the whole project will be reviewed and summarized. Secondly, results and observations arising out of the data and the literature review will be articulated. Thirdly, several recommendations will be made in reference to the effective use of the hand-held calculator in the grade six classroom.

Review of Project

The purpose of this study was to determine whether there was a difference in achievement between a group of students who use the Calculator Package and those using the Non Calculator Package. This determination was made by examining the null hypothesis that, "there will be no significant difference in achievement between the group of students who use the Calculator Package and the group of students who use the Non Calculator Package".

The study tested the hypothesis stated above by using both experimental and control groups in four different grade six classrooms in the River East School

Division in Winnipeg, Manitoba. Five piloting teachers were involved in the study.

Several limitations in relation to both the students and the experimenters were listed. The limitations which were related to the students were the following: 1) generalizations of findings to other grade levels would be limited since all the students involved in the study were grade six students; 2) equal accessibility of the calculator to all the students in the calculator group was not guaranteed since the calculator may not have been available in all of the students' homes, 3) calculator use in the home by those not in the calculator group was not controlled, 4) the time for administering the pre and post test was not controlled.

Two limitations in reference to the experimenters were identified. The particular approach employed by the piloting teacher with his/her group as well as the quality of the relationships between the experimenters and the groups may have affected the outcome of the study. This possible effect was not controlled or measured.

The terms used throughout the study were defined in Chapter One. Terms defined were: achievement, basic math facts, calculator package, computational skills, critical t, curriculum, hand-held calculators, heterogeneous grouping, non calculator package, number theory concepts and problem solving skills.

It was hoped that the results of the study would be useful in answering the questions posed by educators and parents in reference to the use of the calculator in the elementary grades. Some of the questions related to this study were: 1) When, where and how can calculators be used most effectively in the classroom? 2) Are all topics in the mathematics curriculum suitable for calculator use? 3) Do problem solving skills improve with calculator use? 4) How does the availability of the calculator influence performance in testing situations? 5) Are there other studies which have attempted to measure the difference in achievement between students using the calculator materials and students not using the calculator materials. A supplementary question which was also considered was whether there were materials available to measure the difference in achievement between students using calculator materials and students using non calculator materials?

The review of literature showed that there were a variety of opinions about the value of the calculator use in the classroom. Parents, teachers and administrators were divided on the desirability of the general use of the calculator in school. One group felt that banning it from the classroom was the answer. Another group held the position that selected use of the calculator would be

beneficial to the students but calculator use on tests should not be allowed. The third group held that calculator use should be allowed in all situations without limitations.

Thirty-five percent of the many studies conducted, indicated that there was a significant difference in achievement when calculators are used in the classroom whereas forty-four percent of the studies indicate that there was no significant difference. Three percent of the studies report that using the calculator resulted in lower scores than when using pencil and paper.

In her article, "Using Calculators in Pre-College Education", Marilyn N. Suydam (1982) reports that the data continues to support the idea that students who use the calculators for instruction achieve at least as high or higher scores on tests than students not using the calculators, even though the calculator is not used when writing tests.

In two-thirds of the studies in which the question was asked "Does use of the hand held calculator hurt achievement scores?" no significant difference was reported.

A number of factors which would contribute to the most effective way of using the calculator in the classroom were also suggested by the literature. The calculator could be used most effectively for: 1)

teaching and developing concepts; 2) promoting realistic problem solving; 3) practicing estimation skills; 4) drilling with the calculator used as a basic "flash card"; 5) practicing facts and increasing speed on basic math facts; 6) reinforcing computational skills and problem solving skills through the use of calculator games; 7) playing word games and completing crossword puzzles; 8) using a calculator check out centre; and 8) establishing a calculator club.

A survey of the grade six Manitoba mathematics curriculum guide together with a review of available literature, indicates that the following topics would be suitable for the use of the hand-held calculator in the classroom: 1) place value; 2) estimation and rounding; 3) number patterns; 4) negative numbers; 5) scientific notation; 6) prime and composite numbers; 7) decimals; 8) metric measurement; 9) geometry; 10) multiplication and division of whole numbers; 11) averaging; 12) per cent; and 13) problem solving using word problems.

The study design which included the preparations made for the study, a detailed look at the Calculator Study Packet, selection of piloting teachers and classes for the study, and directions for the implementation of the study was discussed in Chapter Three of this thesis. The study was limited to two units of the grade six mathematics' program, namely 1) Numbers, Numerals, Number

Theory and 2) Problem Solving. A Diagnostic Test was to be administered before and after the implementation of the study. This test and the Pre and Post Math Fact Tests were prepared by the researcher.

The researcher prepared a Calculator Study Packet which contained the above listed tests, a Calculator Teaching Package and a Non Calculator Teaching Package, together with instructions for the implementation of the study packet. The Calculator Package is a package of activities with imaginative ideas to teach and develop number theory concepts, reinforce the basic math facts and problem solving skills as well as motivating students to become more proficient in mathematics through the use of the hand-held calculator. The Non Calculator Package contains similar activities with the above purposes in mind but without the use of the hand-held calculator.

The materials for both packages were filed in labelled folders with a color coded key included in a separate duotang folder.

Four grade six classes, a total of one hundred and two students, and five piloting teachers from the River East School Division in Winnipeg, Manitoba were chosen to participate in the study. Fifty-three students were in the experimental group and forty-nine students were members of the control group. The length of time suggested to conduct the study was approximately four

months. Prior to conducting the study the researcher met with the piloting teachers individually in order to explain the expected procedures and discuss the contents as well as the implementation of the Calculator Study. The teachers were instructed to teach the concepts in Unit I which was entitled "Numbers, Numerals and Number Theory" and Unit II which was entitled "Problem Solving", in the regular manner and then incorporate the materials provided in this study as a supplement to the mathematics program.

In Chapter Four a discussion of data collected, procedures used to conduct the t test, and the results of the two tail t test were noted. The formulas used to conduct this test, a basic information chart, Table I, which included the mean, standard deviation and variance, and Table II which tabulates the two-tail test results are part of this chapter.

The Diagnostic Test was administered before and after the implementation of the study package. These test scores as well as the pre and post math fact t test scores for the experimental and the control group are listed in separate charts in Appendix B of this thesis. Each student was given an identification number and his/her scores were listed under that number. In tabulating the scores the students from the four experimental groups became one group and the students from the control group became one group.

In order to determine whether there was any significant difference between the academic progress made by the students in the experimental group and the control group, an independent sample t test was conducted. To do this the researcher found the mean of the test scores, the standard deviation and the variance.

As a result of the independent two-tail t test it was noted that there was no significant difference between the experimental and the control groups' pre and post test scores for Unit I, Unit II, Unit I and II Combined and Math Facts. In order to observe a significant difference the calculated t would have to be greater than the critical t. In this study the calculated t was not greater than the critical t on any of the scores. These results are recorded in Table II.

The researcher has come to the conclusion that the null hypothesis that "there would be no significant difference between the group of students who use the Calculator Package and the group of students who use the Non Calculator Package" must be accepted.

Observations and Conclusion

Questions related to the study in reference to the use of the calculators were listed in Chapter One and in the review section of this chapter. It was hoped that this study would be useful in answering some or all of

these questions. The study has to a large extent answered question number one, "When, where and how can calculators be used most effectively in the classroom?" The when and where can be answered briefly by saying that calculators can be used in the grade six classroom whenever a suitable topic for calculator use is being taught. Chapter Two and the review section of this chapter include many ideas on how the calculator would be used effectively in the classroom.

In reference to question two, "Are all topics in the mathematics curriculum suitable for calculator use?" the researcher would need to say that this is not the case. Suitable topics for such use however, are place value, estimation, rounding, prime and composite numbers, decimals, metric measurement, geometry, multiplication and division of whole numbers, averaging, percent, number patterns, negative numbers, scientific notation and problem solving using word problems.

Question number three, "Do problem solving skills improve with calculator use?" is an important question. On the basis of this study which showed gains when comparing pre and post means for the experimental group, the researcher has come to the conclusion that problem solving skills do improve with calculator use, however, a study which would be conducted over a longer period of time, perhaps years rather than months, may show how much

problem solving skills would actually improve as a result of calculator use.

Question four, "How does the availability of the calculator influence performance in testing situations?" is the next question to be considered. According to this study there was no significant difference between the test scores of the calculator group and the non calculator group inspite of the fact that the calculator group was allowed to use the calculator when writing the final Diagnostic Test. If students understand the concepts however, the use of the calculator should decrease test writing time. This study did however, not measure the time used by each group to write the test.

Question five, "Are there other studies which have attempted to measure the difference in achievement between students using the calculator and students not using the calculator?" has been answered to a large extent in the review of literature section under results of other studies.

The supplementary question which asked whether there are any materials available to measure the difference in achievement between students using calculator materials and students using non calculator materials would have to be answered in the following manner. The researcher found that there were materials available but these materials were to be found in many

different sources and from many different points of focus. In order to have a tool to measure the difference in achievement between the students using calculator materials and students using non calculator materials the researcher needed to locate comparable materials, test these materials in the classroom and then compile them into a useable Calculator Study Packet including a Calculator Package and a Non Calculator Package. When the researcher began this study no suitable prepared tool to measure the difference in achievement between students using calculator materials and students using non calculator materials was available.

As a result of conducting this study the researcher has also been able to make comparisons between the results of this and other studies.

In the review of the literature section the researcher reported that thirty-five percent of the many studies cited indicated there was a significant difference in achievement when calculators were used in the classroom whereas forty-four percent of these studies indicated that there was no significant difference. The researcher's study agreed with the forty-four percent of the studies that there was no significant difference between the students using the calculator and those not using the calculator.

The data cited in Marilyn N. Suydam's (1982) article, "Using Calculators in Pre College Education" continues to support the idea that students who use the calculator for instruction achieve at least as high or higher scores on tests than student not using the calculator even though the calculator is not used when writing tests. As a result of the study described in this thesis the researcher agrees that the students using the calculator scored at least as high as those not using the calculator.

In two-thirds of the studies conducted in which the question was asked, "Does use of the hand-held calculator hurt achievement scores?" no significant difference was reported. This researcher found this to be the case as well. On the basis of the evidence the researcher concludes that there were no adverse affects of calculator use in the classes in which the study was conducted.

The review of the literature on calculator use in the classroom indicates that the mathematics program can be broken down into several distinct categories namely basic computational skills, applied mathematics, and verbal problem solving skills. The researcher has also been convinced that the hand-held calculator will not prevent students from learning the basic math facts and its use could be beneficial in learning certain skills.

In the section on the effective use of the calculator several ideas to enhance the learning of the basic math facts are outlined. With the use of the hand-held calculator problem solving skills would receive greater emphasis in the mathematics program. When the calculator is used in the classroom, the student is no longer bogged down with the tediousness of long drawn out computations and as a result is able to concentrate on the strategies to use in order to solve the problem. When the calculator is used in the classroom, problems which are in the realm of the student's experience can be assigned as well.

Recommendations

As a result of this study the researcher makes the following recommendations. One, that the calculator be used in the classroom in imaginative ways to reinforce learning and to motivate students to become proficient in mathematics. This study has suggested a number of ways in which this can be effectively done. While a wide range of topics have potential for calculator use this study suggests two areas in which the calculator would be extremely beneficial: First, in learning the basic math facts, and second, in helping to improve the students' problem solving skills. Since it is imperative that all students master the basic math facts the students should

be guided in using the calculator through some of the methods outlined in this study.

Two, the hand held calculator should be incorporated into the standard mathematics program. This can be done in several ways. A) Teachers should be encouraged to use the teaching strategies outlined in this study thus using the calculator more effectively in the classroom. B) Educators responsible for curriculum development need to consider possible curricular changes in order to enhance their program by suggesting calculator use with suitable topics. One of the specific changes which ought to be considered is the present expectation that students perform difficult multiplication and division algorithms with pencil and paper. C) Mathematics Textbook writers need to incorporate calculator activities and calculator teaching strategies, for suitable topics mentioned in this thesis, into their textbooks.

Three, that a more extensive calculator study be conducted using similar procedures to those used in this study. A more extensive year long study could more adequately cover all the suitable topics identified in this thesis. The benefits of a more extensive study would be particularly evident in relation to problem solving. One of the limitations of the present study was the fact that problem solving skills and strategies were to be developed in a very brief period of time.

Four, that a similar study be conducted to encompass all elementary grades. Such a study would rely on issues raised in the Literature Review and determine the extent to which the findings of this study are generalizable to elementary grades.

Summary

This chapter focused on three items: review, observations and recommendations. The entire scope and design of the study was reviewed. Observations based on the review of literature and the analysis of the research data were articulated. Finally, on the basis of the literature review and the study, several recommendations for the effective use of the hand-held calculator in the grade six classroom were made.

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APPENDICES

APPENDIX A
CALCULATOR STUDY PACKET

IMPLEMENTATION OF CALCULATOR STUDY

I. PROCEDURE

1. Administer the Diagnostic Test to all students in the class.
 - a) This should be done before you begin teaching the lessons. Do not prepare the students for this test.
 - b) Students may require two sittings of approximately one hour each to complete both sections of the test.
 - c) After the first sitting place tests into the enclosed envelope.
 - d) Upon the completion of the second sitting collect all tests placing them in the envelope provided. Do this in the students' presence.
 - e) Do not mark the Diagnostic Tests.
2. Administer the Math Facts Pretest. Give the students exactly eight (8) minutes to do so.
 - a) You may mark these together with the students, record the marks for your own evaluation or place the tests in the envelope unmarked.
 - b) Seal the envelope and give me a call (evenings: 669-6233). I will pick up the envelope.
3. Choose approximately half of the class for the Experimental Group (Group I) in one of the following ways.

Option One

If you know the approximate ability levels (high, average, low) of your students, make a random selection within each ability level to form the Experimental Group.

This could be done by having the students write their names on slips of paper. The slips of paper would then need to be grouped into the three ability levels.

From each of these three groups of names select half of them by having that number drawn

from a hat. The names of these students should be recorded. They will belong in the Experimental Group (Group I). Those not drawn belong to the Control Group (Group II).

Option Two

Have the students write their names on slips of paper and place all the names into a hat. Have half of the names drawn from the hat. These students would then form the Experimental Group (Group I) and those not drawn would form the Control Group (Group II).

4. Share with the entire class the reason for having divided the class in this way, mentioning that their co-operation and understanding will be very much appreciated.

Point out that there will be two supplementary packages for the students to use. The Experimental Group (Group I) will be allowed to use the calculator when using materials from their packages as well as on most work assigned by the classroom teacher. They will, however, not be allowed to use the calculator on Math Fact tests, Math Fact reviews or on "Learn O' Math."

The Control Group (Group II) will use the calculator with the materials from the "Introduction to the Calculator" and "Games" folders but not on any activities from their Supplementary Package. Math Fact tests, Math Fact reviews, and "Learn O' Math" cards and work assigned by the classroom teacher must also be completed without the use of the calculator.

5. Introduce the entire class to the calculator, using material from the "Introduction to the Calculator" folder. (Since all of the students will be using the calculator with materials from the "Games" folder, they must know how to use it correctly.)
6. Teach the concepts of Unit I and Unit II in your usual way, and incorporate the materials provided in this study as supplements to the math curriculum. You do not need to teach the concepts in the sequence outlined in this study, but all topics should be covered.
7. Option I.
 - a) Choose materials from the folders suited for your students (the difficulty level varies somewhat) or use all the materials, making copies available for each student.
 - b) Instruct the students to place all materials handed to them during the course of the study into a duotang folder

labelled to indicate to which group they belong. (Reminders may be necessary from time to time.)

Option II.

Duplicate only a few copies of the activities you select and ask the students to answer the questions on lined paper which has been placed into their labelled duotang folders.

If the activity sheet is designed in such a way that the work must be completed directly on it, then follow Option I above

8. Where applicable colored answer keys have been provided in the appropriate folders. Instruct the students to answer their own or each other's work.
9. Upon completion of the study (hopefully by Christmas) two tests are to be administered to both groups:
 - a) The Diagnostic Test
 - b) The Math Facts Post Test.

Follow the same procedures in administering these tests as indicated in Procedures 1 and 2 above, with the exception that the students in the Experimental Group (Group I) must use the calculator on the Diagnostic Test. No calculators are to be used on the Math Facts Post Test.

10. Evaluation. Please write a brief evaluation of the study after the work has been completed.

Thank you!

Anne Neufeld

August, 1983.

CALCULATOR STUDY

Contents of Packet

1. Diagnostic Test
2. Math Facts Pretest
3. Math Facts Post Test
4. Experimental Group: Supplementary Calculator Package

Unit I: Numbers, Numerals, and Number Theory

- A. Introduction to the Calculator
- B. Basic Math Facts
- C. Place Value
- D. Rounding and Estimation
- E. Primes and Composites
- F. Factors and Multiples
- G. Patterns, Divisibility, and Comparisons
- H. Puzzles, Tricks, Magic Squares, and Reviews
- I. Games (Group I and II)

Unit II: Problem Solving

- A. Problem Solving (Group I and II)
- B. Problem Solving

5. Control Group: Supplementary Activity Package

Unit I: Numbers, Numerals, and Number Theory

- A. Introduction to the Calculator (Group I and II)
(see above under Unit I, A.)
- B. Basic Math Facts
- C. Place Value
- D. Rounding and Estimation
- E. Primes and Composites

F. Factors and Multiples

G. Patterns, Divisibility, and Comparisons

H. Puzzles, Tricks, and Magic Squares

I. Games (Group I and II)
(see above under Unit I, I.)

Unit II: Problem Solving
(see above under Unit II, A.)

A. Problem Solving (Group I and II)

B. Problem Solving

6. Color-coded Keys for Both Packets

- A. Introduction to Calculator.....
- B. Basic Math Facts.....
- C. Place Value.....
- D. Rounding and Estimation
- E. Primes and Composites.....
- F. Factors and Multiples.....
- G. Patterns, Divisibility, and Comparisons.....
- H. Puzzles, Tricks, Magic Squares, and Reviews.....
- I. Games

PART I: NUMBERS, NUMERALS AND NUMBER THEORY

SECTION A

For each question write the answer in the correct space at the right of the page.

1. How many tens are there in 890? 1. _____
2. Write the numeral for forty thousand seven hundred five 2. _____
3. Which numeral has a 4 in the hundred's place? (1844, 2444, 2004) 3. _____
4. In 9 742 886 what digit is in the million's place? 4. _____
5. Round off 5 234 to the nearest ten. 5. _____
6. Round off 572 to the nearest hundred. 6. _____
7. In a question like $120 \div 4 = 30$ the 4 is called the (quotient, dividend, divisor)? 7. _____
8. Give the correct sign ($>$ $<$ or $=$)
417 741 417000 + 714 8. _____
9. Write the ordinary base ten number for 44×10^3 . 9. _____
10. Write the largest possible whole number using the digits (4, 7, 3, 9) 10. _____

SECTION B. TRUE OR FALSE

Circle the correct answer.

1. The numerals 0, 1, 2, 3, 4, 5.....are used to represent numbers 1. T F
2. The value of a digit depends upon its place in the numeral. 2. T F
3. The numeral 4 is a factor of 78. 3. T F
4. A composite number has only itself and 1 as factors. 4. T F
5. The numeral 8 is a prime factor 5. T F
6. The greatest common factor for 18 and 24 is 6. 6. T F

7. The least common multiple for 15 and 9 is 90 7. T F
8. A number is divisible by 3 if the sum of the digits is divisible by 3, e.g. 417. 8. T F
9. You can rename 180 by writing the equation $18 + 10 = 180$. 9. T F
10. By rounding off to the nearest ten, an estimate of 81×26 would be 240. 10. T F

SECTION C

Answer all questions showing your work wherever possible.

1. Write 358 204 out in words.
- _____
- _____
2. Round off each number to the nearest thousand and then add the two numbers.
- 7300 and 290 645
- _____
- _____
3. Represent the following numbers in expanded notation:
- a) 7 235 _____
- b) 9 564 231 _____
4. Represent the following numbers in expanded notation using the exponent form:
- a) 6 485 _____
- b) 2 374 596 _____
5. Give the prime factorization for the following numbers:
- a) 70 _____
- b) 111 _____
6. List of factors of:
- a) 16 _____
- b) 23 _____
7. List the multiples (to 60) of 12:
- _____

8. Given Set A = (0, 2, 3, 7)

Set B = (1, 3, 5, 7)

i) $A \cup B =$ _____

ii) $A \cap B =$ _____

9 Circle the numerals that represent prime numbers.

21

37

83

42

56

95

19

10. Complete the following patterns:

a) 3, 14, _____, _____, 47.

b) 36, _____, _____, 18, 12, 6.

PART II PROBLEM SOLVING

SECTION A

Solve the following problems using a method of your choice, e.g. diagram, chart or graph, etc. Show your work.

Problem 1

Robert's ping pong club is planning a tournament. If there are 9 people in the club, how many games must be played in order to have every member play every other member just once?

Problem 2

Four girl guides went to Girl Guide Camp. Their names were Brenda, Jennifer, Kenda and Diane. They were from Thompson, Winnipeg, Brandon and Portage La Prairie (not necessarily in that order). Diane is from Winnipeg and Jennifer is not from Portage La Prairie. If Kenda is from Brandon, where is Brenda from?

Problem 3

Brad, Scott, Ken, Jamie and Darren entered a pizza eating contest. Scott came in first, Brad came is last. If Ken was ahead of Jamie and Darren was just behind him, who came in second?

SECTION B

Solve the following problems using the equation "Let $n = \dots$ "

1. Lisa paid \$2.88 for three 16 slice loaves of bread. a) How much did she pay for each loaf? b) What is the cost of one slice of bread? c) How much change would she receive if she gave the clerk \$5.00?

2. The Winnipeg Free Press costs \$1.40 a week. How much would you pay for one year's delivery?

3. This morning Mr. Jones had \$459.00 is his checking account. Since then he wrote checks for \$72.28 and \$63.00. How much money will be in his account after he deposits another \$125.00?

MATH FACTS

NAME _____

SCORE _____

$21 \div 3 =$	$34 \div 6 =$	$3 + 2 =$	$7 \times 9 =$	$4 \times 9 =$
$4 + 6 =$	$6 \times 6 =$	$8 \times 4 =$	$144 \div 12 =$	$10 + 4 =$
$9 \times 8 =$	$64 \div 8 =$	$7 + 3 =$	$11 \times 12 =$	$5 \times 6 =$
$42 \div 6 =$	$110 \div 10 =$	$15 - 6 =$	$7 + 9 =$	$8 \times 8 =$
$7 \times 3 =$	$24 \div 4 =$	$30 \div 6 =$	$12 \times 1 =$	$81 \div 9 =$
$2 - 1 =$	$8 \times 9 =$	$56 \div 7 =$	$12 \times 12 =$	$5 \times 5 =$
$9 + 9 =$	$6 - 6 =$	$9 - 4 =$	$56 \div 8 =$	$16 - 8 =$
$36 \div 9 =$	$12 \times 6 =$	$11 - 3 =$	$18 - 9 =$	$9 \times 9 =$
$4 \div 4 =$	$8 \times 8 =$	$5 + 5 =$	$6 \times 5 =$	$16 - 7 =$
$10 \times 10 =$	$0 + 0 =$	$4 + 1 =$	$7 \times 4 =$	$9 \times 1 =$
$25 \div 5 =$	$9 - 2 =$	$5 + 5 =$	$8 \times 6 =$	$11 \times 2 =$
$1 \div 1 =$	$36 \div 4 =$	$5 \times 7 =$	$12 - 6 =$	$7 - 5 =$
$2 \times 8 =$	$5 - 2 =$	$1 \div 1 =$	$36 \div 6 =$	$7 \times 6 =$
$28 \div 4 =$	$15 + 5 =$	$16 - 9 =$	$7 + 8 =$	$4 \times 8 =$
$4 \times 4 =$	$6 + 6 =$	$12 \times 9 =$	$15 - 5 =$	$1 + 0 =$
$18 \div 2 =$	$54 \div 9 =$	$6 \times 8 =$	$6 \times 9 =$	$6 \times 7 =$
$6 \times 7 =$	$8 - 1 =$	$48 \div 8 =$	$72 \div 9 =$	$9 + 0 =$
$8 + 9 =$	$12 + 0 =$	$72 \div 8 =$	$5 \times 8 =$	$6 \div 6 =$
$7 \times 7 =$	$3 + 3 =$	$9 \times 4 =$	$20 \div 5 =$	$48 \div 6 =$
$10 + 1 =$	$108 \div 9 =$	$42 \div 6 =$	$9 \times 4 =$	$100 \div 10 =$
$11 \times 11 =$	$18 \div 6 =$	$7 - 5 =$	$0 + 6 =$	$9 + 8 =$
$11 - 8 =$	$4 + 7 =$	$7 \times 6 =$	$16 - 4 =$	$7 \times 6 =$
$12 - 3 =$	$15 \div 5 =$	$4 \times 8 =$	$42 \div 7 =$	$9 \times 7 =$
$6 \div 2 =$	$72 \div 6 =$	$5 \times 9 =$	$1 - 0 =$	$7 + 7 =$
$3 + 5 =$	$20 - 17 =$	$49 \div 7 =$	$9 + 6 =$	$63 \div 7 =$
$12 + 3 =$	$7 - 2 =$	$7 \times 1 =$	$2 \times 6 =$	$10 \times 6 =$
$12 \times 12 =$	$5 \div 5 =$	$45 \div 5 =$	$4 \div 2 =$	$6 \times 4 =$
$9 \div 9 =$	$3 \times 5 =$	$0 \times 0 =$	$25 \div 5 =$	$30 \div 5 =$
$10 \div 5 =$	$7 \times 2 =$	$32 \div 4 =$	$7 \times 0 =$	$56 \div 8 =$
$8 - 6 =$	$0 \times 6 =$	$12 \times 6 =$	$4 + 3 =$	$3 \times 7 =$
$12 \div 4 =$	$1 \times 1 =$	$6 + 0 =$	$7 \div 7 =$	$5 + 9 =$
$2 \div 2 =$	$13 - 8 =$	$3 \times 3 =$	$28 \div 4 =$	$3 \times 6 =$
$5 \times 2 =$	$1 - 0 =$	$12 + 3 =$	$6 \times 1 =$	$2 \times 9 =$
$3 \div 3 =$	$1 + 8 =$	$8 + 5 =$	$8 - 2 =$	$6 + 1 =$
$6 \div 1 =$	$2 \times 3 =$	$18 \div 3 =$	$14 \div 2 =$	$10 + 6 =$
$5 + 7 =$	$5 + 6 =$	$27 \div 9 =$	$5 \div 1 =$	$9 + 4 =$
$4 \times 6 =$	$1 \times 8 =$	$9 \times 3 =$	$11 + 3 =$	$7 - 7 =$
$40 \div 8 =$	$7 - 7 =$	$11 + 1 =$	$6 - 3 =$	$8 \times 3 =$
$63 \div 7 =$	$2 \times 5 =$	$9 \times 0 =$	$7 \times 2 =$	$48 \div 6 =$
$7 + 6 =$	$2 \times 4 =$	$5 \times 4 =$	$3 + 9 =$	$1 \times 5 =$
$9 - 2 =$	$6 + 9 =$	$8 + 3 =$	$9 - 5 =$	$7 - 3 =$
$3 - 3 =$	$0 \times 7 =$	$4 \div 1 =$	$11 \times 6 =$	$12 + 6 =$
$24 \div 3 =$	$8 \div 4 =$	$6 + 2 =$	$9 + 3 =$	$0 - 0 =$
$15 \div 3 =$	$11 \times 3 =$	$9 \div 1 =$	$5 + 2 =$	$4 + 9 =$
$3 + 6 =$	$15 - 8 =$	$9 - 7 =$	$28 \div 7 =$	$3 \times 4 =$
$3 \times 0 =$	$8 - 3 =$	$9 + 0 =$	$11 \times 11 =$	$63 \div 9 =$
$0 - 0 =$	$5 - 3 =$	$5 + 4 =$	$0 \times 7 =$	$1 + 7 =$
$4 \times 4 =$	$10 \times 6 =$	$12 \times 4 =$	$5 - 0 =$	$8 - 4 =$
$9 - 6 =$	$35 \div 7 =$	$45 \div 9 =$	$40 \div 5 =$	$24 \div 4 =$
$18 \div 2 =$	$8 \div 2 =$	$5 \times 0 =$	$2 \times 8 =$	$36 \div 9 =$

POST TEST
MATH FACTS

NAME _____
SCORE _____

- | | | | | |
|-----------|------------|-----------|-----------|------------|
| 42 ÷ 7 = | 3 × 2 = | 12 ÷ 3 = | 4 × 8 = | 21 ÷ 7 = |
| 9 + 2 = | 16 ÷ 4 = | 20 ÷ 5 = | 5 × 11 = | 9 - 2 = |
| 2 × 3 = | 55 ÷ 5 = | 10 - 7 = | 30 ÷ 6 = | 11 - 4 = |
| 6 - 3 = | 6 × 11 = | 64 ÷ 8 = | 8 - 8 = | 14 ÷ 2 = |
| 8 × 5 = | 8 + 6 = | 0 × 9 = | 3 + 0 = | 10 × 12 = |
| 54 ÷ 9 = | 4 + 8 = | 12 + 2 = | 40 ÷ 8 = | 7 × 9 = |
| 18 - 9 = | 2 - 2 = | 4 ÷ 4 = | 7 × 7 = | 48 ÷ 6 = |
| 10 × 10 = | 3 × 8 = | 8 × 9 = | 12 × 5 = | 16 + 8 = |
| 40 ÷ 4 = | 100 ÷ 10 = | 6 × 0 = | 56 ÷ 8 = | 7 ÷ 7 = |
| 5 × 3 = | 8 - 4 = | 18 - 2 = | 3 × 5 = | 8 × 11 = |
| 13 - 6 = | 36 ÷ 9 = | 5 + 4 = | 8 + 5 = | 10 × 9 = |
| 8 × 0 = | 10 × 7 = | 5 - 0 = | 6 - 2 = | 36 ÷ 6 = |
| 11 + 2 = | 3 ÷ 3 = | 3 × 12 = | 8 × 3 = | 3 × 0 = |
| 9 × 4 = | 7 - 1 = | 24 ÷ 8 = | 81 ÷ 9 = | 12 × 9 = |
| 48 ÷ 6 = | 1 + 4 = | 11 × 11 = | 15 - 5 = | 24 ÷ 4 = |
| 3 × 3 = | 18 ÷ 9 = | 4 + 8 = | 4 × 2 = | 2 + 7 = |
| 4 - 0 = | 3 × 4 = | 18 - 3 = | 5 + 7 = | 11 + 5 = |
| 8 × 2 = | 0 × 5 = | 9 × 9 = | 36 ÷ 3 = | 5 × 3 = |
| 5 - 1 = | 4 - 4 = | 54 ÷ 6 = | 11 + 11 = | 72 ÷ 8 = |
| 56 ÷ 7 = | 5 × 4 = | 13 + 2 = | 9 - 3 = | 7 - 1 = |
| 3 × 0 = | 27 ÷ 3 = | 48 ÷ 4 = | 10 × 4 = | 3 × 6 = |
| 64 ÷ 8 = | 8 + 8 = | 5 × 7 = | 28 ÷ 4 = | 4 × 8 = |
| 8 - 8 = | 11 × 6 = | 8 × 0 = | 4 - 2 = | 4 + 9 = |
| 3 × 7 = | 40 ÷ 4 = | 7 + 4 = | 6 - 3 = | 49 ÷ 7 = |
| 7 - 3 = | 3 + 8 = | 9 ÷ 1 = | 7 × 6 = | 7 - 5 = |
| 42 ÷ 6 = | 6 × 7 = | 24 ÷ 6 = | 10 - 5 = | 8 ÷ 2 = |
| 13 + 5 = | 7 × 4 = | 8 × 7 = | 36 ÷ 6 = | 6 × 7 = |
| 10 ÷ 2 = | 10 - 4 = | 6 + 9 = | 2 × 12 = | 12 - 3 = |
| 4 × 6 = | 14 + 6 = | 63 ÷ 9 = | 81 ÷ 9 = | 36 ÷ 4 = |
| 60 ÷ 6 = | 36 ÷ 6 = | 11 + 9 = | 18 + 2 = | 15 - 8 = |
| 11 + 6 = | 4 × 5 = | 8 × 3 = | 45 ÷ 9 = | 10 + 5 = |
| 9 - 4 = | 9 - 0 = | 9 + 5 = | 4 × 4 = | 54 ÷ 9 = |
| 11 × 9 = | 11 - 9 = | 22 ÷ 2 = | 12 × 3 = | 7 × 7 = |
| 5 × 9 = | 99 ÷ 9 = | 13 - 8 = | 9 + 3 = | 8 × 4 = |
| 6 + 4 = | 110 ÷ 10 = | 11 - 3 = | 0 + 7 = | 12 × 12 = |
| 3 × 11 = | 4 × 0 = | 45 ÷ 5 = | 80 ÷ 8 = | 110 ÷ 10 = |
| 7 + 9 = | 8 ÷ 4 = | 6 - 6 = | 8 - 5 = | 6 + 2 = |
| 11 - 9 = | 12 × 8 = | 72 ÷ 8 = | 5 × 6 = | 8 × 9 = |
| 12 ÷ 2 = | 6 ÷ 6 = | 4 × 0 = | 10 × 0 = | 9 - 3 = |
| 6 - 2 = | 5 × 5 = | 12 - 8 = | 11 × 11 = | 8 + 6 = |
| 8 - 6 = | 10 - 3 = | 9 × 7 = | 11 - 2 = | 12 - 12 = |
| 3 + 6 = | 35 ÷ 7 = | 48 ÷ 8 = | 63 ÷ 9 = | 6 × 5 = |
| 32 ÷ 4 = | 12 × 2 = | 30 ÷ 5 = | 16 ÷ 4 = | 9 × 5 = |
| 11 - 4 = | 7 + 6 = | 7 - 6 = | 6 + 6 = | 11 × 7 = |
| 9 × 7 = | 9 - 6 = | 40 ÷ 5 = | 72 ÷ 9 = | 7 + 2 = |
| 6 × 7 = | 44 ÷ 4 = | 11 - 8 = | 10 + 8 = | 8 × 2 = |
| 20 ÷ 5 = | 9 - 2 = | 2 - 0 = | 54 ÷ 6 = | 56 ÷ 8 = |
| 0 × 1 = | 14 ÷ 7 = | 14 - 6 = | 11 - 6 = | 9 - 5 = |
| 11 × 4 = | 7 - 5 = | 18 ÷ 2 = | 7 - 2 = | 4 × 5 = |
| 40 ÷ 8 = | 2 + 2 = | 4 × 4 = | 4 - 1 = | 4 + 1 = |

APPENDIX B
TEST SCORES (X) AND (X²)

EXPERIMENTAL GROUP TEST SCORES (X)

Student Number	Unit I Pretest (x)	Unit I Post Test (x)	Unit II Pretest (x)	Unit II Post Test (x)	Combined Unit I & II Pretest (x)	Combined Unit I & II Post Test (x)	Math Facts Pretest (x)	Math Facts Post Test (x)
1.	34	38	15	55	25	47	62	66
2.	37	68	66	92	52	80	63	63
3.	24	43	4	50	14	47	71	-
4.	31	73	52	65	42	69	80	-
5.	35	58	22	77	29	68	69	68
6.	25	41	2	11	14	26	60	65
7.	27	59	20	48	24	54	78	79
8.	24	41	14	86	19	64	62	-
9.	47	50	46	82	47	66	56	67
10.	12	41	38	53	25	47	52	57
11.	12	27	10	48	11	38	71	76
12.	-	60	-	94	-	77	-	-
13.	36	40	9	16	23	28	64	55
14.	40	93	33	100	37	97	74	79
15.	14	66	5	56	10	47	24	55
16.	30	97	12	72	21	85	63	72
17.	38	56	10	56	24	56	62	64
18.	38	98	54	94	46	96	60	77
19.	52	87	13	93	33	90	61	70
20.	47	96	26	78	37	87	73	86
21.	25	88	15	73	20	81	62	67

Student Number	Unit I Pretest (x)	Unit I Post Test (x)	Unit II Pretest (x)	Unit II Post Test (x)	Combined Unit I & II Pretest (x)	Combined Unit I & II Post Test (x)	Math Facts Pretest (x)	Math Facts Post Test (x)
22.	31	95	5	91	18	93	64	71
23.	37	96	16	89	27	93	72	92
24.	26	63	21	80	24	72	39	75
25.	43	100	15	93	29	97	68	90
26.	25	54	12	-	19	56	54	75
27.	40	58	38	49	39	54	60	92
28.	24	42	18	23	27	33	20	46
29.	52	50	53	74	53	62	77	96
30.	30	53	10	6	20	29	48	80
31.	46	59	38	49	42	54	44	92
32.	61	58	54	74	58	66	42	98
33.	22	52	5	40	14	46	58	97
34.	35	57	13	77	24	67	78	96
35.	53	62	64	59	59	61	78	96
36.	51	34	37	48	44	41	53	94
37.	39	51	29	75	34	63	88	97
38.	33	47	33	47	24	51	55	91
39.	34	49	37	67	36	58	79	96
40.	33	45	38	33	36	39	77	97
41.	46	86	30	97	38	92	84	97
42.	39	75	29	18	34	47	65	85

Student Number	Unit I Pretest (x)	Unit I Post Test (x)	Unit II Pretest (x)	Unit II Post Test (x)	Combined Unit I & II Pretest (x)	Combined Unit I & II Post Test (x)	Math Facts Pretest (x)	Math Facts Post Test (x)
43.	11	34	4	2	8	18	52	56
44.	46	72	40	63	43	68	69	89
45.	34	67	29	65	32	66	71	-
46.	32	73	28	89	30	81	71	78
47.	-	78	-	17	-	48	72	80
48.	28	63	9	19	19	41	60	70
49.	45	97	34	60	40	79	54	69
50.	12	28	14	22	13	25	74	80
51.	27	87	2	10	15	49	67	75
52.	52	96	38	82	45	89	-	100
53.	<u>29</u>	<u>28</u>	<u>7</u>	<u>32</u>	<u>18</u>	<u>30</u>	<u>52</u>	<u>75</u>
TOTAL (Σx)	1744	3329	1266	3218	1515	3049	3212	3791

CONTROL GROUP TEST SCORES (X)

Student Number	Unit I Pretest (x)	Unit I Post Test (x)	Unit II Pretest (x)	Unit II Post Test (x)	Combined Unit I & II Pretest (x)	Combined Unit I & II Post Test (x)	Math Facts Pretest (x)	Math Facts Post Test (x)
1.	32	73	12	82	22	78	76	74
2.	46	55	49	83	48	69	73	73
3.	40	54	67	67	54	61	99	-
4.	21	51	18	65	20	58	67	73
5.	37	73	41	80	40	77	87	-
6.	30	39	13	77	22	58	65	62
7.	24	41	38	77	31	59	76	84
8.	-	24	-	27	-	26	41	41
9.	34	63	35	90	35	77	90	-
10.	44	57	56	86	50	72	-	86
11.	29	64	14	60	22	62	71	47
12.	9	32	16	51	13	42	73	69
13.	26	78	40	89	33	84	74	-
14.	-	56	-	70	-	63	-	-
15.	36	70	8	52	22	61	54	69
16.	-	94	-	79	-	87	57	76
17.	46	95	32	92	39	94	74	79
18.	28	55	11	65	20	60	24	55
19.	37	89	9	60	23	75	46	73
20.	37	96	5	96	21	96	67	78
21.	25	51	5	46	15	49	53	75

Student Number	Unit I Pretest (x)	Unit I Post Test (x)	Unit II Pretest (x)	Unit II Post Test (x)	Combined Unit I & II Pretest (x)	Combined Unit I & II Post Test (x)	Math Facts Pretest (x)	Math Facts Post Test (x)
22.	23	67	16	66	20	67	61	83
23.	30	63	37	78	34	71	62	75
24.	50	97	21	95	36	96	72	92
25.	39	100	17	99	28	99	74	97
26.	21	51	4	32	13	42	44	49
27.	37	38	5	24	21	31	22	88
28.	30	58	27	52	29	55	56	84
29.	25	38	6	33	16	36	58	96
30.	37	58	37	50	37	54	83	96
31.	58	63	49	62	54	63	55	94
32.	27	34	10	69	19	52	34	76
33.	24	42	28	75	26	59	49	96
34.	47	52	20	36	34	44	23	76
35.	24	57	35	60	30	59	43	96
36.	51	59	31	78	41	69	38	98
37.	39	46	36	64	38	55	66	-
38.	30	43	16	45	23	44	53	80
39.	39	49	21	51	30	50	58	94
40.	-	20	-	7	-	14	69	70
41.	16	34	3	8	9	21	77	-
42.	24	58	16	59	20	59	38	38

Student Number	Unit I Pretest (x)	Unit I Post Test (x)	Unit II Pretest (x)	Unit II Post Test (x)	Combined Unit I & II Pretest (x)	Combined Unit I & II Post Test (x)	Math Facts Pretest (x)	Math Facts Post Test (x)
43.	38	92	2	48	20	70	72	68
44.	32	43	15	27	24	45	46	45
45.	30	57	28	28	29	44	65	81
46.	47	-	-	-	-	-	74	97
47.	26	60	19	45	23	53	53	53
48.	14	59	10	42	12	51	64	77
49.	37	95	30	44	34	70	46	67
Total (x)	<u>1476</u>	<u>2843</u>	<u>1008</u>	<u>2871</u>	<u>1230</u>	<u>2881</u>	<u>2822</u>	<u>3180</u>

EXPERIMENTAL GROUP TEST SCORES SQUARED (x^2)

Student Number	Unit I Pretest (x^2)	Unit I Post Test (x^2)	Unit II Pretest (x^2)	Unit II Post Test (x^2)	Combined Unit I & II Pretest (x^2)	Combined Unit I & II Post Test (x^2)	Math Facts Pretest (x^2)	Math Facts Post Test (x^2)
1.	1156	1444	225	3025	625	2209	3844	4356
2.	1369	4624	4356	8464	2704	6400	3969	3969
3.	576	1849	16	2500	196	2209	5041	----
4.	961	5329	2704	4225	1764	4761	6400	----
5.	1225	3364	484	5927	841	4624	4761	4624
6.	625	1681	4	121	196	676	3600	4225
7.	729	----	400	----	576	2916	6084	6241
8.	576	1681	196	7396	361	4096	3844	----
9.	2209	2500	2116	6724	2209	4356	3136	4489
10.	144	1681	1444	2809	625	2209	2704	3249
11.	144	1681	100	2304	121	1444	5041	5776
12.	----	3600	----	8836	----	5929	----	----
13.	1296	1600	81	256	529	784	4096	3025
14.	1600	8649	1089	10000	1369	9409	5476	6241
15.	196	4356	25	784	100	2209	576	3025
16.	900	9409	144	5184	441	7225	3969	5184
17.	1444	3136	100	1089	576	3136	3844	4096
18.	1444	9604	2916	8836	2116	9216	3600	5929
19.	2704	7569	169	8649	1089	8100	3721	4900
20.	2209	9216	676	6084	1369	7569	5329	7396
21.	625	7744	225	5329	400	6561	3844	4489

Student Number	Unit I Pretest (x ²)	Unit I Post Test (x ²)	Unit II Pretest (x ²)	Unit II Post Test (x ²)	Combined Unit I & II Pretest (x ²)	Combined Unit I & II Post Test (x ²)	Math Facts Pretest (x ²)	Math Facts Post Test (x ²)
22.	961	9025	25	8281	324	8836	4096	5041
23.	1369	9216	256	7921	729	8836	5184	8464
24.	676	3969	441	6400	576	5184	1521	5625
25.	1849	10000	225	8649	841	9409	4624	8100
26.	625	1681	144	2304	361	3136	2916	5625
27.	1600	3364	1444	2401	1521	2916	3600	8464
28.	576	1764	324	529	729	1089	400	2116
29.	2704	2500	2809	5476	2809	3844	5929	9216
30.	900	2809	100	36	400	841	2304	6400
31.	2116	3481	1444	2401	1764	2916	1936	8464
32.	3721	3364	2916	5476	3364	4356	1764	9604
33.	484	2704	25	1400	196	2116	2304	9409
34.	1225	3249	169	5929	576	4489	6084	9216
35.	2809	3844	4096	3481	3481	3721	6084	9216
36.	2601	1156	1369	2304	1936	1681	2809	8836
37.	1521	2601	841	5625	1156	3969	7744	9409
38.	1089	2209	1089	2209	576	2601	3025	8281
39.	1156	2401	1369	4489	1296	3364	6241	9216
40.	1089	2025	1444	1089	1296	1521	5929	9409
41.	2116	7396	900	9409	1444	8464	7056	9409
42.	1521	5625	841	324	1156	2209	4225	7225

Student Number	Unit I Pretest (x2)	Unit I Post Test (x2)	Unit II Pretest (x2)	Unit II Post Test (x2)	Combined Unit I & II Pretest (x2)	Combined Unit I & II Post Test (x2)	Math Facts Pretest (x2)	Math Facts Post Test (x2)
43.	121	1156	16	4	64	324	2704	3136
44.	2116	5184	1600	3969	1849	4624	4761	7921
45.	1156	4489	841	4225	1024	4356	5041	----
46.	1024	5329	784	7921	900	8561	5041	6084
47.	----	6084	----	289	----	2304	5184	6400
48.	784	3969	81	361	361	1681	3600	4900
49.	2025	9409	1156	3600	1600	6241	2916	4761
50.	144	784	196	484	169	625	5476	6400
51.	729	7569	4	100	225	2401	4489	5625
52.	2704	9216	1444	6724	2025	7921	----	10000
53.	841	784	49	1024	324	900	2704	5625
Total (x2)	66484	228873	45912	213376	53279	221474	210570	308811

CONTROL GROUP TEST SCORES SQUARED (x^2)

Student Number	Unit I Pretest (x^2)	Unit I Post Test (x^2)	Unit II Pretest (x^2)	Unit II Post Test (x^2)	Combined Unit I & II Pretest (x^2)	Combined Unit I & II Post Test (x^2)	Math Facts Pretest (x^2)	Math Facts Post Test (x^2)
1.	1024	5329	144	6724	484	6084	5776	5476
2.	2116	3025	2401	6889	2304	4761	5329	5329
3.	1600	2916	4489	4489	2916	3721	9801	----
4.	441	2601	324	4225	400	3364	4489	5329
5.	1369	5329	1681	6400	1600	5929	7569	----
6.	900	1521	169	5929	484	3364	4225	3844
7.	576	1681	1444	5929	961	3481	5776	7056
8.	----	576	----	729	----	676	1681	1681
9.	1156	3969	1225	8100	1225	5929	8100	----
10.	1936	3249	3136	7396	2500	5184	----	7396
11.	841	4096	196	3600	484	3844	5041	2209
12.	81	1024	256	2601	169	1764	5329	4761
13.	676	6084	1600	7921	1089	7056	5476	----
14.	----	3136	----	4900	----	3969	----	----
15.	1296	4900	64	2704	484	3721	2916	4761
16.	----	8836	----	6241	----	7569	3249	5776
17.	2116	9025	1024	8464	1521	8836	5476	6241
18.	784	3025	121	4225	400	3600	576	3025
19.	1369	7921	81	3600	529	5625	2116	5329
20.	1369	9216	25	9216	441	9216	4489	6084
21.	625	1444	25	1089	225	2401	2809	5625

Student Number	Unit I Pretest (x ²)	Unit I Post Test (x ²)	Unit II Pretest (x ²)	Unit II Post Test (x ²)	Combined Unit I & II Pretest (x ²)	Combined Unit I & II Post Test (x ²)	Math Facts Pretest (x ²)	Math Facts Post Test (x ²)
22.	529	4489	256	4356	400	4489	3721	6889
23.	900	3969	1369	6084	1156	5041	3844	5625
24.	2500	9409	441	9025	1296	9216	5184	8464
25.	1521	10000	289	9801	784	9801	5476	9409
26.	441	2601	16	1024	169	1764	1936	2401
27.	1369	1444	25	576	441	961	484	7744
28.	900	3364	729	2704	841	3025	3136	7056
29.	625	1444	36	1089	256	1296	3364	9216
30.	1369	3364	1369	2500	1369	2916	6889	9216
31.	3364	3969	2401	3844	2916	3969	3025	8836
32.	729	1156	100	4761	361	2704	1156	5776
33.	576	1764	784	5625	676	3481	2401	9216
34.	2209	2704	400	1296	1156	1936	529	5776
35.	576	3249	1225	3600	900	3481	1849	9216
36.	2601	3481	961	6084	1681	4761	1444	9604
37.	1521	2116	1296	4096	1444	3025	4356	-----
38.	900	1849	256	2025	625	1936	2809	6400
39.	1521	2401	441	2601	900	2500	3364	8836
40.	-----	400	-----	49	-----	196	4761	4900
41.	256	1156	9	64	81	441	5929	-----
42.	576	3364	256	3481	400	3481	1444	1444

Student Number	Unit I Pretest (x2)	Unit I Post Test (x2)	Unit II Pretest (x2)	Unit II Post Test (x2)	Combined Unit I & II Pretest (x2)	Combined Unit I & II Post Test (x2)	Math Facts Pretest (x2)	Math Facts Post Test (x2)
43.	1444	8464	4	2304	400	4900	5184	4624
44.	1024	1849	225	729	576	2025	2116	2025
45.	900	3240	784	784	841	1936	4225	6561
46.	2209	-----	-----	-----	-----	-----	5476	9409
47.	676	3600	361	2025	529	2809	2809	2809
48.	196	3481	100	1764	144	2601	4096	5929
49.	1369	9025	900	1936	1156	4900	2116	4489
Total	(Σx^2) 53076	183131	33438	195598	39714	189685	178585	251792