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ABSTRACT

The purpose of this study was to investigate the effects on achievement and attitude resulting from the use of a calculator-based curriculum and a classroom set of hand-held calculators in ninth-grade general mathematics. Six teachers participated in the study, each having one class in the calculator treatment and one class in the non-calculator treatment. Students in both groups were given pretests in mathematics achievement and attitude. Both treatment groups were given units of instruction on estimation, computation, and problem solving using the four arithmetic operations on whole numbers. The calculator group used a classroom set of hand-held calculators in instruction. The non-calculator group used paper and pencil only. Posttests in mathematics achievement and attitude were given to both groups. Half of each group took the achievement posttest with a hand-held calculator as an aid. The other half of each group took the achievement posttest using paper and pencil only. The resulting data were analyzed using analysis of covariance. Among the findings were that the use of calculator-based curriculum did not significantly affect student achievement in computation or student attitude toward mathematics but did have a positive effect on student achievement in problem solving. (MN)

THE EFFECT OF A HAND-HELD CALCULATOR CURRICULUM IN SELECTED FUNDAMENTALS OF MATHEMATICS CLASSES

by

BILLY LYNN HOPKINS, B.A., M.S.

DISSERTATION

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THE EFFECT OF A HAND-HELD CALCULATOR CURRICULUM IN SELECTED FUNDAMENTALS OF MATHEMATICS CLASSES

APPROVED BY SUPERVISORY COMMITTEE:

E. Glenadine Gibb

Ralph W. Cain

L. Ray Carry

James W. Reynolds

W. T. Guy, Jr.

This dissertation is dedicated to

my wife, Anita, my children, Bryan and Amy, and my
parents, Mr. and Mrs. J. G. Hopkins
for their love, support, and
encouragement.

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INTRODUCTION

The development of computer technology has brought about many changes in today's society. The computer now has become an integral part of science, government, business, and education. Science employs the computer in countless areas of research. The computer has become essential in aviation and in various forms of transportation guidance systems. Government and business depend upon the computer in many ways, including record keeping, data processing, and research. The use of computers in education is developing rapidly. Some schools use computer-assisted instruction for students who need individual assistance in a particular area or who have special interests. Often schools will offer computer mathematics, or a special course in which a computer is used. Also, computer management systems are widely used in education.

With this increase in computer technology has come the development of hand-held calculators. The development of these devices has been such that hand-held calculators are being purchased inexpensively and used by millions of individuals throughout the country. Projections of calculator sales led Usiskin and Bell (1976) to make the following statement:

> Assuming such projections prove to be accurate, we can conclude that whatever the response of schools, people outside of schools will have nearly universal access to cheap and easy calculation by 1980, ... (p. 2)

With so many students owning a personal calculator or having access to the use of a calculator, teachers are faced with many decisions regarding the classroom use of these devices. Among the questions for which teachers and school administrators seek answers are the following (Suydam, 1976):

> (1) Will the use of hand-held calculators destroy student motivation for learning the basic facts?
> (2) Will the use of calculators destroy the basic, mainstream mathematics of the elementary school curriculum?
> (3) Will the cost of calculators prohibit their use?
> (4) Are calculators appropriate for slow learners?
> (5) Will the child's notion of the nature of mathematics be changed by the use of calculators?
> (6) Will the use of calculators reduce children's ability to detect errors?
> (7) Are paper-and-pencil algorithms still necessary?
> (8) Will the use of hand-held calculators discourage mathematical thinking?
> (9) How can parents be dealt with who are opposed to the use of calculators in the schools? (pp. 16-17)

In recent years, there have been investigations to determine whether or not calculating devices have positive motivational or instructional value in students' learning of mathematics. The earlier studies in this area involved desk calculators (Fehr, 1956; Beck, 1960; Ellis, 1969; Mastbaum, 1969; Advani, 1972; Cech, 1972; Ladd, 1973; Shea, 1974; Gaslin, 1975; Nichols, 1976). More recently the focus of this type of research has been on the hand-held calculator (Bitter and Nelson, 1975; Hawthorne and Sullivan, 1975; Hutton, 1976; Weaver, 1976). The emphasis of much of this research has been on the use of hand-held calculators as a supplement to the regular curriculum, such as for motivational exercises and games or for use in checking paper-and-pencil calculations, or simply as a computational aid. Kessner (1975), for example, used "gamelike modules" with simplified calculators with first graders. Hawthorne and Sullivan (1975) used calculators for working and checking cumputational exercises in grade 6. Zepp (1976) used the hand-held calculator as a computational aid with college freshmen. Much of this research reveals no significant improvement in computation skills. There has been found, however, a tendency toward improved motivation when calculators are used in the classroom, though none of the above studies showed significant differences.

If our society is to have access to "cheap and easy calculation," as projected by Usiskin and Bell, an important responsibility of mathematics education is to ensure that people in our society can use computation in a way that will enable them to function in everyday problem situations. Usiskin and Bell illustrate this point by referring to the

1972-73 National Assessment of Mathematics results, which indicate that computation may not be a serious problem in our society. For example, 92% of seventeen year olds and 86% of adults could correctly add a problem involving dollars and cents, and 78% of seventeen year olds and 74% of adults could correctly subtract a simple decimal problem. However, only 1% of seventeen year olds and 16% of adults could find the correct answer on a moderately complicated checkbook balancing problem (NAEP Reports, 1975). This indicates that there may be more reason for concern in problem solving, or applications of computation skills, than in computation alone.

High school courses in general mathematics often are considered "low-level" courses in mathematics. A general mathematics program can be traced to the National Committee on Mathematics Requirements, whose final report, The Reorganization of Mathematics in Secondary Education, was published in 1923. The report advocated a general mathematics program for grades 7-9, which would include topics from arithmetic, algebra, intuitive geometry, numerical trigonometry, graphs, and descriptive statistics. By the late 1930's, the mathematics programs of junior high schools were less dominated by arithmetic and turned more to the general mathematics concepts. By

1932, the general mathematics concept was accepted extensively in grades 7 and 8. For grades above the eighth, however, general mathematics, as defined above, has never been generally accepted. Following the 1930's, general mathematics at the ninth-grade level often was planned and taught as a lower-level alternative to algebra rather than as the continuation of a broadly planned general mathematics program.

Need for the Study

The National Advisory Committee on Mathematics Education (1975) makes the following statement, regarding courses in general mathematics, which indicates that calculators may have a place in this type of course:

> ...arithmetic proficiency has commonly been assumed as an unavoidable prerequisite to conceptual study and application of mathematical ideas. This practice has condemned many low achieving students to a succession of general mathematics courses that begin with and seldom progress beyond drill in arithmetic skills. Providing these students with calculators has the potential to open a rich new supply of important mathematical ideas for these students. (pp. 41-42)

As indicated earlier in this chapter, there are many questions to be answered regarding the use of calculators in a classroom. This investigator was concerned in particular with the effects that the use of calculators in the classroom has on achievement in mathematics and attitudes toward mathematics.

One question to be considered is in regard to achievement in computation. It might be hypothesized that students would become dependent upon a calculator if they were allowed to use the device during instruction. This, in turn, could result in students' loss of skill in computation when using paper and pencil only. Some studies have attempted to answer this question. Fehr, McMeen, and Sokol (1956) concluded that there was more gain in computation achievement with fifth graders who used desk calculators than with those who did not use calculators. In a study with seventh and eighth graders, Durrance (1964) found no significant improvement in arithmetic achievement that could be attributed to the use of calculators. Mastbaum (1969) stated that there was no improvement in non-calculator computational skill in a study with 171 slow learners in grades 7 and 8. Stocks (1972) found in a study with fifteen educable mentally retarded primary students, that the students maintained their gains in division skills even when these skills were tested without a calculator available.

There are other studies in which improvement was found in computation by students using calculators (Bitter and

Nelson, 1975; Kelley and Lansing, 1975; Hawthorne and Sullivan, 1975; Spencer, 1975). These studies, however, did not answer the question regarding how a student performs who uses a calculator in instruction, but not on a test, particularly for the general mathematics student.

A second question considered by this investigator regards achievement in problem solving. It could be hypothesized that classroom use of a calculator might free the student from the burden of computation and allow them to concentrate more carefully on the problem itself, which could improve ability in problem solving. This would be of particular benefit in the general mathematics class in which computation often is laborious for the students. The NACOME Report (1975) states, "Providing these (general mathematics) students with calculators has the potential to open a rich new supply of important mathematical ideas for these students." (p. 42)

The literature indicates that little is known regarding the effect that using calculators in instruction has on problem solving in general mathematics. Mastbaum (1969) found no improvement in problem solving ability with slow learners in grades 7 and 8, using desk calculators. Ladd (1973) found significant improvement in achievement with ninth grade low achievers. The improvement was in favor of the treatment group that used calculators in instruction. No significant differences were found, however, between treatment groups who used calculators in instruction and those who did not. No other studies were found in which problem solving skills in ninth grade general mathematics were compared for students using calculators in instruction and students not using calculators in instruction.

A third question considered by this investigator regards student attitude toward mathematics. It could be hypothesized that classroom achievement in mathematics could be improved in general mathematics classes if student attitudes toward mathematics were improved. Furthermore, it could be hypothesized that the classroom use of calculators during instruction in general mathematics classes would help improve student attitude toward mathematics.

Many of the studies involving classroom use of calculators have measured student attitudes toward mathematics. In a study with slow learners in grades 7 and 8, Mastbaum (1969) reported that the use of calculators did not significantly improve attitude. Advani (1972) found significant increases in student interest and positive attitudes toward mathematics in a study with eighteen children, twelve to fifteen years of age, who were identified as having learning disabilities and behavior problems. Cech (1972) could not support the hypothesis that the use of calculators in the instructional program with ninth grade, low-achieving mathematics students, improves their attitude toward the study of mathematics. Ladd (1973) found no significant difference in attitude between ninth grade low achievers who used calculators in learning and those who did not. Nichols (1976) found, in a study involving basic mathematics, that the use of electronic calculators is significantly more beneficial in improving attitude toward mathematics for students of higher aptitude in mathematics than for students with lower aptitude in mathematics. In a study involving four Algebra I classes, Hutton (1976) found no significant difference in students' attitude toward mathematics between groups using mini-calculators as either teaching or student aids and groups not using mini-calculators.

Of the studies on hand-held calculators which have been reported, few compare the non-use of calculators with the use of calculators where an instructional curriculum for using the calculator is provided. This was done by Bitter and Nelson (1975) with grades 4-7; by project EQUIP (Kelley and Lansing, 1975) with first year algebra; and by Jamski (1976) in middle school. None of these studies involved general mathematics in grade 9.

In a recent report of a National Science Foundation study on hand-held calculators (Suydam, 1976), there is evidence to indicate that in order for a hand-held calculator program to have much effect, there must be a curriculum designed for the use of the device. A summary of needed research from this report indicates that research is needed on the effect of calculator use with specific content and curricula. Weaver (1976) asked, "What are the effects of implementing certain other calculator-inspired curricular changes?" (p. 39) Furthermore, the NACOME Report (1975) asked the question, "What special types of curricula materials are needed to exploit the classroom impact of calculators?" (p. 43)

In summary, there is a need to study the effects of using a classroom set of hand-held calculators with a calculator-based curriculum in general mathematics classrooms, for the following reasons:

(1) The fact that hand-held calculators are becoming readily

available to the general public at a very low cost;
(2) The fact that many education publications and national teacher organizations are recommending the use of hand-held calculators in general mathematics classrooms;
(3) The inconclusive results of previous studies of classroom use of hand-held calculators in general mathematics; and
(4) The lack of studies on the effects of using hand-held calculators with a calculator-based curriculum in general mathematics classrooms.

Statement of the Problem

The purpose of this study was to investigate the effects on achievement and attitude resulting from the use of a calculator-based curriculum and a classroom set of hand-held calculators in ninth grade general mathematics. Two different treatments were used: 1) a unit of instruction on the four arithmetic operations on whole numbers in which a hand-held calculator was provided for each student and the calculator was an integral part of instruction; 2) a unit of instruction on the four arithmetic operations on whole numbers in which no calculators were available and the calculator was not a part of instruction.

More specifically, the study was designed to seek answers to the following questions:

1. Will the use of a calculator-based curriculum with a classroom set of hand-held calculators have an effect on students' achievement in computation?

2. Will the use of a calculator-based curriculum with a classroom set of hand-held calculators have an effect on students' achievement in problem-solving?

3. Will the use of a calculator-based curriculum with a classroom set of hand-held calculators have an effect on students' attitudes toward mathematics?

Learning Material

The learning material of this study consisted of a set of lessons that placed emphasis on computation and problem solving using the four arithmetic operations with whole numbers. There were three primary reasons for choosing this set of lessons as the learning material. First, it was necessary to choose material which essentially followed the "Quarter Course Outline for Basic Mathematics," of the district in which the study was conducted. The study was implemented in Basic Mathematics classes, and the teachers and administrators involved were concerned that the time be spent on the outlined curriculum.

Second, work with basic operations in general mathematics has been emphasized as a problem area, particularly in applications. The National Advisory Committee on Mathematics Education (NACOME) stated in their report Overview and Analysis of School Mathematics, Grades K-12 (1975):

> Conceptual thought in mathematics must build on a base of factual knowledge and skills. But traditional school instruction far over-emphasized the facts and skills and far too frequently tried to teach them by methods stressing rote memory and drill. These methods contribute nothing to a confused child's understanding, retention, or ability to apply specific mathematical knowledge. (p. 24)

This leads to a third reason for emphasizing the problem-solving aspect of the curriculum. The NACOME Report further stated that calculator use will provide students with greater opportunities to address more genuine problems in mathematics:

> With de-emphasis on the purely mechanical aspects of arithmetic comes an opportunity to pay close attention to other crucial aspects of the problem solving process and to treat more genuine problems with the "messy" calculations they inevitably involve. (p. 42)

Implications of the Study

1. If students in the calculator treatment achieve equally as well or better in computation than students in the non-calculator treatment, particularly when a calculator is not used on the posttest, then classroom use of hand-held calculators should be considered for use in instruction in ninth grade general mathematics.

2. If students in the non-calculator treatment achieve significantly higher in computation than students in the calculator treatment, then perhaps the use of calculators in instruction would not be appropriate for teaching computation skills in ninth grade general mathematics.

3. If students in the calculator treatment achieve significantly higher in problem solving than students in the non-calculator treatment, then hand-held calculators should be considered for use in instruction in ninth grade general mathematics.

4. If students in the non-calculator treatment achieve significantly higher in problem solving than students in the calculator treatment, then perhaps hand-held calculators would not be appropriate for use in instruction in ninth grade general mathematics.

5. If the calculator treatment is significantly more effective than the non-calculator treatment in improving attitudes toward mathematics, then the classroom use of hand-held calculators should be considered for use as a motivational device for ninth grade general mathematics.

CHAPTER II

REVIEW OF RELATED RESEARCH

This chapter presents an overview of the research related to this study. The discussion includes nonempirical reports on calculators, research involving desk calculators, and research on the use of hand-held calculators. The non-empirical reports on calculators lend insight toward the impact of hand-held calculators in the general mathematics classroom. Furthermore, the research with desk calculating devices appeared to have some transfer to hand-held calculator use.

Nonempirical Reports on Calculators in the Schools

There have been numerous articles and papers written that take the position that the use of hand-held calculators in classroom instruction will have positive academic and motivational value. These articles and papers often cite ways in which the calculator may be used to enhance the learning process.

Denmon (1974) gives a discussion regarding the potential values of using a calculator in the classroom.

She indicates that possible values of the calculator are in the areas of intrinsic motivation and reinforcement as a checking device.

Gibb (1975) describes possible uses of calculators in the classroom which have potential value for learning. The uses mentioned were checking answers, debugging problems, checking knowledge of basic facts in the four computation areas, assessing insight, making the calculator speak, making patterns, and solving problems. Gibb also describes changes that might take place in classrooms as a result of using calculators. Among these possible changes are 1) the study of rational numbers expressed as decimals might appear earlier in the curriculum; 2) change in what we teach and how we teach computation might occur; 3) estimating and error checking skills might receive greater emphasis; and 4) more stress might be placed on problem solving.

Stultz (1975) provides a list of ways calculators may be used in the classroom. The list includes the following ideas: 1) using the calculator to count in preschool, kindergarten, and first grade; 2) motivating students by allowing them to make up their own problems; 3) checking answers and debugging problems; 4) calculator use in teaching place value; 5) immediate reinforcement; 6) changing fractions to decimals; 7) use in enforcing correct order in chain operation; 8) use in number approximations, truncation errors, and rounding off numbers; and 9) evaluation of formulas.

The National Council of Teachers of Mathematics has taken an active role in suggesting potential uses for the hand-held calculator in the classroom. The NCTM Instructional Affairs Committee (1976) lists justifications and example problems for using the hand-held calculator in the schools. The committee states that the mini-calculator can be used to: 1) encourage students to be inquisitive and creative as they experiment with mathematical ideas; 2) reinforce the learning of the basic number facts and properties; 3) develop the understanding of computational algorithms by repeated operations; 4) serve as a flexible "answer key" to verify the results of computation; 5) be a resource tool that promotes student independence in problem solving; 6) solve problems that previously have been too time consuming or impractical to be done with paper and pencil; 7) formulate generalizations from patterns of numbers that are displayed; and 8) decrease the time needed to solve difficult computations.

There is evidence that the general public favors the use of calculators, at least to some degree. For example, a

Mathematics Teacher Editorial Panel (1974) found the following results from a survey conducted with laymen, teachers, and mathematicians who were sampled on computational issues.

> 96% believed, 'Availability of calculators will permit treatment of more realistic applications in mathematics, thus increasing student motivation'; and 28% even went so far as to say, 'Every seventh-grade mathematics student should be provided with an electronic calculator for his personal use throughout secondary school.' (pp. 485, 488)

Some mathematics educators foresee extensive curricular changes as a result of school use of the hand-held calculator. Illustrating this is the following statement made by Bell (1974):

> 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)

The National Council of Teachers of Mathematics has taken the position that calculators have much potential value as an instructional aid. NCTM encouraged the use of hand-held calculators in schools, when the Board of Directors adopted the following position statement in September, 1974:

> 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.

In summary, the nonempirical reports on the hand-held calculator indicate that:

1) There is much potential value for using hand-held calculators in the classroom.

2) There are numerous suggestions available for classroom use of hand-held calculators at virtually all levels of instruction.

3) There are implications for changes in the school mathematics curriculum due to calculator availability.

4) There is widespread support and encouragement for using the hand-held calculator in mathematics instruction.

Research with Desk Calculating Devices

The following discussion includes a review of research with desk calculators at different levels of learning. Some researchers investigated the use of calculators with students identified as having learning disabilities or as being mentally retarded. The results of these studies may have implications for using calculators in general mathematics classrooms, since students in special education are often "mainstreamed" into general mathematics classrooms.

Advani (1972) conducted a study with eighteen children, twelve to fifteen years of age, who were identified as having learning disabilities and behavior problems. The students were assessed to determine the effect of desk calculators on their achievement, attitude, and behavior. The students, whose I.Q.'s ranged from 68 to 116, used four desk calculators in a mathematics class for six months. The calculators were placed in a corner of the room, and the students were encouraged to check their problems on them. The machines also were used to enrich and reinforce a new unit. Comparison of pre- and posttest data, as measured by a questionnaire, showed significant increases in student interest and positive attitudes toward mathematics. A reduction in disruptive behavior was noted.

Stocks (1972) worked with fifteen educable mentally retarded primary students being taught long division with the use of electronic calculators. Gains, as measured by differences from pre- to posttest scores, were recorded by all students involved. These gains remained even when skills were tested without the calculator being available.

Other studies investigated the effects of using calculators with students at the elementary level. Though not directly related to ninth grade general mathematics, the investigator felt that these studies could have implications for calculator use in general mathematics. The students in general mathematics often have a wide range of ability.

The students who made up the sample of this study were at least two grade levels below ninth-grade achievement in mathematics, based on achievement test scores and teacher recommendation, implying that the mathematics achievement level of the subjects in this study were at the seventh grade level or below.

Beck (1960) reported on an unfinished study involving desk calculators in grades 4, 5, and 6. Personal observations were given which indicated that calculators were suitable for student use for their motivational value and for their assistance in the development of good work habits. No data was given.

Fehr, McMeen, and Sokol (1956) conducted a half-year experiment in which four fifth-grade classes were experimentally grouped. The control group was scattered into four communities in which the same text and/or syllabus was used, but no calculating machines were used. The experimental group used hand-operated computing machines. The students were pre- and posttested with the Stanford Intermediate Arithmetic Achievement Test, Forms J and K, respectively. A gain was shown by the experimental group both in computation and in reasoning. There was not a statistically significant difference, however, in the final achievement standing between the two groups at the end of the experiment. Based on this study, the investigators concluded the following: 1) There was more gain by students in reasoning ability. 2) There was more gain by students in computation ability. 3) Students learned more since they understood machine computation as well as ordinary arithmetic. 4) Interests in students and teachers were heightened.

In a thirty-week study by Shea (1974), "conventional instruction" was contrasted with calculator flow-charting instruction in fourth-grade mathematics. The latter instruction was based on the use of the Olivetti-Underwood Divisumma 24. The findings of the study indicate that the calculator group scored higher than the non-calculator group on computation but not on other achievement tests or attitude.

Two studies are reported involving seventh and eighth grade students. Durrance (1964) studied seventh and eighth graders using rotary calculators daily. The pairs of students were matched by grade level, I.Q., and standardized arithmetic test scores. The group showed major learning difficulties with basic operations using whole numbers, fractions, and decimals. No evidence was found in the study that the use of the calculators assisted in overcoming these difficulties. There was no significant improvement in arithmetic achievement that could be attributed to the use of calculators. There was a significant effect recorded on reasoning in grade seven.

Mastbaum (1969) compared electronic calculators and computational skills kits with 171 slow learners in grades seven and eight. It was reported in this study that the use of calculators did not significantly improve attitude, or increase ability in mathematics. Furtnermore, there was no improvement in non-calculator computational skill, mastery of concepts, or problem solving ability. Mastbaum stated that in calculator situations, students could solve the problems if they were only one step in length and presented in a straightforward manner.

Several studies have been conducted regarding the use of desk calculating devices with high school low achievers in mathematics. The implications of these studies could have a direct relationship to this study, since the age and ability of the subjects are similar to the sample of this study.

Ellis (1969) reported a study to determine the effects of using printing calculators in a mathematics laboratory for students in mathematics classes for low achievers. Criterion instruments were administered to an experimental class and a control class at the beginning and at the conclusion of the study. The use of printing calculators by the experimental group produced no statistically significant gains in mathematics achievement. A more favorable attitude toward mathematics and a weaker degree of academic motivation were recorded by both groups at the conclusion of the study. After a study of the objective findings, tne researchers generalized that the laboratory environment was the most critical factor in student achievement and attitude.

Cech (1972) tested the following three hypotheses in an experimental study with low-achieving ninth graders: 1) The use of calculators in the instructional program with ninth grade, low-achieving mathematics students improves their attitude toward the study of mathematics. 2) The use of calculators in the instructional program with ninth grade, low-achieving students improves their computational skills. 3) Ninth grade, low-achieving students can compute better with calculators than without calculators. The study involved four classes, two experimental and two control, in a high school in Illinois. During the seven-week study, students were to check their work with calculators. The control group merely checked their work. All the groups were given a pre- and posttest, which measured attitude toward mathematics and computational skills with whole numbers. The analysis, which was a t-test on mean differences, supported the third hypothesis only.

Ladd (1973) sought to determine if the use of electronic calculators could improve interest and achievement in mathematics. The study involved ten ninth-grade classes of low achievers in mathematics for a total of 201 students. A pretest was given, followed by an instructional sequence in which the experimental group used calculators and the control group did not. This sequence was followed by a posttest. It was determined that both experimental and control groups showed significant improvement in terms of attitude and achievement. No significant differences were recorded, however, between the groups in either interest or achievement in mathematics.

Gaslin (1975) conducted a ten-week study in the fall of 1971 with three ninth grade general mathematics classes at each of two schools in Minnesota. Three treatments were used. The first two treatments, one with calculators and the other without calculators, involved a "Conventional Algorithm Set" (CAS), In these treatments operations on positive rational numbers were performed according to the "usual" textbook approach. The third treatment was the "Alternative Algorithm Set" (AAS). In this treatment each fractional operand was converted to a decimal on the calculator. The indicated operation then was performed on the decimal numbers using the calculator. No significant differences in achievement, transfer, retention, attitude, or rate were recorded. It was concluded that the calculator algorithm (AAS) is a viable alternative to the conventional algorithm, with or without the use of calculators.

In summary, the following list indicates findings from the research with desk calculators, which may have implications for using calculators with ninth-grade low achievers:

1) Students who are mentally retarded or who have learning disabilities may profit from the use of calculators.

2) There appears to be academic and motivational advantage for using calculators with elementary children.

3) The use of calculators might have positive effects on students' reasoning ability.

4) Low achievers in high school mathematics may profit from using calculators, but there is no conclusive evidence that they will achieve more with a calculator than without one.

5) The use of calculators in learning may improve attitudes toward mathematics in some students.

Research with Hand-Held Calculators

The research reported involving hand-held calculators involves many levels of learning, as did the research with desk calculators. The following discussion groups the studies by level of learning.

Since 1973, Weaver (1976) has been studying the use of various calculators at several grade levels. These studies relate to previous research on mathematical sentences and properties of operations which he and his students have carried out. Weaver states that the purpose of this project has been an informal exploration as a necessary step to precede controlled experimentation. The emphases of this work include chaining, doing and undoing, and related number sentences. The findings indicate that students encounter no consequential problem using calculators.

Some research has been conducted which investigated the effect of using calculators for specific purposes at different grade levels. Zepp (1976) conducted a study to investigate the interaction of a computational aid (the pocket calculator) with specific reasoning ability (proportional thinking) at different age levels. It was hypothesized that a computational aid, such as an electronic calculator, would increase success in a computational problem involving proportions. One hundred seventy ninth-grade students and 198 college freshmen were given a pretest, a treatment, and a posttest. Half of the students were given pocket calculators. It was found that students using calculators did not perform better than students using only pencil and paper. Also, there was no significant interaction of calculators with reasoning ability. The hypothesis that students could understand a train of thought better if the hurdle of computation were cleared was not supported.

Four of the studies which follow involve elementary students. Research in elementary grades may have some implications for calculator use in general mathematics, due to the achievement level of many of the students in general mathematics.

Schafer, Bell, and Crown (1975) reported on an "inquiry" involving the use of calculators with fifth graders. The calculator group was given a pretest, followed by work with calculators for two days. The students were encouraged to ask questions about the calculator. A posttest was given one week later. No overall significant differences were found between the calculator group and the non-calculator group. Students who had calculators did score significantly higher on examples in which the calculator could be used. On the non-calculator examples, the calculator group scored lower than the non-calculator group, but the differences were not significant.

Spencer (1975) conducted a study in which forty fifth graders and forty-fou sixth graders were assigned at random to an experimental or control group. The Arithmetic sections of the Iowa Test of Basic Skills was given to all pupils, Form 1 as the pretest and Form 2 as the posttest. Each treatment period was 35 to 40 minutes, four days a week, for eight weeks. Both groups worked with computation worksheets prepared by the experimenter. The experimental group used calculators, while the control group did not use calculators. In grade 5 there was a significant difference in favor of the experimental group on the gain scores of the reasoning test. There were no other significant differences in this grade. In grade 6 there was a significant difference between the treatment groups in favor of the experimental group on both computation and the total arithmetic test that included computation and application. The difference between treatments approached significance on reasoning ability.

Hawthorne and Sullivan (1975) conducted a one-year study with 96 students in grade 6, in which hand-held calculators were used for working and checking. The investigators did not intend to change the mathematics program to fit the calculator. The objective was to discover whether or not hand-held calculators could be used to "enrich, supplement, support, and motivate the regular curriculum." (p. 29) Ways in which the students used the calculator were expanded on by Barrett and Keefe (1974). The experimental group was compared with a control group, and the mean scores of students using calculators were significantly higher on the concepts and computation sections of the test than were the corresponding scores for students not using calculators. The scores of the two groups were about the same on the problem-solving section of the test.

A diagnostic curriculum which utilizes the hand-held calculator for remediation in mathematics, grades 4-7, was developed by Bitter and Nelson (1975). Four groups were compared in the study. One group used the above-mentioned curriculum. The second group used a commercial hand-held calculator mathematics remediation program. A third group used a standard curriculum with calculators available. The fourth group used a standard curriculum with no calculators available. The investigators indicated that the three calculator approaches achieved significant gains in both achievement and attitude. However, the investigators reported no data in the article.

Two studies follow involving subjects in grades 7 and 8. The nature of these studies has a more direct relationship to this study, though the curriculum content of the first study differs from the content of this study.

A study was conducted by Jamski (1976) in which the general aim was to determine what effect the use of hand calculators had in the middle school when used as an instructional aid in the learning of "the six simplified rational number-decimal-percent conversion algorithms" (p. 35). The study involved 162 seventh graders, who were members of six classes in University Middle School, Bloomington, Indiana. Three classes were randomly assigned to be experimental classes, using hand calculators during instruction, and three classes were assigned to be control classes, using paper and pencil. No significant differences were found in achievement in any of the areas tested in the study.

Kelley and Lansing (1975) reported analysis of data from project EQUIP, which was a mini-calculator program for teaching mathematics, sponsored by Berkeley schools. The project involved two low-achiever classes in mathematics from grades 7 and 8. Results of the California Test of Basic Skills showed no statistically significant gains in both the experimental and control group. The mean on the October pretest for the experimental group was 4.87, while that group's mean on the May posttest was 4.98. The respective scores for the control group were 5.29 and 5.30. The calculator group did significantly better on the CTBS computation subtest, with scores of 4.9 for the control group and 6.5 for the experimental group. On the NLSMA Reasoning Test, the gain of the control group was significant at the .08 level, while the gain of the calculator group was significant at the .01 level.

Summary

The research findings indicate that children can learn to use hand-held calculators at the elementary level and may improve their skills by using the calculator in arithmetic. There may be an achievement advantage in using calculators at this level in the area of reasoning ability. Also, elementary children may profit in mathematics remediation by having access to a diagnostic calculator curriculum. Sixth graders may profit in concepts and computation achievement by having a calculator to supplement and enrich their regular mathematics program. Improvements in reasoning ability could be expected to be made by low achievers in grades 7 and 8 who are taught mathematics using a mini-calculator program. The investigator feels that these findings may have implications for achievement in computation and in problem solving for students in ninth grade general mathematics.

Little has been established regarding the use of calculators with low-achievers in ninth-grade mathematics. There have been four studies made in this area using desk calculators which could have potentially transferable findings. One study (Ellis, 1969) used calculators in a laboratory setting. A second study (Cech, 1972) used calculators in checking answers to their paper-and-pencil work. A third study, (Ladd, 1973) provided an instructional sequence in which the experimental group used calculators and the control group did not. The fourth study (Gaslin, 1975) provided an instructional sequence on positive rational numbers using a calculator.

No conclusive evidence was found from these studies. There were some indications, however, that low achievers may profit from using calculators. The lack of conclusive evidence in this area indicates a need for further research.

Two of the studies mentioned above provided an instructional sequence in which using the calculator was a part of the learning process. Various summaries of needed research indicate that additional study is required in this area. For example the NACOME Report (1975) asked, "What special types of curricular materials are needed to exploit the classroom impact of calculators?" (p. 43) Weaver (1976) posed the question, "What are the effects of implementing certain other calculator-inspired curricular changes?" (p. 39) Suydam (1976) listed "effect of calculator use with specific content and curricula" (p. 38) as a part of her summary of needed research on the hand-held calculator.

CHAPTER III

DESIGN OF THE STUDY

Statement of the Problem

This study was designed to investigate the effects on achievement and attitude resulting from the use of a calculator-based curriculum anc a classroom set of hand-held calculators in ninth grade general mathematics. The questions for which the study was designed to answer were stated in Chapter I. The questions are repeated here for the convenience of the reader.

1. Will the use of a calculator-based curriculum with a classroom set of hand-held calculators have an effect on students' achievement in computation?
2. Will the use of a calculator-oased curriculum with a classroom set of hand-held calculators have an effect on students' achievement in problem solving?
3. Will the use of a calculator-based curriculum with a classroom set of hand-held calculators have an effect on students' attitudes toward mathematics?

Hypotheses

The following hypotheses were tested in order to answer the preceding questions:

1. There is no significant difference in posttest means in computation between groups using the calculator in instruction and groups not using the calculator in instruction.
2. There is no significant difference in posttest means in computation between groups taking the posttest with a calculator and groups taking the posttest without a calculator.
3. There is no significant interaction between treatment and calculator use on the posttest when computation is used as the criterion variable.
4. There is no significant difference in posttest means in problem solving between groups using the calculator in instruction and groups not using the calculator in instruction.
5. There is no significant difference in posttest means in problem solving between groups taking the posttest with a calculator and groups taking the posttest without a calculator.
6. There is no significant interaction between treatment and calculator use on the posttest when a measure of problem-solving achievement is used as the criterion variable.
7. There is no significant difference between treatment posttest means on the attitude measure "Math vs. Non-Math."

8. There is no significant difference between treatment posttest means on the attitude measure "Math Fun vs. Dull."

9. There is no significant difference between treatment posttest means on the attitude measure "Pro-Math Composite."

10. There is no significant difference between posttest means on the attitude measure "Math Easy vs. Hard."

Definitions

The following definitions were used in this study:

Achievement in computation was defined operationally as a student's score on the computation portion of the Stanford Achievement Test, Intermediate Level I.

Achievement in problem solving was defined operationally as a student's score on the applications portion of the Stanford Achievement Test, Intermediate Level II.

Attitudes toward mathematics were defined operationally as a student's scores on the PY407, PY408, PY409, and PY410 Scales of the Form 9151 Attitude Test, developed by the School Mathematics Study Group (Begle, 1968).

Calculator-based curriculum was defined as an instructional sequence designed for use in ninth grade general mathematics classrooms, using a classroom set of hand-held calculators in instruction.

Classroom set of hand-held calculators was defined as a set of hand-held calculators that provides one calculator for every student in the class.

Hand-held calculator was defined as a pocket-size electronic device, with an eight digit display, that can perform the four arithmetic operations on whole and decimal numbers.

Variables of the Study

The independent variables were the calculator or non-calculator designation of the treatment groups and the use or non-use of calculators on the posttest.

Concomitant variables were pretest means on computation achievement, on problem-solving achievement, and on attitudes toward mathematics.

The dependent variables were posttest means on computation achievement, on problem-solving achievement, and on attitudes toward mathematics.

Instructional Materials

"Basic Mathematics" is designed to be a one-quarter course for students who are two or more grade levels below in mathematics achievement. This course is designed to review basic computation and problem solving skills in mathematics. Most students low in mathematics ability take this course during the fall quarter of their ninth grade year.

The district in which this study was conducted uses the following multiple adoption of textbooks for this course: Trouble-Shooting Mathematics Skills, Holt, Rinehart and Winston, Inc., 1974; Applications in Mathematics: Course A, Scott, Foresman and Co., 1974; Elements of Mathematics, Silver Burdett, 1974; Essentials of Mathematics 3, Ginn, 1969.

The content of this course, as outlined in the district's "Quarter Course Outline for Basic Mathematics," includes the following: whole numbers, fractions, decimal fractions, and percents. The subject matter of this study dealt only with whole numbers.

The following is the whole number section of the course outline for "Basic Mathematics":

A. Understanding whole numbers

   1. Reading and writing whole numbers
   2. Writing the value of each digit in a given number
   3. Writing a word statement as a number
   4. Writing a word statement for a number in a given fact
   5. Rounding off whole numbers to the nearest ten, hundred, thousand, etc.

B. Adding whole numbers

1. Adding at least five whole numbers of at least three [illegible]s each
2. Setting up whole numbers that are to be added, lining up the digits correctly
3. [illegible], when the number of digits in the addends vary
4. Adding horizontally

C. Subtracting whole numbers

1. Subtracting without borrowing
2. Subtracting with borrowing
3. Subtracting with borrowing from a minuend with zeros

D. Multiplying whole numbers

1. Multiplying with a single digit in the multiplier
2. Multiplying with two or more digits in the multiplier
3. Multiplying with zeros in the multiplicand
4. Multiplying with zeros in the multiplier

E. Dividing wh[illegible]e numbers

1. Dividing without a remainder
2. Dividing with a remainder
3. Dividing with zeros in the quotient
4. Finding averages

The subject matter of this experiment involved sections A-5, B, C, D, and E, of the above outline.

The materials used during the experiment were arranged into individual lesson form, with each student receiving daily worksheets on which to record his or her work. The materials used in the calculator treatment consisted of one introductory lesson on using hand-held calculators and nine lessons on estimation, computation and problem solving with whole numbers. The exercises and problems used in the student lessons were taken, with permission from the publisher, from the book Problem Solving with the Calculator by Jacobs, Jacobs Publishing Company, 1977. The titles of the lessons were as follows:

Introduction:	"Introducing the Calculator"
Lesson 1C	"Rounding Whole Numbers:
Lesson 2C	"Addition"
Lesson 3C	"Subtraction"
Lesson 4C	"Addition and Subtraction"
Lesson 5C	"Multiplication"
Lesson 6C	"Division-- Zero Remainder"
Lesson 7C	"Multiplication and Division"
Lesson 8C	"Combined Operations"
Lesson 9C	"Division-- Nonzero Remainder"

Lessons 2C through 9C were composed of two major sections, a section on computation and a section on problem solving. Furthermore, many of the lessons contained a section called "Calculator Capers," which consisted of games and activities for using a calculator. Lessons 2C through 9C were designed to be two-day lessons. The first day was to be used for estimation activities. The students were required to compute an approximate answer for each of the exercises and problems in the lesson by rounding and performing the computation with rounded numbers. Calculators were not available for these activities. On the second day the students were required to work a selected number of the exercises by paper-and-pencil computation. The remainder of the exercises were to be done using a hand-held calculator. All of the student activities were preceded by teacher instruction. A copy of the lessons for the calculator treatment is presented in Appendix B.

A teacher's guide was prepared for the participating teachers. This guide states the goals and objectives of each lesson, as well as instructions for how students are to use the lessons. Furthermore, the guide provides an instructional sequence for each lesson, including examples for use in instruction. A copy of the "Teacher's Guide for the Calculator

Treatment" is presented in Appendix A.

The materials used in the non-calculator treatment were very similar in appearance to the materials used in the calculator treatment. These materials consisted of nine lessons. The titles of Lessons 1 through 9 were the same as those of Lessons 1C through 9C listed earlier. As in the calculator treatment materials, Lessons 2 through 9 were composed of two sections, a section on computation and a section on problem solving. Of course, there were no sections on calculator activities. Lessons 2 through 9 were designed to be two-day lessons, as were the calculator treatment lessons, with the first day's activities being estimation. The second day's activities were different for this group in that all the exercises and problems were computed using paper and pencil only. The problems and exercises in the lessons of both the calculator and non-calculator treatments were identical. A copy of the lessons for the non-calculator treatment is presented in Appendix D.

As in the calculator treatment, a teacher's guide was prepared for the participating teachers to use in the non-calculator treatment. This guide was similar to the calculator treatment teacher's guide in that it outlined the goals and objectives of each lesson and gave instructions to the teachers for using the lessons. A copy of the "Teacher

Guide for the Non-Calculator Treatment" is presented in Appendix C. A comparison of the guides in Appendices A and C, along with the appropriate lessons in Appendices B and D will indicate to the reader the similarities and differences of the two treatments.

The Achievement Test

The content for this study included the four operations of arithmetic using whole numbers only. Both computation and problem solving were stressed. The researcher reviewed many standardized tests which would be appropriate for the content of the study and for the level of the students involved in the study. The test selected was the Mathematics Computation and Applications portions of the Stanford Achievement Test, Intermediate Level II. Form A was used for the pretest and Form B was used for the posttest.

Though this test was judged by the researcher to be most appropriate for the needs of the study, some of the items measured objectives that were not a part of the curriculum of the study. Students were instructed to omit such items during the testing, and those items were not considered in the evaluation results. Most of the items omitted involved fractions or decimals. After these items were omitted, there remained 36 items on the computation portion of the test and 32 items on the problem solving portion of the test.

Each item on both tests was multiple choice and was graded as either correct or incorrect, with no partial credit given. Although the reliability was reported as .89, not all items were used, as noted earlier. Thus, the reliability for each modified test was determined using a parallel forms method of computing reliability coefficients. A Pearson product-moment correlation coefficient was computed between pretest and posttest scores, as suggested by Downie and Heath (1970), p. 243. The reliability coefficient for the computation test was .60. The reliability coefficient for the problem-solving test was .70.

The Attitude Test

Both experimental and control groups were given a pre- and posttest on attitudes toward mathematics, using the Form 9151 Attitude Test developed by the School Mathematics Study Group (Begle, 1968). Permission was secured from the author for the use of this instrument. The following scales were used from the attitude instrument referred to above: PY407, PY408, PY409, and PY410.

The PY407 scale, which consists of eight items, is entitled "Math vs. Non-Math." This scale is designed to measure how well a student likes mathematics and considers it important in relation to other school subjects.

The PY408 scale, which consists of four items, is entitled "Math Fun vs. Dull." This scale is designed to measure the pleasure of boredom a student experiences with regard to mathematics both in the absolute sense and comparatively with other subjects.

The PY409 scale is called "Pro-Math Composite." This scale consists of eleven items and is designed to measure general attitude toward mathematics.

The PY410 scale, entitled "Math Easy vs. Hard" consists of nine items. This scale is designed to measure the ease or difficulty which a student associates with mathematics performance.

All the items on the attitude instrument are multiple choice. The score was determined by numerically ranking the item selections from most negative to most positive, with the most positive answer being the high score. The scores of the items were totaled to determine each student's score on each scale.

The Pilot Study

In the summer of 1977, two classes of the course "Basic Mathematics" were taught in the Austin Independent School District, in which the teachers agreed to use the materials designed for this study. All students in the two classes took the pretests on computation, problem solving, and attitudes. One class used the materials for the non-calculator treatment, and the other class used the materials for the calculator treatment, using a classroom set of hand-held calculators. Posttests were given on computation, problem solving, and attitudes. The tests were scored and compared, but no statistical analysis of the test scores was made.

As a result of this study, many changes and modifications were made with the instructional material. The original set of material included lessons on decimal fractions. These lessons were omitted because of time constraints on the duration of the study. Also, the original material contained much instruction to the students within the individual student lessons. It was found in the pilot study that this information was ignored by most of the students. Hence, this material was omitted from the student lessons, and teacher guides were prepared to enable the teachers to provide the required instruction for the students. Finally, the teachers involved in the pilot study felt that the material was too cluttered and that the problems were too close together. Hence, much of the wordiness was removed from the materials and more space was provided between exercises.

Sample

The sample for this study was selected within an urban district in Texas. This district has nine high schools, each containing grades 9 through 12. During the Fall Quarter of 1977, 60 classes of the Fundamentals of Mathematics course "Basic Mathematics" were being taught, with a total enrollment in these courses of approximately 1,412 students.

Seven of the high schools had two or more teachers who were teaching at least two of the "Basic Mathematics" classes. Three of these schools had two teachers who were willing to participate in the study. These schools were selected for the study. Two of these high schools consisted primarily of students from middle-class families. One school consisted of students from lower socioeconomic families. This school had a higher minority population than that of the other two schools. For each of the schools selected, the two teachers who were agreeable to participate in the study had five or more years of teaching experience in secondary mathematics and were teaching two classes of "Basic Mathematics." For each teacher, one class was selected, by a coin flip, to receive the calculator treatment, and the other class was given the non-calculator treatment.

Part of the criterion for being placed in a Fundamentals of Mathematics classroom is that the student be at least two grade levels behind in mathematics achievement. This designation generally is determined by standardized test scores and teacher recommendation. A typical class of Fundamentals of Mathematics is composed of students whose ability levels in mathematics range from third grade to eighth grade.

The experiment began on September 8, 1977. The initial enrollment for the six classes of the calculator group was 126, while the initial enrollment for the six classes in the non-calculator group was 119. Often the enrollment and attendance in Fundamentals of Mathematics classes is not stable. The classes in this experiment were no exception. Table 3.1 indicates the number of students in the two groups taking the pre- and posttests. In all classes of both treatment groups, there were students who were dropped out and students who were added at different times during the study. In the analysis for this study, data were used only for the students who took the pretests, were enrolled during the treatment phase, and who took the posttests.

Table 3.1

Sample Size at Pretests and Posttests

	Calculator Treatment	Non-Calculator Treatment
Number of Students Taking Pretests	126	119
Number of Students Taking Posttests	120	110
Number of Students Taking Both Pre- and Posttests	83	84

Administrative Procedures

In the week prior to the study, the investigator met with the two participating teachers in each of the three high schools. During these meetings the teachers were provided with the instructional materials, including the pretests in computation, problem solving, and attitude; the teacher guides for both the calculator and the non-calculator treatments; and the student lessons for both treatments. Also, the two teachers at each school were issued one classroom set of hand-held calculators to be shared by the teachers throughout the study. Administrative procedures were discussed at these meetings, and teachers were asked to follow the teacher guides as closely as possible, in order to reduce teacher effect throughout the study.

On Thursday, September 8, 1977, the participating teachers administered the attitude pretest and the computation pretest. The problem solving pretest was administered on the following day.

On the following Monday all teachers began the treatments, which lasted approximately four weeks. During this time the investigator visited each teacher at least once a week to discuss the study's progress and to try to remedy any problems which might have occurred with materials or calculators. The investigator was able to visit many classrooms during the study to observe and often talk with the students participating in the experiment.

At the conclusion of the study, posttests were administered to all students. Students in both treatment groups were divided randomly so that there were two groups of approximately the same number in each of the twelve classes. In each class one group was given the achievement posttest with a hand-held calculator available, and the other group took the posttest without a hand-held calculator. The students took the attitude posttest and the computation posttest on the first day of testing, and the problem-solving posttest was administered on the second day of testing.

Experimental Design

This study had a design similar to the type classified by Campbell and Stanley (1963) as a Nonequivalent Control Group Design. This design involves an experimental group and a control group which are both given a pretest and a posttest, but the two groups do not have pre-experimental sampling equivalence. In the Nonequivalent Control Group Design, one group is given a treatment and the other group is not. The design of this study, however, differs slightly in that both groups were given treatments, namely a unit of instruction on estimation, computation, and problem solving with whole numbers. One treatment was designed for use with hand-held calculators and the other treatment was not.

There were two types of treatment variable, calculator and non-calculator. The use or non-use of a calculator on the posttest also was a variable, and the teacher was a third variable. An illustration of the structure of this study is given in Figure 3.1.

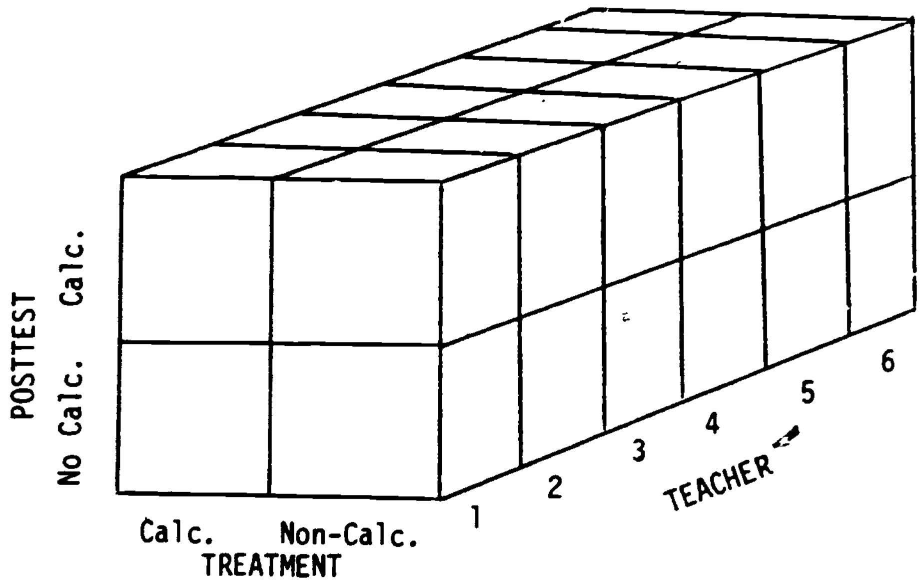


Figure 3.1

Variable Cell Structure

The Nonequivalent Control Group Design is considered by Campbell and Stanley to be a design well worth using in instances in which randomization of students to treatment is not possible. They state (p. 48) that assuming the experimental and control group are similar in their recruitment, the design can be regarded as controlling the main effects of history, maturation, testing, and instrumentation.

Statistical Analysis

The data relevant to Hypotheses 1 through 10 were tested using analysis of covariance. Each pretest was used as a covariate for its respective posttest, since it was conjectured that there may have been initial differences in abilities of the groups.

Each achievement hypothesis was tested using a three-way analysis of covariance, with the following three independent variables: treatment, whether or not a calculator was used on the posttest, and teacher.

Each attitude hypothesis was tested using a two-way analysis of covariance, with treatment and teacher as the independent variables.

The ANOVA program of the Statistical Package for the Social Sciences (SPSS) collection was used in the analysis calculation. The 5% level of significance was used for all the stated hypotheses.

Summary

Twelve classes of the Fundamentals of Math course "Basic Mathematics" in a Texas urban district were assigned to one of two treatment groups during the Fall Quarter of 1977.

Six teachers participated in the study, each having one class in the calculator treatment and one class in the non-calculator treatment. Three high schools were involved, each having two participating teachers. Students in both groups were given pretests in mathematics achievement and attitude. Both treatment groups were given units of instruction on estimation, computation, and problem solving using the four arithmetic operations on whole numbers. The calculator group used a classroom set of hand-held calculators in instruction. The non-calculator group used paper and pencil only. Posttests in mathematics achievement and attitude were given to both groups. Half of each group took the achievement posttest with a hand-held calculator as an aid. The other half of each group took the achievement posttest using paper and pencil only. The resulting data were analyzed using analysis of covariance. Results of the analysis are reported in Chapter IV.

CHAPTER IV

RESULTS OF ANALYSIS OF DATA

This chapter contains the statistical analysis of the data collected in this study and the tests of Hypotheses 1 through 10, as stated in Chapter III. Interpretations of the results also are presented in this chapter. The data used in the analyses were scores on pretests and posttests in computation, problem solving, and four scales of attitudes toward mathematics.

Analysis of Data

The ten hypotheses stated in Chapter III were tested using analysis of covariance. The posttest means for computation and problem solving were compared by treatment, use of calculator on the posttest, and teacher, using the respective pretests as covariates. The four attitude scales were compared by treatment and teacher.

The analyses of data are reported in the two sections which follow. The first section gives the data analyses for the hypotheses on mathematics achievement, and the second gives the data analyses for the hypotheses on mathematics attitudes.

Tests of Achievement Hypotheses

Hypothesis 1

1. There is no significant difference in posttest means in computation between groups using the calculator in instruction and groups not using the calculator in instruction.

Hypothesis 1 was tested using the analysis of covariance found in Table 4 1.

Table 4.1

Analysis of Covariance Summary Table for Computation
(Covariate: Pretest on Computation)

Source	df	MS	F	p
Treatment	1	3.0	.1	.77
Calculator on Posttest	1	352.0	10.6	.01*
Teacher	5	53.1	1.6	.17
Tr X C	1	60.2	1.8	.18
Tr X Te	5	34.1	1.0	.41
C X Te	5	17.9	.5	.75
Tr X C X Te	5	31.5	.9	.45
Error	142	33.3		

*significant at the .05 level

The F-ratio computed to test this hypothesis was not significant at the .05 level. Hypothesis 1, therefore, was not rejected. Means and standard deviations for the computation pretest and posttest are given for these groups in Tables 4.2 and 4.3, respectively.

Table 4.2

Computation Pretest Means by Treatment

treatment	mean	sd	n
Calculator	20.6	7.2	83
Non-Calculator	16.9	7.1	84

Maximum possible score = 36   Overall mean = 18.8

Table 4.3

Computation Posttest Means by Treatment

treatment	mean	sd	n	adjusted mean
Calculator	25.1	7.2	83	24.2
Non-Calculator	23.0	7.4	84	23.9

Maximum possible score = 36   Overall mean = 24.1

These results indicate that when posttest means are adjusted for pretest differences, the adjusted means do not differ significantly. It should be noted, however, that while the calculator group gained 4.5 points in raw score, the non-calculator group gained 6.1 points in raw score. Since adjusted posttest means made by both treatment groups were about the same, it can be concluded that students having instruction using hand-held calculators with this curriculum were not significantly hindered in computation.

Hypothesis 2

2. There is no significant difference in posttest means in computation between groups taking the posttest with a calculator and groups taking the posttest without a calculator.

Hypothesis 2 was tested using the analysis of covariance found in Table 4.1. The F-ratio computed to test this hypothesis was significant at the .05 level. Thus, Hypothesis 2 was rejected. Means and standard deviations for the computation pretest and posttest are given for these groups in Tables 4.4 and 4.5, respectively.

Table 4.4

Computation Pretest Means by Calculator Use on the Posttest

posttest	mean	sd	n
Calculator	19.4	7.5	83
No Calculator	18.1	7.3	84

Maximum possible score = 36   Overall mean = 18.8

Table 4.5

Computation Posttest Means by Calculator Use on the Posttest

posttest	mean	sd	n	adjusted mean
Calculator	25.9	7.2	83	25.5
No Calculator	22.2	7.1	84	22.6

Maximum possible score = 36   Overall mean = 24.1

Rejection of Hypothesis 2 can be interpreted to indicate that students in this population would be expected to score higher on computation tests if they were allowed to use a hand-held calculator on the test. The use of a calculator on the test appears to reduce computation errors with the students of this population. It also was noted by test observation that students were more likely to work all the problems on the test if they had a hand-held calculator available for use if needed.

Hypothesis 3

3. There is no significant interaction between treatment and calculator use on the posttest when computation is used as the criterion variable.

Hypothesis 3 was tested using the analysis of covariance found in Table 4.1. The F-ratio computed to test this hypothesis was not significant at the .05 level. Thus, Hypothesis 3 was not rejected. Means and standard deviations for each treatment according to whether the posttest was taken with a calculator or without a calculator are given for the pretest and posttest, respectively, in Tables 4.6 and 4.7.

Table 4.6

Computation Pretest Means: Treatment X Calculator Use on Posttest

posttest use of	Calculator Treatment mean	sd	n	Non-Calculator Treatment mean	sd	n
Calculator	20.3	7.6	41	18.5	7.4	42
No Calculator	20.9	6.9	42	15.3	6.5	42

Maximum possible score = 36 Overall mean = 18.8

Table 4.7

Computation Posttest Means: Treatment X Calculator Use on Posttest

posttest use of	Calculator Treatment mean	sd	n	adj. mean	Non-Calculator Treatment mean	sd	n	adj. mean
Calculator	25.9	7.5	41	24.7	26.0	7.1	42	26.1
No Calculator	24.4	7.0	42	22.7	20.0	6.6	42	22.9

Maximum possible score = 36 Overall mean = 24.1

It appears that students in this population do better on computation tests if they are allowed to use a calculator on the test, regardless of whether or not calculators were used in instruction.

A comparison of the treatment adjusted posttest means for the group that used a calculator on the posttest indicates that the adjusted mean for the students in the non-calculator treatment was 1.4 points higher than the adjusted mean for the students in the calculator treatment. These data indicate that in computation, using a calculator on the posttest may be of more benefit to students not using calculators in instruction than to students who do use calculators in instruction. No statistical analysis of this hypothesis was made, however, in this study.

A comparison of the adjusted treatment posttest means for the group that did not use a calculator on the posttest indicates that there was practically no difference between these means. Not using a calculator on the posttest did not appear to be of more benefit to one treatment group over the other.

Hypothesis 4

4. There is no significant difference in posttest means in problem solving between groups using the calculator in instruction and groups not using the calculator in instruction.

Analysis for Hypothesis 4 is found in Table 4.8.

Table 4.8

Analysis of Covariance Summary Table for Problem Solving
(Covariate: Pretest on Problem Solving)

Source	df	MS	F	p
Treatment	1	181.3	6.1	.015*
Calculator on Posttest	1	169.9	5.7	.018*
Teacher	5	110.1	3.7	.004*
Tr X C	1	420.7	14.1	.001*
Tr X Te	5	25.2	.8	.52
C X Te	5	34.4	1.2	.34
Tr X C X Te	5	35.8	1.2	.31
Error	142	29.9		

*significant at the .05 level

The F-ratio computed to test this hypothesis was significant at the .05 level. Hypothesis 4, therefore, was rejected. The means and standard deviations for the problem-solving pretest and posttest are given for the treatment groups in Tables 4.9 and 4.10, respectively.

Table 4.9

Problem Solving Pretest Means by Treatment

treatment	mean	sd	n
Calculator	14.7	7.8	83
Non-Calculator	12.6	8.3	84

Maximum possible score = 32 Overall mean = 13.7

Table 4.10

Problem Solving Posttest Means by Treatment

treatment	mean	sd	n	adjusted mean
Calculator	17.3	7.9	83	16.7
Non-Calculator	13.9	8.7	84	14.6

Maximum possible score = 32 Overall mean = 15.6

Rejection of Hypothesis 4 and a comparison of adjusted posttest means by treatment indicates that this population would be expected to do significantly better in problem solving when given a calculator-based curriculum.

The use of hand-held calculators in instruction allowed students to focus more on problem-solving situations. Students in the calculator group seemed to take their attention off the computation aspect of the problem and to focus more on the problem itself. Students in the non-calculator group, however, seemed to spend the bulk of their time laboring with computation.

Hypothesis 5

5. There is no significant difference in posttest means in problem solving between groups taking the posttest with a calculator and groups taking the posttest without a calculator.

Hypothesis 5 was tested using the analysis of covariance found in Table 4.8. The F-ratio computed to test this hypothesis was significant at the .05 level. Thus, Hypothesis 5 was rejected. Means and standard deviations for the pretests and posttests of these groups are given in Tables 4.11 and 4.12, respectively.

Table 4.11

Problem Solving Pretest Means by Calculator Use on the Posttest

posttest	mean	sd	n
Calculator	14.3	8.7	83
No Calculator	13.0	7.5	84

Maximum possible score = 32 Overall mean = 13.7

Table 4.12

Problem Solving Posttest Means by Calculator Use on the Posttest

pcsttest	mean	sd	n	adjusted mean
Calculator	17.1	7.6	83	16.6
No Calculator	14.1	9.0	84	14.6

Maximum possible score = 32 Overall mean = 15.6

Rejection of Hypothesis 5 and a comparison of posttest means by whether or not the posttest was taken with a calculator indicates that this population would be expected to do significantly better on a test in problem solving when allowed to use a calculator on the posttest, regardless of the type of instructional treatment received.

The investigator feels that students who were allowed to use a hand-held calculator on the posttest in many cases exhibited greater confidence in their attitude toward the test. This seemed particularly true for students who had not been given the calculator treatment. This opinion is based on the investigator's observation of students during test-taking. This greater confidence could be a reason for higher scores for the group taking the test with a hand-held calculator.

A second reason for increased achievement in problem solving, for students who took the posttest using a hand-held calculator, could be that students made fewer computation mistakes using the calculator than students who did not have a calculator. This reason may be valid, since students who took the posttest using a hand-held calculator did significantly better in computation achievement that students who took the test without a calculator (Table 4.1).

Hypothesis 6

6. There is no significant interaction between treatment and calculator use on the posttest when a measure of problem-solving achievement is the criterion variable.

Hypothesis 6 was tested using the analysis of covariance found in Table 4.8. The F-ratio computed to test this hypothesis was significant at the .05 level. Problem solving pretest and osttest means for this group are given in Tables 4.13 and 4.14 respectively.

Table 4.13

Problem Solving Pretest Means: Treatment X Calculator Use on the Posttest

posttest use of	Calculator Treatment			Non-Calculator Treatment		
	mean	sd	n	mean	sd	n
Calculator	14.7	8.5	41	14.0	8.9	42
No Calculator	14.7	7.0	42	11.2	7.6	42

Maximum possible score = 32 Overall mean = 13.7

Table 4.14

Problem Solving Posttest Means: Treatment X Calculator Use on the Posttest

posttest use of	Calculator Treatment mean	sd	n	adj. mean	Non-Calculator Treatment mean	sd	n	adj. mean
Calculator	16.8	7.8	41	15.9	17.5	7.5	42	17.2
No Calculator	17.9	7.9	42	16.9	10.3	8.4	42	12.4

Maximum possible score = 32 Overall mean = 15.6

The treatment X calculator use on the posttest interaction is described by the graphs in Figure 4.1.

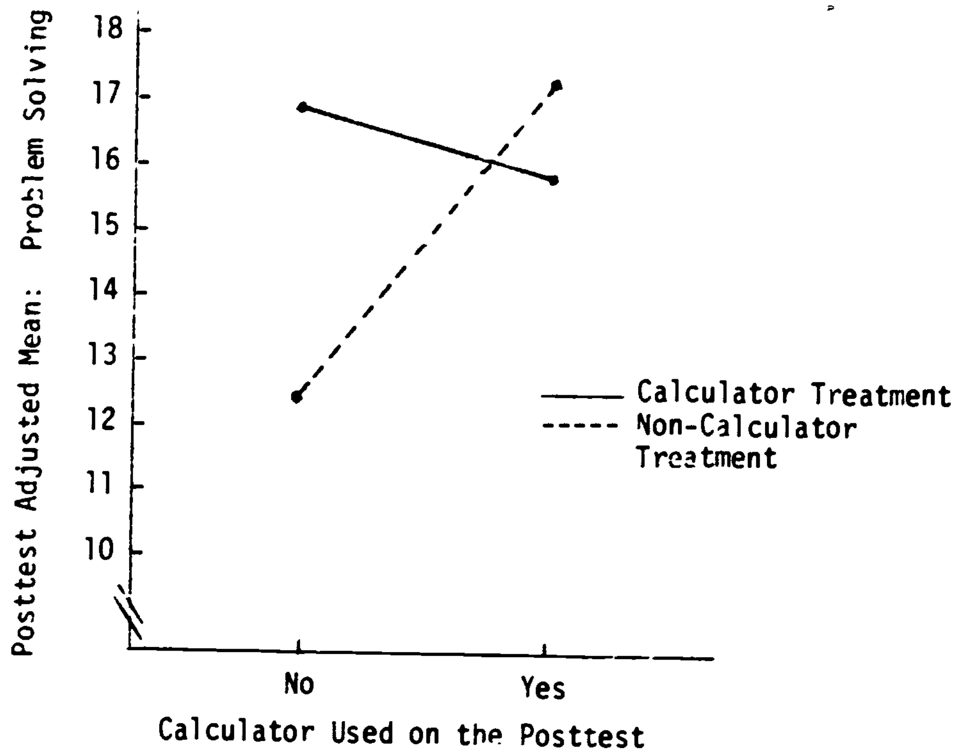


Figure 4.1

Treatment X Calculator Use on the Posttest Interaction

The graphs in Figure 4.1 illustrate that there was little difference in the treatment posttest adjusted means for the group that took the posttest using a calculator. There is a lower adjusted mean in the calculator treatment for this group. Since these means were adjusted statistically, according to pretest scores, statistical analyses of the differences were not deemed appropriate.

A comparison of the treatment posttest adjusted means for the group that took the posttest without a calculator shows a larger difference in means. This difference would appear to be highly significant, though this analysis was not done in this study.

The raw scores of the group in the non-calculator treatment who took the posttest without a calculator indicate that 12 of the 42 students in this group scored 0 on the posttest in problem solving. These zeros lowered the overall mean to 10.3. If these students' scores were removed from the data, the mean of this group would be 14.5. It is not clear why so many students failed to work any exercises on the problem-solving test. Most of the students who scored 0 made no attempt to answer any of the exercises.

The investigator observed students taking the posttests. It appeared in many cases that students made little effort in problem solving if they did not have a calculator on the posttest This seemed especially true of students who had not had the calculator treatment. These students seemed to believe that having the calculator on the test was very important. It may be that students who had used a calculator in learning had gained a confidence in their problem solving ability that remained, even when they had no calculator on the test. The students who had used hand-held calculators in learning did not seem to believe that their use of a calculator on the posttest was of such great importance.

The Teacher Variable in Achievement

The lessons of both treatments were designed to minimize teacher effect. Teachers were involved, however, in instruction and in assisting students with problem areas. Because of this, teacher bias may have affected some results. The following discussion indicates how the teacher variable may have affected results.

The data indicate no significant teacher effect in computation (Table 4.1). Computation posttest means and adjusted means are given by teacher in Table 4.15.

Table 4.15

Computation Posttest Means by Teacher

teacher	mean	sd	adjusted mean
1	25.0	8.0	25.3
2	23.6	6.5	23.2
3	25.7	6.9	23.0
4	20.5	8.2	22.2
5	24.4	7.9	25.5
6	24.5	5.4	24.5

The data do indicate a significant teacher effect in problem solving (Table 4.8). Problem solving posttest means are given by teacher in Table 4.16.

Table 4.16

Problem Solving Posttest Means by Teacher

teacher	mean	sd	adjusted mean
1	16.9	9.8	18.7
2	17.3	5.7	16.2
3	19.0	7.4	15.8
4	8.9	9.0	12.5
5	15.6	8.3	14.8
6	15.4	5.6	16.2

These means illustrate that the student mean of Teacher 4 was noticeably lower than the means of the other teachers, which may have produced the teacher effect. Teacher 4 had 26 students in the two treatments of this study. Of these students, 10 scored 0 on the problem solving posttest. The investigator's observation of these two classes indicated that many students in both classes were making little or no effort on the treatment lessons or on the tests.

The design of this study should compensate for the teacher effect. Since analysis of covariance was used, with pretests as covariates, significant differences in means recorded should be conservative. However, since such large differences in posttest means were recorded for Teacher 4, the data were analyzed omitting the data from Teacher 4. Tables 4.17 and 4.18 give the summary tables for the analysis of covariance for computation and problem solving, respectively, when the data from Teacher 4 is omitted.

Table 4.17

Analysis of Covariance Summary Table for Computation (Data from Teacher 4 Omitted)

Source	df	MS	F	p
Treatment	1	26.2	.8	.34
Calculator on Posttest	1	302.2	9.8	.002*
Teacher	4	36.0	1.2	.33
Tr X C	1	29.1	.9	.33
Tr X Te	4	28.4	.9	.46
C X Te	4	20.9	.7	.61
Tr X C X Te	4	32.9	1.1	.38
Error	120	30.9		

*significant at the .05 level

Table 4.18

Analysis of Covariance Summary Table for Problem Solving
(Data from Teacher 4 Omitted)

Source	df	MS	F	p
Treatment	1	212.9	7.1	.009*
Calculator on Posttest	1	98.6	3.3	.07
Teacher	4	55.7	1.9	.12
Tr X C	1	264.5	8.8	.004*
Tr X Te	4	24.4	.8	.52
C X Te	4	27.6	.9	.45
Tr X C X Te	4	31.4	1.0	.39
Error	120	29.9		

*significant at the .05 level

A comparison of Table 4.1 with Table 4.17 revealed no changes in significant differences. The use of a calculator on the posttest still has a significant effect.

A comparison of Table 4.8 with Table 4.18 does indicate a change in main effects. Treatment is slightly more significant with the data from Teacher 4 omitted. The use of a calculator on the posttest is no longer significant at the .05 level, though it approaches significance. The teacher effect is no longer significant, and the treatment X calculator use on the posttest interaction is still strongly significant.

Summary of the Results of Analyses on Achievement Hypotheses

The following is a summary of findings, based on the preceding analyses of data.

1. There was no significant difference between the two treatments on computation achievement.

2. There was a significant difference in computation achievement between groups who took the posttest with a calculator and groups who took the posttest without a calculator. The group using hand-held calculators on the posttest exhibited higher scores in computation than the group not using hand-held calculators on the posttest.

3. There was no interaction effect between treatment and calculator use on the posttest in computation achievement.

4. There was a significant difference between the two treatments in problem-solving achievement. The group having the calculator treatment exhibited higher achievement.

5. There was a significant difference in problem-solving achievement between groups who took the posttest with a calculator and groups who took the posttest without a calculator.

The group using hand-held calculators on the posttest exhibited higher scores in problem solving than the group not using hand-held calculators on the posttest.

6. There was an interaction effect between treatment and calculator use on the posttest in problem solving achievement. The group in the non-calculator treatment who took the posttest using a calculator scored higher in problem-solving achievement than the group in this treatment who took the posttest without a calculator. The group in the calculator treatment who took the posttest with a calculator scored lower in problem-solving achievement than the group in this treatment who took the posttest without a calculator.

Tests of Attitude Hypotheses

Hypothesis 7

7. There is no significant difference between treatment posttest means on the attitude measure "Math vs. Non-Math."

Hypothesis 7 was tested using the analysis of covariance found in Table 4.19.

Table 4.19

Analysis of Covariance Summary Table for "Math vs. Non-Math"
(Covariate: Pretest on "Math vs. Non-Math")

Source	df	MS	F	p
Treatment	1	8.8	.8	.38
Teacher	5	37.6	3.4	.007*
Tr X Te	5	11.1	.9	.43
Error	154	11.2		

*significant at the .05 level

The F-ratio computed to test this hypothesis was not significant at the .05 level. Thus, Hypothesis 7 was not rejected. The pretest and posttest means are given by treatment in Tables 4.20 and 4.21, respectively.

Table 4.20

"Math vs. Non-Math" Pretest Means by Treatment

treatment	mean	sd	n
Calculator	21.0	4.1	83
Non-Calculator	19.8	4.3	84

Maximum possible score = 34 Overall mean = 20.4

Table 4.21

"Math vs. Non-Math" Posttest Means by Treatment

treatment	mean	sd	n	Adjusted mean
Calculator	21.2	4.4	83	20.8
Non-Calculator	19.9	4.1	84	20.3

Maximum possible score = 34 Overall mean = 20.6

Hypothesis 8

There is no significant difference between treatment posttest means on the attitude measure "Math Fun vs. Dull."

Hypothesis 8 was tested using the analysis of covariance found in Table 4.22.

Table 4.22

Analysis of Covariance Summary Table for "Math Fun vs. Dull" (Covariate: Pretest on "Math Fun vs. Dull")

Source	df	MS	F	p
Treatment	1	2.8	.4	.54
Teacher	5	5.8	.8	.58
Tr X Te	5	14.8	1.9	.09
Error	154	7.6		

The F-ratio computed to test this hypothesis was not significant at the .05 level. Therefore, Hypothesis 8 was not rejected. The pretest and posttest means for this scale are given by treatment in Tables 4.23 and 4.24, respectively.

Table 4.23

"Math Fun vs. Dull" Pretest Means by Treatment

treatment	mean	sd	n
Calculator	13.7	3.6	83
Non-Calculator	12.3	3.0	84

Maximum possible score = 21   Overall Mean = 13.0

Table 4.24

"Math Fun vs. Dull" Posttest Means by Treatment

treatment	mean	sd	n	adjusted mean
Calculator	13.9	3.6	83	13.6
Non-Calculator	12.9	2.9	84	13.3

Maximum possible score = 21   Overall mean = 13.4

A comparison of pretest and posttest scores indicates practically no gain for this measure.

Hypothesis 9

9. There is no significant difference between treatment posttest means on the attitude measure "Pro-Math Composite."

Hypothesis 9 was tested using the analysis of covariance found in Table 4.25.

Table 4.25

Analysis of Covariance Summary Table for "Pro-Math Composite"
(Covariate: Pretest on "pro-Math Composite")

Source	df	MS	F	p
Treatment	1	28.8	1.4	.24
Teacher	5	47.9	2.3	.045*
Tr X Te	5	13.3	.65	.66
Error	154	20.5		

*significant at the .05 level

The F-ratio computed to test this hypothesis was not significant at the .05 level. Thus, Hypothesis 9 cannot be rejected. The pretest and posttest means for this scale are given by treatment in Tables 4.26 and 4.27, respectively.

Table 4.26

"Pro-Math Composite" Pretest Means by Treatment

treatment	mean	sd	n
Calculator	29.6	4.5	83
Non-Calculator	28.9	4.5	84

Maximum possible score = 45   Overall mean = 29.3

Table 4.27

"Pro-Math Composite" Posttest Means by Treatment

treatment	mean	sd	n	adjusted mean
Calculator	30.5	5.7	83	30.2
Non-Calculator	29.1	4.6	84	29.4

Maximum possible score = 45   Overall mean = 29.8

A comparison of pretest and posttest scores on this measure indicates a very slight gain in group means for each treatment.

Hypothesis 10

10. There is no significant difference between posttest means on the attitude measure "Math Easy vs. Hard."

Hypothesis 10 was tested using the analysis of covariance found in Table 4.28.

Table 4.28

Analysis of Covariance Summary Table for "Math Easy vs. Hard"
(Covariate: Pretest on "Math Easy vs. Hard")

Source	df	MS	F	p
Treatment	1	1.1	.08	.88
Teacher	5	11.9	.85	.52
Tr X Te	5	9.2	.66	.66
Error	154	14.0		

The F-ratio computed to test this hypothesis was not significant at the .05 level. Hypothesis 10, therefore, cannot be rejected. The pretest and posttest means for this scale are given by treatment in Tables 4.29 and 4.30, respectively.

Table 4.29

"Math Easy vs. Hard" Pretest Means by Treatment

treatment	mean	sd	n
Calculator	28.4	5.4	83
Non-Calculator	26.5	4.5	84

Maximum possible score = 45   Overall mean = 27.5

Table 4.30

"Math Easy vs. Hard" Posttest Means by Treatment

treatment	mean	sd	n	adjusted mean
Calculator	26.8	4.4	83	26.5
Non-Calculator	26.5	3.5	84	26.7

Maximum possible score = 45   Overall mean = 26.7

A comparison of pretest and posttest mean scores on this measure indicates a slight decrease in the calculator treatment grcup and no change in the non-calculator group.

The Teacher Variable in Attitude

The teacher variable may have effect on students' attitudes toward mathematics. The following discussion indicates how the teacher variable was involved in the results of the analyses of attitude data in this study.

Table 4.19 indicates that that there was a significant teacher effect on the attitude measure "Math vs. Non-Math." A look at the adjusted means in Table 4.31 indicates that the mean for Teacher 3 was noticeably higher than the means for the other teachers.

Table 4.31

"Math vs. Non-Math" Posttest Means by Teacher

teacher	mean	sd	adjusted mean
1	19.4	4.6	19.5
2	21.6	5.1	20.8
3	23.1	3.6	22.6
4	19.8	3.7	20.1
5	19.0	3.8	19.9
6	20.5	4.0	20.3

The "Math vs. Non-Math attitude scale was designed to measure how well a student likes mathematics and considers it important in relation to other school subjects. It seems likely that the attitudes displayed by the individual teacher could strongly effect student attitude in this area.

Table 4.25 indicates that there was a significant teacher effect on the "Pro-Math Composite" attitude measure. The posttest means by teacher are given for this scale in Table 4.32.

Table 4.32

"Pro-Math Composite" Posttest Means by Teacher

teacher	mean	sd	adjusted mean
1	28.9	4.8	28.3
2	29.5	8.2	29.2
3	31.8	4.3	31.9
4	29.6	4.2	30.1
5	29.5	4.4	30.0
6	29.0	5.6	28.6

This table shows that the mean for Teacher 3 was noticeably higher than the means for the other teachers. The "Pro-Math Composite" scale was designed to measure general attitudes toward mathematics. Teacher attitude toward the subject and class could influence this variable.

No significant teacher effects were found on the attitude measures "Math Fun vs. Dull" or "Math Easy vs. Hard."

Summary of the Results of Analyses on Attitude Hypotheses

1. There was no difference between the two treatments on the attitude measure "Math vs. Non-Math," which measures how well a student likes mathematics and considers it important in relation to other school subjects.
2. There was no difference between the two treatments on the attitude measure "Math Fun vs. Dull," which measures the pleasure or boredom a student experiences with regard to mathematics, both in the absolute sense and comparatively with other subjects.
3. There was no difference between the two treatments on the attitude measure "Pro-Math Composite," which measures general attitudes toward mathematics.
4. There was no difference between the two treatments on the attitude measure "Math Easy vs. Hard," which measures the ease or difficulty which a student associates with mathematics performance.

CHAPTER V

SUMMARY, CONCLUSIONS AND LIMITATIONS

Summary

The purpose of this study was to investigate the effects of using a calculator-based curriculum and a classroom set of hand-held calculators in ninth grade general mathematics. The subjects of the study were students in twelve classes of the Fundamentals of Mathematics course "Basic Mathematics" in an urban district in Texas, during the Fall Quarter, 1977. Three high schools were involved, each having two participating teachers, with each teacher having one class in each treatment.

The two treatments were: 1) a calculator-based curriculum using a classroom set of hand-held calculators; and 2) a non-calculator curriculum. Both treatment groups were given units of instruction on estimation, computation, and problem solving using the four arithmetic operations on whole numbers. The calculator treatment group used a classroom set of hand-held calculators as an instructional aid. The non-calculator treatment group used paper and pencil only.

Students in both treatment groups were given pretests in mathematics achievement and attitudes. The Stanford Achievement

Test, Intermediate Level II, Form A, was given as the pretest to measure mathematics achievement prior to treatment. The computation portion of this test measured student achievement in computation, and the applications portion of the test measured student achievement in problem solving. The Form 9151 Attitude Test, Scales PY407 through PY410, developed by the School Mathematics Study Group, was used to pretest attitudes toward mathematics.

At the conclusion of the two treatments, which lasted approximately four weeks, both groups were given posttests in achievement and attitude. Form B of the Stanford Achievement Test cited above was used to measure mathematics achievement. The attitude instrument cited above was used to measure attitude.

Ten hypotheses were tested using an analysis of covariance design.

Conclusions

This study was conducted in an attempt to answer three questions, as stated in Chapter I. Each question follows, with a response to it based on the results reported in Chapter IV.

Question 1- Will the use of a calculator-based curriculum and a classroom set of hand-held calculators have an effect on students' achievement in computation?

No evidence was found to indicate that the use of a calculator-based curriculum will increase student achievement in computation. The results indicate, however, that students would not be expected to lose skills in computation if they were given instruction using hand-held calculators, as gains in computation achievement were consistent with gains of students not using calculators in instruction. The gains were consistent even when calculators were not available on the test. This result is consistent with the results of Durrance (1964), Mastbaum (1969), Ellis (1969), Cech (1972), and Ladd (1973). In all these studies, use of a calculator treatment failed to produce significant differences in computation achievement.

A possible explanation for these results in this study lies in the design of the curricular materials. Though the calculator materials were designed for using the hand-held calculator in learning, work also was done that involved computation using paper and pencil. The estimation portion of the materials required students to round off numbers to one significant digit and then compute the results using the rounded numbers. This gave the students practice in computation using basic facts. Also, the second day of each lesson required students to work approximately five exercises using paper and pencil only. It could be that this practice was enough to maintain and improve skills in computation using paper and pencil only.

The evidence seems to indicate that the use of a hand-held calculator on the test increases achievement in computation, regardless of the treatment used in instruction. From observation during the testing and analysis of the posttests, the use of a hand-held calculator on the posttest seemed to reduce computation errors, to allow students time to check their work, and to improve student confidence while taking the test.

Question 2- Will the use of a calculator-based curriculum with a classroom set of hand-held calculators have an effect on students' achievement in problem solving.

Evidence was found to indicate that the use of a calculator-based curriculum with a classroom set of hand-held calculators does have positive effect on students' achievement in problem solving. Students receiving the calculator treatment did perform significantly better in problem solving than students receiving the non-calculator treatment. This result seems to be unique to the studies reported. There have been significant findings on reasoning ability, however, which may have transfer to problem solving. Durrance (1964) found a significant effect on reasoning in grade 7, using rotary calculators daily. Kelley and Lansing (1975) found a significant gain on the NLSMA Reasoning Test by students in grades 7 and 8 who used a calculator curriculum. Spencer (1975) found a significant difference on the gain scores of a reasoning test by students in grade 5 who were in the calculator group.

Based on the evidence of this study, the investigator concludes that the use of hand-held calculators in instruction gives students in ninth grade general mathematics more opportunity to develop problem-analyzing and attack skills. It may be that the use of the hand-held calculator causes students to take their attention off the computation aspect of the problem, and to focus their attention more directly on the problem itself. Additionally, the mere availability of the hand-held calculator may cause students to have greater confidence and a greater willingness to attack word problems.

The data of this study indicate that students who used a hand-held calculator on the posttest did significantly better in problem-solving achievement than students who did not use a calculator on the posttest. Many students who were allowed to use a hand-held calculator on the posttest appeared to exhibit more positive attitudes regarding their ability to do well on the test. Having a calculator available seemed very important for many students, especially those who had been given the non-calculator treatment. A second reason for this increased achievement in problem solving could be that students made fewer computation errors using the calculator than students who did not have a calculator. This reason is logical, since students who took the posttest using a hand-held calculator did significantly better in computation achievement than students who took the test without a calculator.

An interaction was found in this study between treatment and calculator use on the posttest, when problem solving was the criterion variable. There was little difference between treatment adjusted posttest means for the group of students who took the posttest using a calculator. For that group the mean was slightly lower for the calculator treatment. For the group of students who took the posttest not using a calculator, there was, however, a large difference between treatment posttest adjusted means. The mean for the calculator treatment was noticeably higher than for the non-calculator treatment when calculators were not used on the posttest. Also, there was little difference in problem-solving achievement in the calculator treatment group between students who took the posttest with a hand-held calculator and students who took the test without a calculator. This fact may indicate that problem-solving skills were acquired, through the use of a calculator in learning, which remained even when a calculator was no longer present. The large difference in problem-solving achievement in the non-calculator treatment between groups using calculators on the posttest and students not using calculators on the posttest could be a result of attitudes exhibited by students in this treatment at the posttest. Students in this treatment group who were given calculators appeared to make a greater effort on the posttest than students who did not use a calculator on the posttest. The difference also might be attributed to fewer errors in computation made by students who had a calculator on the posttest.

Question 3- Will the use of a calculator-based curriculum and a classroom set of hand-held calculators have an effect on students' attitudes toward mathematics?

No evidence was found to indicate that the use of a calculator-based curriculum with a classroom set of hand-held calculators has an effect on students' attitudes toward mathematics. This result is consistent with the results of Mastbaum (1969), Ladd (1973), Gaslin (1975), and Hutton (1976). In all of these studies, use of a calculator treatment failed to produce significant differences between calculator and non-calculator treatments in attitudes toward mathematics.

The answer to this question was sought using four attitude scales developed by the School Mathematics Study Group. The first scale was "Math vs. Non-Math," which was designed to measure how well a student likes mathematics and considers it important in relation to other school subjects. A significant teacher effect was found on this variable, indicating that the teacher influence on students toward this type of attitude had more effect than the treatment method used. The second attitude scale was "Math Fun vs. Dull," which was designed to measure the pleasure or boredom a student experiences with regard to mathematics, both in the absolute sense and comparatively with other subjects. No significant effects were found with this variable. The third attitude measure was "Pro-Math Composite," which was designed to measure general attitudes toward mathematics. There was a significant teacher effect on this variable. It might be concluded that teacher attitude strongly influences student attitude in this area. The fourth attitude measure was "Math Easy vs. Hard," which was designed to measure the ease or difficulty which a student associates with mathematics performance. There were no significant effects found with this variable.

Limitations of the Study

The results of this study should be considered and evaluated with respect to the following limitations:

1. The learning material of this study was limited to estimation, computation, and problem solving involving the four arithmetic operations with whole numbers. Results may be limited to this specific content, though the data seem to indicate that similar results could be achieved using a broader curriculum.

2. Attempts were made to minimize the teacher differences in instruction by providing teacher guides outlining goals, objectives, and instructional activities for each lesson. No attempts were made, however, to control teacher bias or attitudes that may have influenced some results.

3. The time limitation of this study should be considered in evaluating the results. The instructional treatments lasted approximately four weeks. This limited time may not have been sufficient to determine effects calculators have on student learning or on attitudes.

Recommendations for Future Research

This study was designed to investigate the effects using hand-held calculators in the classroom has on learning, with low achievers in ninth grade mathematics. The results of the study do not provide conclusive evidence for answering the questions of the study. These questions are still open for investigation. However, significant results were found in the study which warrant further research, particularly in problem solving. The following are recommendations for future research based on the results of this study:

1. Replicate the basic design of this study, but extend the instructional material to provide a complete quarter course of learning with a calculator-based curriculum and a non-calculator curriculum.

2. Replicate the basic design of the study, but include a follow-up on students who participated in the study to investigate retention of problem-solving effects.

3. Replicate the basic design of this study, but conduct the study with different levels of students. Investigations are needed in grades 6, 7, and 8, with average and above-average ability students.

4. Conduct a longitudinal study, investigating the achievement of students in problem solving who use calculators in learning compared to students who do not. Also investigate student attitudes toward mathematics as they develop over long periods of time.

Implications for Education

The following are implications for education, which are based on the results of this study:

1. Students in ninth grade general mathematics can improve their skills in computation and problem-solving achievement using a calculator-based curriculum in learning.

2. Students in ninth grade general mathematics who use a calculator-based curriculum in learning may acquire greater achievement in problem solving than students who use a non-calculator curriculum in learning.

3. Students in ninth grade general mathematics who are allowed to use hand-held calculators while taking tests achieve higher scores in computation and problem solving than students who are not allowed to use calculators on tests.

4. Students in ninth grade general mathematics who use a calculator-based curriculum in learning do not appear to lose

computation skills when tested using paper and pencil only.

Concluding Statement

The investigator was hesitant to make strong generalizations from the results of this study, due to the fact that the results were not supported in the literature. There are elements in the design of the study, though, which may account for the apparent discrepancy.

The design of this study placed significant controls on student use of calculators, on the learning materials, and on teacher variables. A specific curriculum was specified, and the instructional sequence was consistent with all groups. The teacher guides provided step-by step instructional material for teachers to use in their classrooms.

The results of this study provide rather strong evidence supporting the use of hand-held calculators in instruction in ninth grade general mathematics. The data indicate that those students using calculators in instruction progressed equally as well in computation as their peers not using calculators in instruction. Students in this study suffered no loss in computation skill using a hand-held calculator in instruction.

The results of this study indicate further that students in ninth grade general mathematics using hand-held calculators in instruction achieve significantly better in problem solving than students not using calculators in instruction. Since most courses in general mathematics attempt to prepare students for the mathematics of the real world, this result in problem solving could have far-reaching implications for curriculum planning in this type of course.

APPENDIX A

Teacher's Guide for the Calculator Treatment

INTRODUCTION

As hand-held calculators have become more and more common in everyday usage, questions naturally arise regarding the effect this usage will have on students' mathematics skills. Many mathematics educators feel that students should be allowed to use calculators as an instructional aid in their mathematics curriculum.

Before meaningful decisions can be made regarding the role hand-held calculators should play in the mathematics curriculum, controlled experimentation is necessary to provide a basis for decision-making. The purpose of this study is to gather information which will aid in predicting the benefits, if any, for the use of the hand-held calculator in Fundamentals of Mathematics classes.

This study, as designed, can be effected to extend over approximately 22 days of instruction. Included in this are two days of testing in the beginning of the study and two days of testing at the end of the study. The testing includes a pre- and posttest on attitudes in mathematics, computation with whole numbers, and problem solving with whole numbers.

The material, designed for approximately 18 lessons, focuses on the four operations with whole numbers. Estimation and problem solving are emphasized throughout. Each teacher will use this material with the class which uses the calculator as an instructional aid.

The teaching guides describe objectives and classroom activities for each lesson. In order for the results of the study to be meaningful, it is important that the participating teachers do essentially the same thing for the same lesson. Thus, it is requested that the activities described for each lesson in the teacher guide be adhered to as closely as possible.

INTRODUCING THE CALCULATOR

LESSON OBJECTIVES:

(1) To familiarize students with hand-held calculators.

(2) To provide practice for entering numbers into calculators.

LESSON DURATION:

One day.

CLASSROOM ACTIVITIES:

(1) Distribute the calculators.

(2) Instruct students in the basic operation of the calculator. (Be sure to emphasize the importance of turning the calculator off when not in use.)

(3) Discuss with the students the function of the clear key $\boxed{C}$. On some it is marked CE/C.

(4) Have students go through the following examples as you write them on the board (or overhead projector):

Example 1:

Enter 843.
Press $\boxed{C}$ Press $\boxed{8}$ Press $\boxed{4}$ Press $\boxed{3}$
If you press the wrong key, simply press the clear key $\boxed{C}$. It acts like an eraser. Then start all over. On some calculators, pressing $\boxed{C}$ once erases the last number entered. Pressing $\boxed{C}$ twice erases the entire problem.

Example 2:

Enter 9057.
Press [C] Press [9] Press [0] Press [5]
Press [7] .
Always check the display to make sure each number is entered correctly. If you enter the wrong number, simply press [C] once. Then try again. There is no key for a comma. Ignore commas when you enter a number.

Example 3:

Enter 34,587. Follow the same procedure as in Examples 1 and 2.

(5) Distribute the worksheets. On Exercises 1-28, have students place a check mark (✓) beside each number they entered correctly the first time.

LESSON 1C

ROUNDING WHOLE NUMBFRS

LESSON OBJECTIVES:

(1) To develop awareness of the importance of rounding numbers for estimation.

(2) To develop skills in rounding numbers to the nearest 10, 100, 1000, etc.

LESSON DURATION:

One day.

CLASSROOM ACTIVITIES:

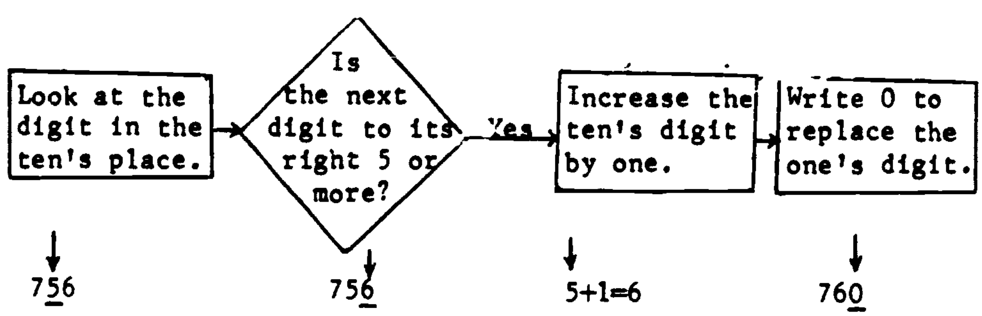
(1) Review place value to millions.

(2) Discuss the need for estimation, especially when using calculators. For example, it is easy to make ..istakes by punching the wrong button on a calculator. Also, the calculator might not be working properly.

(3) Discuss, as a class activity, the following examples. The flowchart method of explanation is optional.

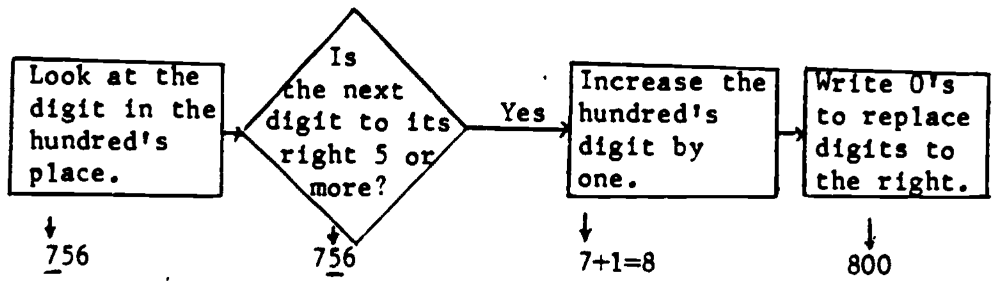
Example 1:

Round 756 to the nearest ten.



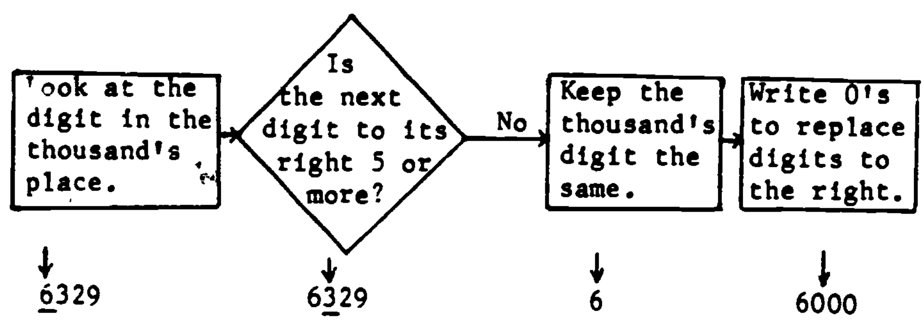
Example 2:

Round 756 to the nearest hundred.



Example 3:

Round 6329 to the nearest thousand.



Here are some other examples.

Number	Round to the nearest	Approximation
874	ten	870
3,195	hundred	3,200
64,970	thousand	65,000
64,970	ten thousand	60,000
25,000	ten thousand	30,000
73,058	thousand	73,000
550,063	hundred thousand	600,000
8,498	thousand	8,000

Example 4:

Round the number in the following sentence to the nearest ten thousand.

The number of persons attending the concert was 17,483.

ten thousands	thousands		hundreds	tens	ones
1	7	,	4	8	3

20,000 ⟵ The digit in the ten thousand's place was increased by one.

(5) Distribute the worksheets.

(6) Have students work all exercises except the following: 15, 16, 27, 28, 39, 40, 48, and 56.

(7) When students show that they have completed these exercises, issue them a calculator for the Calculator Capers.

LESSON 2C

ADDITION

LESSON OBJECTIVES:

(1) To develop estimation skills in addition.

(2) To develop computation skills in addition, both without and with a calculator.

(3) To develop problem-solving skills in addition.

LESSON DURATION:

Two days.

CLASSROOM ACTIVITIES:

<u>First Day</u>.

(1) Discuss the meaning of addition and computation techniques in addition.

(2) Discuss and work the following examples by rounding and estimating:

Example 1:

$$\begin{array}{r} 23 \\ +\underline{59} \end{array} \qquad 23 + 59 = \underline{\ ?\ }$$

Round to the nearest ten in estimating.

$$\begin{array}{rcl} 23 & \longrightarrow & 20 \\ +\underline{59} & \longrightarrow & +\underline{60} \\ & & \overline{80} \leftarrow \text{Estimate} \end{array}$$

Example 2:

```
 14        14 + 28 + 47 = ?
 28
+47
```

Round to the nearest ten in estimating.

```
 14 →  10
 28 →  30
+47 → +50
       90 ← Estimate
```

Example 3:

A store sold 127 items on Wednesday, 215 items on Thursday, 254 items on Friday, and 346 items on Saturday. How many items did the store sell in all on these four days?

```
 127       127 + 215 + 254 + 346 = ?
 215
 254
+346
```

Round to the nearest hundred in estimating.

```
 127 →  100
 215 →  200
 254 →  300
+346 → +300
        900 ← Estimate
```

Example 4:

```
 17,283     17,283 + 6,856 + 32,050 = ?
  6,856
+32,050
```

Round each number according to its largest place value.

```
 17,283 →  20,000  Rounded to ten thousands
  6,856 →   7,000  Rounded to thousands
+32,050 → +30,000  Rounded to ten thousands
           57,000  Estimate
```

(3) Have students round and estimate Exercises 1-50.

Second Day.

(1) Distribute the calculators.

(2) Discuss and work, as a class activity, Examples 1-4 by hand calculation and by using the calculator. Compare results with previous estimations.

(3) Distribute the worksheets.

(4) Have students work by hand computation Exercises 1, 7, 10, 13, 19, 23, 25, and 32. Students must show you this work before they can use the calculator.

(5) When students show you this work, allow them to complete the worksheet with a calculator.

LESSON 3C

SUBTRACTION

LESSON OBJECTIVES:

(1) To develop estimation skills in subtraction.

(2) To develop computation skills in subtraction, both without and with a calculator.

(3) To develop problem-solving skills in subtraction.

LESSON DURATION:

Two Days.

CLASSROOM ACTIVITIES:

First Day.

(1) Discuss the meaning of subtraction and computation techniques in subtraction.

(2) Discuss and work, as a class activity, the following examples by rounding and estimating:

Example 1:

$$\begin{array}{r} 56 \\ -29 \\ \hline \end{array} \qquad 56 - 29 = \underline{\ ?\ }$$

Round to the nearest ten in estimating.

$$\begin{array}{rcr} 56 & \rightarrow & 60 \\ -29 & \rightarrow & -30 \\ \cline{3-3} & & 30 \leftarrow \text{Estimate} \end{array}$$

Example 2:

$$\begin{array}{r} 73{,}205 \\ \underline{-9{,}476} \end{array} \qquad 73{,}205 - 9{,}476 = \underline{\ ?\ }$$

Round each number according to its largest place value.

$$\begin{array}{rcr} 73{,}205 & \rightarrow & 70{,}000 \\ \underline{-0{,}476} & \rightarrow & \underline{-9{,}000} \\ & & 61{,}000 \leftarrow \text{Estimate} \end{array}$$

Use other examples as needed for understanding before students work individually.

(2) Distribute the worksheets.

(3) Have students round and estimate Exercises 1-37.

Second Day.

(1) Distribute the calculators.

(2) Discuss and work, as a class activity, Examples 1 and 2 by hand computation and by using a calculator. Compare the results with previous estimations. Discuss other exercises as needed for understanding.

(3) Have students work Exercises 1, 6, 11, 16, 17, 22, 28, and 35 by hand computation.

(4) When students show you this work, allow them to complete the worksheet with a calculator.

LESSON 4C

ADDITION AND SUBTRACTION

LESSON OBJECTIVES:

(1) To develop estimation skills in addition-subtraction combination problems.

(2) To develop computation skills in addition-subtraction combination problems, both without and with a calculator.

(3) To develop problem-solving skills in addition-subtraction combination problems.

LESSON DURATION:

Two Days.

CLASSROOM ACTIVITIES:

First Day.

(1) Work and discuss the following examples by rounding and estimating. Emphasize that the order of operations is from left to right.

Example 1:

$437 - 192 + 286 = \underline{\ ?\ }$

Round to the nearest hundred.

$$\begin{array}{ccccc} 437 & - & 192 & + & 286 \\ \downarrow & & \downarrow & & \downarrow \\ \underbrace{400 - 200} & & & + & 300 \end{array}$$

$200 + 300 = 500 \leftarrow$ Estimate

Example 2:

2943 - 856 + 461 - 1017 = ?

Round each number according to its largest place value.

$$\begin{array}{ccccccc} 2943 & - & 856 & + & 461 & - & 1017 \\ \downarrow & & \downarrow & & \downarrow & & \downarrow \end{array}$$

$$\underbrace{3000 - 900} + 500 - 1000$$

$$\underbrace{2100 \quad + 500} - 1000$$

$$2600 \quad - 1000 \quad \text{Estimate}$$

Discuss other examples as necessary to achieve understanding.

(2) Distribute the worksheets.

(3) Have students round and estimate Exercises 2-32 (even).

Second Day.

(1) Distribute the calculators.

(2) Discuss and work, as a class activity, Examples 1 and 2 by hand computation and by using a calculator. Compare results with previous estimations. Discuss other examples as needed for understanding.

(3) Have students work Exercises 2, 4, 7, 12, 17, and 22 by hand computation.

(4) When students show this work, have them complete the worksheet with a calculator.

LESSON 5C

MULTIPLICATION

LESSON OBJECTIVES:

(1) To develop estimation skills in multiplication.

(2) To develop computation skills in multiplication, both without and with a calculator.

(3) To develop problem-solving skills in multiplication.

LESSON DURATION:

Two Days.

CLASSROOM ACTIVITIES:

First Day.

(1) Discuss and work the following examples by rounding and estimating.

Example 1:

$$\begin{array}{r} 18 \\ \underline{\times 13} \end{array} \qquad 18 \times 13 = \underline{\ ?\ }$$

Round to the nearest ten in estimating.

$$\begin{array}{rcr} 18 & \rightarrow & 20 \\ \underline{\times 13} & \rightarrow & \underline{\times 10} \\ & & 200 \leftarrow \text{Estimate} \end{array}$$

Example 2:

$$\begin{array}{r} 48 \\ \underline{\times 12} \end{array} \qquad 12 \times 48 = \underline{\ ?\ }$$

Round to the nearest ten in estimating.

$$\begin{array}{rcl} 48 & \rightarrow & 50 \\ \underline{\times 12} & \rightarrow & \underline{\times 10} \\ & & 500 \leftarrow \text{Estimate} \end{array}$$

Example 3:

$21 \times 36 \times 109 = \underline{\ ?\ }$

Round each number according to its largest place value.

$$\begin{array}{ccccc} 21 & \times & 36 & \times & 109 \\ \downarrow & & \downarrow & & \downarrow \\ \underbrace{20 \times 40}_{800} & & & \times & 100 = 80{,}000 \leftarrow \text{Estimate} \end{array}$$

Discuss other examples as needed for understanding.

(2) Distribute the worksheets.

(3) Have students round and estimate Exercises 1-34.

Second Day.

(1) Distribute the calculators.

(2) Discuss and work, as a class activity, Examples 1-3 by hand computation and by using a calculator. Discuss other examples as needed for student understanding of the process and technique of multiplication.

(3) Distribute the worksheets.

(4) Have students work Exercises 3, 5, 9, 15, 20, 27, and 31. by hand computation.

(5) When students show this work. allow them to use their calculator to complete the worksheet.

LESSON 6C

DIVISION-ZERO REMAINDER

LESSON OBJECTIVES:

(1) To develop estimation skills in division.

(2) To develop computation skills in division, both without and with a calculator.

(3) To develop problem-solving skills in division.

LESSON DURATION:

Two Days.

CLASSROOM ACTIVITIES:

First Day.

(1) Discuss and work, as a class activity, the following examples by rounding and estimating:

Example 1:

$34\overline{)442}$ $\qquad 442 \div 34 = \underline{\ ?\ }$

Round each number according to its largest place value.

$34 \longrightarrow 30 \qquad 442 \longrightarrow 400$

$13 \leftarrow$ Estimate

$3\cancel{0}\overline{)40\cancel{0}}$

Example 2:

$24 \overline{)10296}$ $10296 \div 24 = \underline{\ ?\ }$

Round each number according to its largest place value.

$24 \longrightarrow 20$ $10296 \longrightarrow 10000$

$2\cancel{0} \overline{)1000\cancel{0}}^{\,500}$ Estimate

Discuss other examples as needed for understanding.

(2) Distribute the worksheets.

(3) Have students work Exercises 2-34 (even) by rounding and estimating.

Second Day.

(1) Distribute the calculators.

(2) Discuss and work, as a class activity, Examples 1 and 2 by hand computation and by using a calculator.

(3) Distribute the worksheets.

(4) Have students work Exercises 2, 4, 6, 8, 19, 25, 30, and 31 by hand computation.

(5) When students show this work, allow them to complete the worksheet using their calculator.

LESSON 7C

MULTIPLICATION AND DIVISION

LESSON OBJECTIVES:

(1) To develop estimation skills in multiplication-division combination problems.

(2) To develop computation skills in multiplication-division combination problems, both without and with the calculator.

(3) To develop problem-solving skills in multiplication-division combination problems.

LESSON DURATION:

Two Days.

CLASSROOM ACTIVITIES:

<u>First Day</u>.

(1) Discuss and work the following examples by rounding and estimating. Emphasize that the order of operations is from left to right.

Example 1:

$12 \times 26 \div 24 = \underline{\ ?\ }$

Round to the nearest ten in estimating.

$12 \times 26 \div 24$

$\underbrace{10 \times 30} \div 20$

$\underbrace{30\cancel{0} \div 2\cancel{0}}$

15 Estimate

Example 2:

$6003 \div 87 \times 24 \div 36 = \underline{\ ?\ }$

Round each number according to its largest place value.

$$
\begin{array}{l}
6003 \div 87 \times 24 \div 36 \\
\ \ \downarrow \qquad 10\downarrow \quad \downarrow \quad \ \downarrow \\
\underbrace{600\cancel{0} \div \cancel{0}\cancel{0}} \times 20 \div 40 \\
\qquad \underbrace{60 \qquad \times 20} \div 40 \\
\qquad\quad \underbrace{120\cancel{0} \quad \div \quad 4\cancel{0}} \\
\qquad\qquad\qquad 30 \qquad \text{Estimate}
\end{array}
$$

Discuss other examples as necessary for understanding.

(2) Distribute the worksheets.

(3) Have students work Exercises 1-33 (odd) by rounding and estimating.

<u>Second Day</u>.

(1) Distribute the calculators.

(2) Discuss and work, as a class activity, Examples 1 and 2 by hand computation and by using a calculator.

(3) Distribute the worksheets.

(4) Have students work Exercises 1, 2, 3, 21, 26, and 31 by hand computation.

(5) When students show you this work, allow them to complete the worksheet using their calculator.

LESSON 8C

COMBINED OPERATIONS

LESSON OBJECTIVES:

(1) To develop estimation skills in combined operations problems involving addition, subtraction, multiplication, and division.

(2) To develop computation skills both without and with the calculator in combined operations problems involving addition, subtraction, multiplication, and division.

(3) To develop problem-solving skills in combined operations problems involving addition, subtraction, multiplication, and division.

LESSON DURATION:

Two Days.

CLASSROOM ACTIVITIES:

First Day.

(1) Discuss and work, as a class activity, the following examples by rounding and estimating. Emphasize that multiplication and division must be done from left to right before addition and subtraction is done from left to right. Show that parentheses may be used to help with the order of operations.

Example 1:

528 + 24 x 97 = ___?___

Round each number according to its largest place value. Insert parentheses to show what operations are to be done first.

$$\begin{array}{l} 528 + 24 \times 97 \\ \downarrow \quad \downarrow \quad \downarrow \\ 500 + \underbrace{(20 \times 100)} \\ \underbrace{500 + 2000} \\ 2500 \leftarrow \text{Estimate} \end{array}$$

Example 2:

$4086 - 42 \times 38 + 965 = \underline{\ ?\ }$

Round off each number and insert parentheses.

$$\begin{array}{l} 4086 - 42 \times 38 + 965 \\ \downarrow \quad \downarrow \quad \downarrow \quad \downarrow \\ 4000 - \underbrace{(40 \times 40)} + 1000 \\ \underbrace{4000 - 1600} + 1000 \\ \underbrace{2400 + 1000} \\ 3400 \leftarrow \text{Estimate} \end{array}$$

(2) Distribute the worksheets.

(3) Have students work Exercises 2-22 (even) and 23-27 by rounding and estimating.

<u>Second Day</u>.

(1) Distribute the calculators.

(2) Discuss and work, as a class activity, Examples 1 and 2 by hand computation and by using a calculator. Compare results with previous estimations. Discuss other examples as needed for understanding.

(3) Have students work Exercises 1, 2, 7, 9, 19, and 27 by hand computation.

(4) When students show you this work, allow them to complete the worksheet using their calculator.

LESSON 9C

DIVISION - NONZERO REMAINDER

LESSON OBJECTIVES:

(1) To improve estimation skills in division.

(2) To improve computation skills in division both without and with the calculator.

(3) To develop skill in finding remainders using the calculator.

(4) To improve problem-solving skills in division problems.

LESSON DURATION:

Two Days.

CLASSROOM ACTIVITIES:

<u>First Day</u>.

(1) Discuss and work, as a class activity, the following example by rounding and estimating.

Example.

$42 \overline{)238}$ $238 \div 42$

Round each number according to its largest place value.

$42 \longrightarrow 40$ $238 \longrightarrow 200$

$4\cancel{0} \overline{)20\cancel{0}}$ with quotient $5 \longleftarrow$ Estimate

Discuss other examples as necessary for student understanding.

(2) Distribute the worksheets.

(3) Have students round and estimate Exercises 1-26.

Second Day.

(1) Distribute the calculators.

(2) Discuss and work, as a class activity, the following example by hand computation and by using a calculator. Compare the results with the previous estimation on this example. Emphasize checking by multiplying.

Example:

$42\overline{)238}$ $\qquad 238 \div 42 = \underline{\ ?\ }$ $\qquad$ (5 r 28)

Find the quotient and the remainder. To find the remainder with a calculator, the following formula may be used:

$$\text{remainder} = \underset{\substack{\downarrow \\ 238}}{\text{dividend}} - \underset{\substack{\downarrow \\ 5}}{\text{quotient}} \times \underset{\substack{\downarrow \\ 42}}{\text{divisor}}$$

$$\text{check: } \underset{\substack{\downarrow \\ 5}}{\text{quotient}} \times \underset{\substack{\downarrow \\ 42}}{\text{divisor}} + \underset{\substack{\downarrow \\ 28}}{\text{remainder}} = \underset{\substack{\downarrow \\ 238}}{\text{dividend}}$$

Discuss other examples as necessary for understanding.

(3) Distribute the worksheets.

(4) Have students work Exercises 1, 3, 5, 7, 9, and 24 by hand computation.

(5) When students show you this work, allow them to complete the worksheet using their calculator.

APPENDIX B

Lessons for the Calculator Treatment

INTRODUCING THE CALCULATOR

EXERCISES

Enter each number on the calculator. Check the display for each number. Remember to press $\boxed{C}$ before you enter a new number.

1.	97	2.	56	3.	80
4.	319	5.	708	6.	524
7.	999	8.	106	9.	1038
10.	5729	11.	9856	12.	9001
13.	8989	14.	7050	15.	1111
16.	2643	17.	13,257	18.	59,724
19.	78,505	20.	96,203	21.	437,126
22.	800,980	23.	595,627	24.	999,909
25.	1,328,417	26.	3,409,277	27.	28,500,000
28.	40,908,710				

CALCULATOR CAPERS

The table below shows what letter you can read for each digit on the display if you turn the calculator upside down.

Digits	0	1	2	3	4	5	6	7	8
Letters	O	I	Z	E	H	S	G	L	B

A. Enter each number. Then turn the calculator upside down and read the display. Write the word you see. Press $\boxed{C}$ before entering the next number.

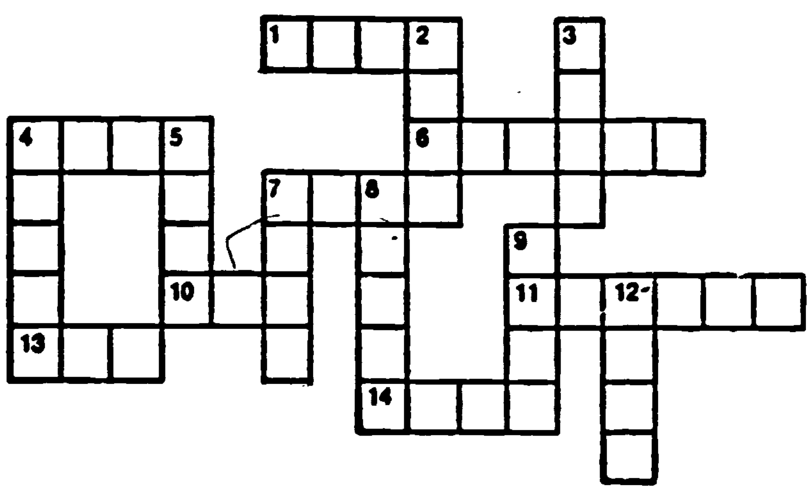
Number	Word
3705	SOLE
3215	____
7715	____
36718	____
35006	____
55178	____

B. Write a word for each group of numerals. Then write the secret message.

35006 53507 3045 32135 7714

C. Enter each number. Then turn the calculator upside down to read a word on the display. Complete the crossword puzzle by filling in a word for each number.

Across				Down			
1.	5514	4.	5537	2.	4615	3.	3807
6.	378806	7.	4614	4.	73817	5.	3215
10.	733	11.	378804	7.	3704	8.	55076
13.	607	14.	3705	9.	3045	12.	5508



LESSON 1C

ROUNDING WHOLE NUMBERS

EXERCISES

Round to the nearest ten.

1.	89	2.	73	3.	45	4.	96
5.	263	6.	578	7.	981	8.	695
9.	4384	10.	5741	11.	3286	12.	9612
13.	70,823	14.	29,576	15.	47,209	16.	76,814

Round to the nearest hundred.

17.	263	18.	578	19.	981	20.	695
21.	4384	22.	5741	23.	3286	24.	9612
25.	70,823	26.	29,576	27.	47,209	28.	76,814

Round to the nearest thousand.

29.	4834	30.	5741	31.	2534	32.	9612
33.	3286	34.	5491	35.	70,823	36.	29,576
37.	47,209	38.	580,000	39.	80,057	40.	555,555

Round to the nearest ten thousand.

41.	70,823	42.	29,576	43.	47,209	44.	580,000
45.	74,800	46.	800,561	47.	84,631	48.	555,555

Round to the nearest hundred thousand.

49.	580,000	50.	555,555	51.	800,561	52.	251,999
53.	109,000	54.	190,009	55.	671,256	56.	781,010

Round the number in each sentence to the given place.

57. The club has 493 dollars in its treasury. (nearest hundred)

58. The distance between two cities is 87 kilometers. (nearest ten)

59. The factory has 3254 workers. (nearest thousand)

60. 268,000 recordings of the song have been sold. (nearest ten thousand)

61. There are 619 pupils in the school. (nearest ten)

62. A family had an income of $17,824 for one year. (nearest ten thousand)

63. Erika's mother bought 83 balloons for the party. (nearest ten)

64. The number of refrigerators produced in one year was 5,982,000. (nearest million)

CALCULATOR CAPERS

A. Round each number to the given place. Then enter the approximation on the calculator. Tu·.. i+ upside down and read a word.

1. 714 to the nearest ten is greasy.

2. ͻ51 to the nearest hundred shows joy.

3. 3084 to the nearest ten makes music.

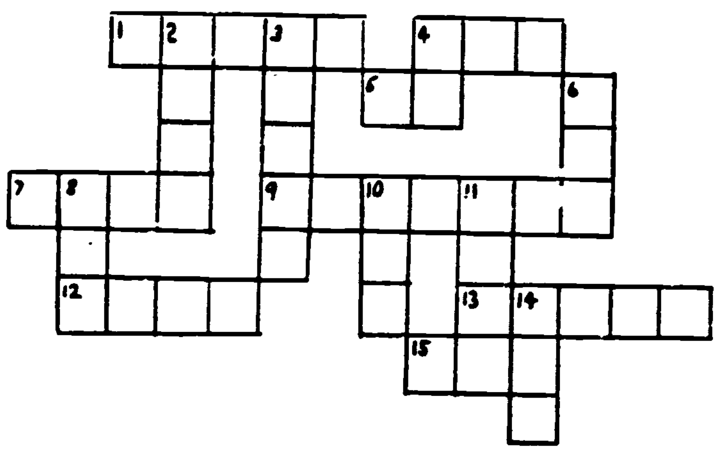
4. 368 to the nearest ten is a Spanish che...

5. 3167 to the nearest hundred is slime.

6. 3755 to the nearest ten means to look at.

B. Enter each number. Then turn the calculator upside down to read a word on the display. Complete the crossword puzzle.

Across				Down			
1.	36718	4.	618	2.	3751	3.	35336
5.	34	7.	3376	4.	38	6.	514
9.	5372215	12.	5306	8.	637	10.	612
13.	32135	15.	638	11.	3507	14.	663



LESSON 2C

ADDITION

EXERCISES

1. 19 + 16	2. 17 + 15	3. 18 + 19
est.______	est.______	est.______
comp.______		
calc. ____	calc.____	calc.____
4. 13 + 25	5. 29 + 34	6. 56 + 97
est.______	est.______	est.______
calc.____	calc.____	calc. ____
7. 13 + 28	8. 89 + 74	9. 92 +47
est. ______	est.____	est.____
comp.______		
calc.______	calc.___	calc.___

10. 51
+88

11. 29
+76

12. 59
+81

est.______
comp.______
calc.______

est.______
calc.______

est.______
calc.______

13. 18 + 15 + 17

14. 19 + 19 + 19

15. 18 + 13 + 15

est.______
comp.______
calc.______

est.______
calc.______

est.______
comp.______
calc.______

16. 12 + 38 + 87

17. 23
19
+42

18. 68
97
+51

est.______
calc.______

est.______
calc.______

est.______
calc.______

19. 71
34
+52

20. 25
75
+50

21. 5,286
+7,823

est.______
comp.______
calc.______

est.______
calc.______

est.______
calc.______

22. 25,682
+ 7,981

est.____

calc.____

23. 12,809
+164,201

est.____

comp.____

calc.____

24. 17,289
+ 9,858

est.____

calc.____

25. 8,712
3,196
+41,839

est.____

comp.____

calc.____

26. 23,408
57,196
+62,100

est.____

calc.____

27. 78,556
21,008
+39,927

est.____

calc.____

28. 438,672
+753,905

est.____

calc.____

29. 6 + 29 + 5,397 + 86 + 409

est.____

calc.____

30. 23,438 + 9,817 + 67 + 53

est.____

calc.____

31. 37 + 5,273 + 569 + 8 est.______

calc.______

32. 867 + 4,238 + 59 + 3,824 est.______

comp.______

calc.______

APPLICATIONS

The chart below shows the number of employees in the U.S. Postal Service for a recent year.

Postal Clerks	286,384
City Carriers	212,561
Rural Carriers	50,309
Mail Handlers	43,303
Postal Supervisors	38,102
Postmasters	30,731
Maintenance Service Workers	23,962
Motor Vehicle Operators	6,466
Vehicle Maintenance Workers	5,823
Protection Force	1,919
Postal Inspectors	1,589
Other	5,251

Find the total number of employees in each exercise below.

33. City Carriers and Rural Carriers

est.______

calc._____

34. Protection Force and Postal Inspectors

est.______

calc._____

35. Postal Supervisors and Postmasters

est.______

calc._____

36. All maintenance workers

est.______

calc._____

37. Postal Clerks and Mail Handlers

est.______

calc._____

38. Total number of postal employees

est.______

calc._____

The chart below shows how many students each mathematics teacher of West End School has for each class period.

Periods

	1	2	3	4	5	6	7
G. Brown	25	0	28	19	0	23	26
R. Dodd	21	27	0	31	0	24	28
D. Grove	20	26	32	0	19	0	27
F. Sanchez	17	28	0	26	29	23	0
M. Kimball	24	24	25	18	0	27	0
A. Pierce	30	29	0	15	0	26	27
T. Young	19	23	25	0	31	29	0

39. Find the total number of students in M. Kimball's classes.

est.______

calc._____

40. Find the total number of students in T. Young's classes.

est.______

calc._____

41. Find the total number of students in D. Grove's classes. est.______ calc._____

42. Find the total number of students in G. Brown's classes.

est.______

calc._____

43. Find the number of students who take math the first period.

est.______

calc._____

44. Find the number of students who take math the fourth period.

est.______

calc._____

45. Find the number of students who take math the sixth period.

est.______

calc._____

46. Find the number of students who take math the second period.

est.______

calc._____

The chart below shows the number of calories in some foods.

Food	Calories
Beef Roast, 3-oz. serving	180
Sirloin Steak, 3-oz. serving	185
Pork Tenderloin, 3-oz. serving	215
Chicken, 3-oz. serving	140
Codfish, 3-oz. serving	145
Tuna, 3-oz. serving (in oil)	170
Green Beans, ½ cup	15
Lettuce, ½ head	35
Celery, 3 stalks	10
Radishes, 4 small	5
Tomato, 1 small	20
Potato (baked) 1 medium	90
Apple, 1 medium	80
Banana, 1 medium	100
Dates, 3 or 4	85
Orange, 1 medium	65
Watermelon, 1 slice	115
Pineapple, ½ cup	40
Strawberries, ½ cup	30
Milk, 1 glass	166
Cola Beverage, 1 glass	105
Coffee, 1 cup with cream	30

In exercises 47 - 50, find the total number of calories in each meal.

47. 3 ounces of chicken
4 radishes
½ cup of green beans
½ cup of strawberries
1 glass of milk

est.______

calc.______

49. 3 ounces of tuna
3 stalks of celery
4 small radishes
1 medium orange

est.______

calc.______

48. 3 ounces of codfish
½ head of lettuce
1 small tomato
1 slice of watermelon
1 cup of coffee with cream

est.______

calc.______

50. 3 ounces of roast beef
1 medium baked potato
½ cup of pineapple
1 glass of cola

est.______

calc.______

CALCULATOR CAPERS

A. Special methods can be used to add numbers that are too large for a calculator.

Example:

```
  876,549,127
 +634,187,293
```

Form two or more problems with 8 or fewer digits in each number.

```
  8765  49127
 +6341  87293
     1  36420    49127 + 87293 (Use a calculator)
 15106           8765 + 6341 (Use a calculator)
 15107  36420    Answer: 1,510,736,420
```

Use a calculator to help you work the following problems.

```
1.   7,543,286,928      2.   298,750,381,987
    +6,938,468,495          +873,644,965,235
```

```
3.   8,403,279,513,072
    +3,175,048,915,316
```

B. Work each problem to complete the magic square. The sums in the rows, columns, and diagonals are equal.

1. 1245 + 1597
2. 764 + 293
3. 1532 + 183 + 728
4. 512 + 1203
5. 755 + 1359
6. 934 + 752 + 827
7. 539 + 1246
8. 809 + 1273 + 1089
9. 214 + 29 + 648 + 495

1	2	3
4	5	6
7	8	9

LESSON 3 C

SUBTRACTION

EXERCISES

1. 73 - 59	2. 96 - 57	3. 81 - 59
est.______ comp._____ calc._____	est.______ calc._____	est.______ calc._____
4. 67 - 25	5. 812 - 675	6. 786 - 421
est.______ calc.______	est.______ calc._____	est.______ comp._____ calc._____
7. 128 - 89	8. 237 - 148	9. 506 - 359
est.______ calc.______	est.______ calc._____	est.______ calc.______

10. 713
−285

est. ______

calc. ______

11. 999
−751

est. ______
comp. ______
calc. ______

12. 901
−698

est. ______

calc. ______

13. 6432
−2587

est. ______

calc. ______

14. 12,417
− 9,528

est. ______

calc. ______

15. 42,037
−38,928

est. ______

calc. ______

16. 10,000
−7,846

est. ______
comp. ______
calc. ______

17. 23,502
−19,738

est. ______
comp. ______
calc. ______

18. 92,175
−47,246

est. ______

calc. ______

19. 328,912
−117,456

est. ______

calc. ______

20. 3,298,016
−1,456,729

est. ______

calc. ______

21. In 1950, there were 4,931 golf courses in the United States. There were 10,188 in 1970. How many more were there in 1970?

est.______

calc.______

22. In 1950, there were 6,325 bowling alleys in the United States. By 1970, there were 9,140. How many more were there in 1970?

est.______

comp.______

calc.______

23. The Oakland Raiders scored 355 points in a recent season. They had a total of 228 points scored against them. How many more points did Oakland score than their opponents?

est.______

calc.______

24. In a recent year 1,313,000 persons stayed overnight in Yellowstone National Park. That same year 787,000 persons stayed overnight in Grand Canyon National Park. Find the difference between the two numbers.

est.______

calc.______

25. There were 2664 state parks in the United States in 1960. The number increased to 3245 by 1970. How many more state parks were there in 1970 than in 1960?

est.______

calc.______

The table shows weekly earnings for workers in certain occupations for five years.

Occupations	1970	1971	1972	1973	1974
Professional and Technical	181	189	192	212	228
Managers and Administrators	190	200	214	238	250
Salesworkers	133	141	151	163	172
Clerical	109	115	121	130	140
Craftspeople	157	167	172	195	211
Non-farm - Laborers	110	117	123	138	149

26. How much more per week did a professioanl make in 1974 than in 1970?

est.______

calc.______

27. In 1973, how much more per week did a manager make than a craftsperson?

est.______

calc.______

28. Find the increase in salesworkers' weekly earnings from 1970 to 1974.

est.______
comp.______
calc.______

29. Find the difference between the highest and lowest earnings in the table for 1972.

est.______

calc.______

This formula gives the profit of a business based on income and expenses.

Profit = Income - Expenses

$$P = I - E$$

Find the value of P for the given values of I and E.

30. I = $26,428
    E = 19,792

est.______

calc.______

31. I = $328,402
    E = 237,539

est.______

calc.______

32. I = $2,472,341
    E = 2,128,574

est.______

calc.______

33. I = $868,115
    E = 753,437

est.______

calc.______

34. The John Hancock building in Chicago is is 1107 feet high. The World Trade Center in New York is 1250 feet high. Find the difference between their heights.

1250 - 1107 = ___?___ est.______

calc.______

35. In 1960, there were 1,015, 461 acres of city and county parks in the U.S. In 1970, there were 965,785 acres. How much did the area decrease?

est.______
comp.______
calc.______

36. The average rainfall in New York is 108 centimeters. In Los Angeles it is 37 centimeters. How much greater is the amount in New York than in Los Angeles?

est.______

calc.______

37. The airline distance from New York to Honolulu by way of San Francisco is 7950 kilometers. The distance from New York to San Francisco is 4118 kilometers. Find the distance from San Francisco to Honolulu.

est.______

calc.______

CALCULATOR CAPERS

A. Special methods can be used to subtract numbers too large for the calculator.

Example:
```
  927,385,726
 -759,468,395
```

Form two or more problems with 8 or fewer digits in each number.

```
 9273   85726     Separate so top
-7594   68395     number is greater.
        17331     85726 - 68395 (Use a calculator)
 1679             9273 - 7594 (Use a calculator)
 1679   17331     Answer:  167,917,331
```

Use a calculator to help you work these problems.

```
1.  5,208,713,641     2.  12,228,576,450
   -3,597,537,067         -9,573,624,980

3.  23,246,245,137
   - 9,975,397,849
```

B. Work each problem to complete the magic square. The sums in the rows, columns, and diagonals are equal.

1. 591 - 98 = ?
2. 635 - 237 = ?
3. 1569 - 1065 = ?
4. 1303 - 827 = ?
5. 974 - 509 = + ?
6. 832 - 378 = ?
7. 1185 - 759 = ?
8. 1179 - 647 = ?
9. 3712 - 3275 = ?

1	2	3
4	5	6
7	8	9

LESSON 4C

ADDITION AND SUBTRACTION

EXERCISES

1. 86 - 19 - 28

comp.______
calc.______

2. 314 + 59 - 178

est.______
comp.______
calc.______

3. 386 - 72 - 83

calc.______

4. 1228 - 914 + 16

est.______
comp.______
calc.______

5. 3723 + 1519 - 2086

calc.______

6. 13,293 - 5,408 + 399

est.______

calc.______

7. 60,482 - 12,438 - 17,937

comp.______
calc.______

8. 536,928 + 47,586 - 277,923 est.________

calc.________

9. 228 - 74 + 139 - 213 calc.________

10. 1073 - 827 - 69 + 526 est.________

calc.________

11. 158 - 107 + 93 - 29 calc.________

12. 433 - 208 - 87 + 329 est.________

comp.________

calc.________

13. 704 + 593 - 217 - 378 calc.________

14. 326 - 497 + 1091 - 324 est.________

calc.________

15. 137 - 61 - 19 + 28 calc.________

16. 243 - 76 + 23 + 109 est.________

calc.________

17. 278 + 916 - 432 + 187 - 365 - 78 est.________

calc.________

18. $2056 + 1217 + 5948 - 3279 - 983$

comp.__________

calc.__________

19. The owner of a hot dog stand buys $54 worth of hot dogs and $18 worth of buns. The discount is $12. Find the total bill.

calc.______

20. At the beginning of June, the merchandise of a business was valued at $35,728. During the month $21,375 worth of merchandise was sold. Also, $12,529 worth of additional merchandise was purchased. Find the value at the end of June.

35,728 - 21,375 + 12,529 = ___?___

est.______

calc.______

21. Sales of hamburgers at the Silver Arches Drive-In are shown below. Find how many more hamburgers of all three kinds were sold on Saturday than on Sunday.

	Saturday	Sunday
Regular Hamburgers	593	378
Deluxe Hamburgers	419	255
Cheeseburgers	271	147

593 + 419 + 271 - 378 - 255 - 147 = ___?___

calc.______

22. The attendance at Cinema I for three nights was 518, 673, and 925. The attendance at Cinema II for the same three nights was 724, 796, and 688. Which cinema had the greater attendance? How much greater was it?

est.______
comp.______
calc.______

23. A family has a monthly income of $950. Expenses for one month are listed below. How much does the family have left at the end of the month?

Rent: $250 Food: $190 Clothing: $55

Transportation: $115 Taxes: $170

Recreation: $75 Miscellaneous: $65

calc.______

24. The table shows the number of certain electronic products sold in the United States in 1965 and 1974. Each number represents 1000 units. For example, in the table
6,245 means that 6,245 thousands or 6,245,000 phonographs were sold. Find how much more the total number in the table for 1974 is than the total for 1965.

	1965	1974
Phonographs	6,245	4,807
Radios	14,082	33,231
Television Sets	11,028	15,280
Tape Recorders	3,445	10,400

est.______

calc.______

25. At the beginning of September, Wilson School had 678 pupils. During the year, 38 new pupils entered and 49 pupils moved to other schools. Roosevelt School started the year with 713 pupils. During the year, 29 new pupils entered and 57 pupils left. Which school had the greater enrollment at the end of the year. How much greater?

calc.______

The following items were sold in a school bookstore in the months shown.

	Sept.	Oct.	Nov.	Dec.
Pencils	942	875	628	735
Ballpoint Pens	368	402	295	319
Felt Pens	276	226	198	253

26. How many more pencils than ballpoint pens were sold during the four months?

est.________

calc.________

27. How many more ballpoint pens than felt pens were sold?

calc.________

28. How many more writing instruments were sold in September than in October?

est.________

calc.________

29. The table below shows both the business and pleasure mileage of two cars for one year. How many more miles was the first car driven than the second?

	First Car	Second Car
Business	8258 miles	256 miles
Pleasure	4723 miles	5097 miles

calc.__________

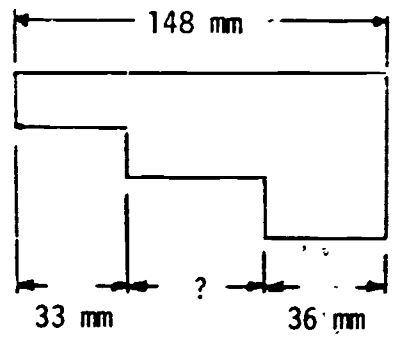
30. The table shows the size in pounds for five offensive linemen on two football teams. Which team has the heavier line? How much heavier?

	Spartans	Bruins
Right Tackle	212 lbs	205 lbs
Right Guard	197 lbs	186 lbs
Center	192 lbs	188 lbs
Left Guard	185 lbs	176 lbs
Left Tackle	207 lbs	209 lbs

est.__________

calc.__________

31. Find the unknown length in the drawing at the right.



calc.____________

32. In order to reach a vacation site, a couple went 1029 kilometers by plane. They then went a distance by jeep and completed the journey by hiking 38 kilometers. How far did they travel by jeep if the total trip was 1284 kilometers?

est.____________

calc.____________

LESSON 5C

MULTIPLICATION

EXERCISES

1. $\begin{array}{r} 19 \\ \underline{x8} \end{array}$

est.______

calc.______

2. $\begin{array}{r} 34 \\ \underline{x9} \end{array}$

est.______

calc.______

3. $\begin{array}{r} 45 \\ \underline{x7} \end{array}$

est.______

comp.______

calc.______

4. $\begin{array}{r} 58 \\ \underline{x37} \end{array}$

est. ______

calc.______

5. $\begin{array}{r} 69 \\ \underline{x83} \end{array}$

est.______

comp.______

calc.______

6. $\begin{array}{r} 96 \\ \underline{x79} \end{array}$

est.______

calc.______

7. $\begin{array}{r} 479 \\ \underline{x53} \end{array}$

est.______

calc.______

8. $\begin{array}{r} 637 \\ \underline{x89} \end{array}$

est.______

calc.______

9. $\begin{array}{r} 719 \\ \underline{x266} \end{array}$

est.______

comp.______

calc.______

10. 12 x 19 x 23

est.__________

calc.__________

11. 27 x 34 x 46 est._______

calc._______

12. 86 x 25 x 13 est._______

calc._______

13. 215 x 16 x 11 est._______

calc._______

14. 45 x 29 x 206 est._______

calc._______

15. 34 x 18 x 312 est._______

comp._______

calc._______

16. 14 x 17 x 8 x 39 est._______

calc._______

17. 52 x 9 x 83 x 79 est._______

calc._______

18. 17 x 19 x 34 x 47 est._______

calc._______

APPLICATIONS

19. The teachers in District 20 received salary increases of $390 per year. Find the total cost of the increase for 538 teachers.

    390 x 538 = ?

    est._______

    calc.______

20. A supermarket received a shipment of 64 cartons of soup. There were 24 cans in a carton. How many cans of soup were in the shipment?

    est._______
    comp.______
    calc.______

21. A family spends $48 per week for food. Find the cost of their food for a year.

    52 x 48 = ?

    est._______

    calc.______

22. A family budget allows $136 per month toward a retirement plan. How much will be paid into the plan in 15 years?

    est._______

    calc.______

23. A ski resort had a daily average of 628 registrations for the 59 days in February and March. Find the total number of persons registered over the two months.

est.______

calc.______

24. A scuba diving club chartered a boat for a trip. The cost was $75 per member. Find the total cost for the 52 club members.

est.______

calc.______

25. The auditorium of a school has 72 rows of seats. There are 46 seats in each row. How many seats are in the auditorium?

est.______

calc.______

26. A school schedules 56 English classes. The average size of each class is 28 students. How many students are enrolled in English classes?

est.______

calc.______

27. On a group flight of 248 passengers, each person is allowed 44 pounds of luggage. What is the maximum amount of luggage there can be on the flight?

est.______
comp.______
calc.______

28. Find the length of a 21-mile marathon race in yards. (1 mile = 1760 yards)

est.______

calc.______

29. A company shipped 1028 cartons. Each carton weighed 14 kilograms. Find the total number of kilograms.

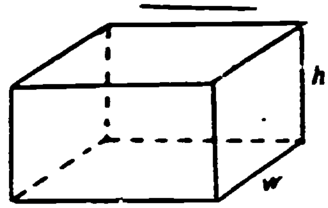
est._______

calc._______

30. In Mobile, Alabama, the average rainfall per month is 144 millimeters. Find the average yearly rainfall in millimeters.

est._______

calc._______



The formula for the volume of a rectangular solid is shown below.

Volume = Length x Width x Height

V = l x w x h

Find the value of V for the values of l, w, and h.

31. l = 54 feet

w = 29 feet

h = 18 feet

est._____ comp._____ calc.____

32. l = 1088 yards

w = 876 yards

h = 95 yards

est._____ calc.___

33. l = 128 centimeters

w = 124 centimeters

h = 96 centimeters

est.____ calc.____

34. l = 527 meters

w = 390 meters

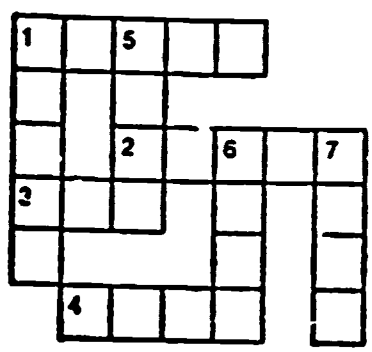
h = 223 meters

est.____ calc.___

CALCULATOR CAPERS

Work each problem. With the answer showing on the display, turn the calculator upside down to read a word. Write each word in the cross-word puzzle.

Across	Down
1. 5 x 6427	1. 75 x 601
2. 97 x 761	5. 11 x 11 x 31
3. 5 x 67	6. 4 x 1777
4. 7 x 221 x 5	7. 49 x 113



LESSON 6C

DIVISION - ZERO REMAINDER

EXERCISES

1. $9\overline{)207}$

   calc._____

2. $8\overline{)272}$

   est._____
   comp._____
   calc._____

3. $17\overline{)323}$

   calc._____

4. $13\overline{)234}$

   est._____
   comp._____
   calc._____

5. $36\overline{)864}$

   calc._____

6. $38\overline{)722}$

   est._____
   comp._____
   calc._____

7. $72\overline{)3240}$

   calc._____

8. $57\overline{)2394}$

   est._____
   comp._____
   calc._____

9. $83\overline{)58764}$

   calc._____

10. $94\overline{)16826}$

    est._____
    calc._____

11. $66\overline{)22638}$ calc.____

12. $65\overline{)16185}$ est.____ calc.____

13. $257\overline{)23644}$ calc.____

14. $108\overline{)24732}$ est.____ calc.____

15. $439\overline{)90434}$ calc.____

16. $1296\overline{)815184}$ est.____ calc.____

17. $2034\overline{)1153278}$ calc.____

18. $4375\overline{)3198125}$ est.____ calc.____

19. A basketball player scored 228 points in 12 games. Find the average number of points scored per game.

228 12 = ?

comp.______
calc.______

20. A total of 65,364 persons attended the 13 home games of a basketball team. Find the average attendance.

est.______

calc.______

21. A golfer had a total score of 288 in a 72-hole tournament. What was the golfer's average score per hole?

calc.______

22. The sum of Daphne's bowling scores for 15 games was 2130. What was her average score per game?

est.______

calc.______

23. The total cost to a club of 160 members for a charter flight to Europe was $62,880. What was the cost per member?

calc.______

24. A student took 12 tests over a semester and earned a total of 996 points. What was the student's average test score?

est.______

calc.______

25. Proceeds from the sale of a school's yearbook amounted to $7000. If a yearbook cost $8, how many were sold. comp.____ calc.____

26. A school has 3538 students and 122 teachers. Find the average number of students per teacher.

est.______

calc.______

27. A shipment of books weighs 27,300 pounds. The books are in cartons of 42 pounds each. How many cartons are in the shipment?

calc.______

28. The first United States manned suborbital space flight reached a height of 601,920 feet. What is this height expressed in miles?

est.______

calc.______

29. One aspirin tablet weighs about 325 milligrams. How many aspirin tablets weigh 4875 milligrams?

calc.______

30. One barrel of crude oil produces about 72 liters of gasoline. How many barrels are needed to produce 11,160 liters of gasoline?

est.______
comp.______
calc.______

The following formula gives the price per item if the total cost and the number of items are known.

$$\text{price per item} = \frac{\text{total cost}}{\text{number of items}} \quad \text{or} \quad p=\frac{C}{n}$$

Find the value of p for the given values of C and n.

31. C = $768
n = 128 shirts
comp.____ calc.____

32. C = $2592
n = 96 radios
est.____ calc.____

33. C = \$439,530
n = 345 motors
calc.____

34. C = \$81,648
n = 729 suits
est.____ calc.___

CALCULATOR CAPERS

Work each problem to complete the magic square. The sums in the rows, columns, and diagonals are equal.

1. 418 ÷ 19
2. 4648 ÷ 56
3. 2442 ÷ 37
4. 1616 ÷ 16
5. 41,211 ÷ 723
6. 32,617 ÷ 2509
7. 1296 ÷ 27
8. 22,909 ÷ 739
9. 78,476 ÷ 853

1	2	3
4	5	6
7	8	9

LESSON 7C

MULTIPLICATION AND DIVISION

EXERCISES

1. $24 \times 35 \div 21$

   est.________
   comp.________
   calc.________

2. $318 \times 42 \div 63$

   comp.________
   calc.________

3. $1024 \div 64 \times 309$

   est.________
   comp.________
   calc.________

4. $1980 \div 165 \times 429$

   calc.________

5. $19313 \div 89 \times 186$

   est.________

   calc.________

6. $305592 \div 428 \times 93$

   calc.________

7. 600754 ÷ 77 ÷ 94 est.______

calc.______

8. 206973 ÷ 29 ÷ 61

calc.______

9. 16920 ÷ 94 x 41 est.______

calc.______

10. 323 x 76 ÷ 34

calc.______

11. 167475 ÷ 319 x 1084 est.______

calc.______

12. 1892856 ÷ 593 ÷ 168

calc.______

13. 3575 ÷ 13 x 24 ÷ 25 est.______

calc.______

14. 182 x 57 ÷ 21 ÷ 19

calc.______

15. 1012 ÷ 22 x 106 ÷ 1219

est.______

calc.______

16. 1548 ÷ 12 x 43 x 38

calc.______

17. 2106 ÷ 39 x 118 177

est.______

calc.______

18. 67 x 438 ÷ 73 x 304

est.______
comp.______
calc.______

19. 127 x 548 ÷ 73 x 304

est.______

calc.______

20. 21808 ÷ 376 ÷ 29 x 115 x 87

calc.______

APPLICATIONS

21. Excluding interest, the payment on Jon's car is \$96 per month for 48 months. Find his monthly payment if he decides to pay for the car in 36 months.
$96 \times 48 \div 36 = \underline{?}$

est._______
comp._______
calc._______

22. The cost for 40 Ski Club members on a trip by bus will be \$36 each. How much will it cost each person if only 32 members go and the total cost is the same?

calc._______

23. An infantry division contains 13 battalions with 6 companies in each battalion. There are 200 persons in each company. The battalions are grouped into brigades of 3900 persons each. Find the number of brigades.
$200 \times 6 \times 13 \div 3900 = \underline{?}$

est._______

calc._______

24. A printing company packages 46 books in a carton. The cartons are shipped on skids with each skid holding 24 cartons. How many skids will be needed for 20,976 books?
$20976 \div 46 \div 24 = \underline{?}$

calc._______

25. The length of an auto race track is 1320 yards. How many laps (times around) are needed for a race of 300 miles? (Hint: One mile equals 1760 yards.)
$300 \times 1760 \div 1320 =$ ___?

est.________

calc.________

26. A floor with an area of 126 square feet is to be covered with tile. How many pieces of tile will be needed if each tile has an area of 81 square inches? (Hint: A square foot equals 144 square inches.)

comp.________
calc.________

A formula for computing the brake horsepower of an automobile is shown below.

$$\text{Brake Horsepower} = \frac{\text{Torque x RPM}}{5250}$$

$$H = \frac{T \times R}{5250} \text{ or } H = T \times R \div 5250$$

Find the values of <u>H</u> for the given values of <u>T</u> and <u>R</u>.

27. T = 300
R = 4550

est.________

calc.________

28. T = 250
R = 1890

calc.________

29. T = 455 est._______
    R = 2250
    calc._______

30. T = 350
    R = 2925
    calc._______

The formula for the area of a triangle is shown below.

$$A = \frac{bh}{2} \text{ or } A = b \times h \div 2$$

Find the value of A for the given values of b and h.

31. b = 15 inches est._______
    h = 8 inches comp._______
    calc._______

32. b = 224 feet
    h = 193 feet
    calc._______

33. b = 1056 meters est._______
    h = 537 meters
    calc._______

34. b = 609 centimeters
    h = 286 centimeters
    calc._______

LESSON 8C

COMBINED OPERATIONS

EXERCISES

1. 36 + 19 x 27

comp.______
calc.______

2. 15 x 24 + 187

est.______
comp.______
calc.______

3. 728 x 14 + 221

calc.______

4. 25 x 186 + 89

est.______

calc.______

5. 353 + 378 x 59

calc.______

6. 47 x 139 + 76

est.______

calc.______

7. 728 - 18 x 14

comp.______
calc.______

8. 6966 - 5022 ÷ 54

est.______

calc.______

9. 8575 - 421 x 9 + 4786

comp.______
calc.______

10. 53,104 - 743 x 56 + 13,299 est.______

calc.______

11. 29,101 - 48 x 13 x 29

calc.______

12. 4078 - 256 x 12 - 94 est.______

calc.______

13. 54,361 - 19,275 ÷ 75 x 201

calc.______

14. 327,102 - 31,428 ÷ 9 x 87 est.______

calc.______

15. 945 ÷ 15 + 38 x 19

calc.______

16. 38 + 23 x 45 - 298 est.______

calc.______

17. 3592 ÷ 449 x 123 - 798 calc.______

18. 1008 - 18 x 2924 ÷ 102 est.______

calc.______

19. 38 + 23 x 45 - 297 ÷ 9

comp._____
calc._____

20. 9288 ÷ 129 + 387 ÷ 43 x 19 est.______

calc._____

21. 353 x 59 - 278 x 50 - 1080 ÷ 30

calc._____

22. 13,271 - 147,088 ÷ 29 - 323 x 24 est.______

calc._____

APPLICATIONS

23. The yearly cost of an insurance policy from Company A is $372. A similar policy has a yearly cost of $348 from Company B. How much less is the monthly cost of a policy from Company B than from Company A?

372   12 - 348   12 = ? est._______

calc._______

24. A store purchased 25 refrigerators for $395 each and 40 color TV sets for $375 each. Find the total cost.

est._______

calc._______

25. A family used 433 kilowatt hours of electricity in one month. They were charged 6 cents for each of the first 50 kilowatt hours and 4 cents for each of the remaining kilowatt hours. Find the amount of the electric bill in cents.

50 x 6 + 383 x 4 = ? est._______

calc._______

26. Find the total number of watts for these appliances.

est.______

calc.______

Appliance	Volts	x	Amps	=	Watts
Iron	115	x	10	=	____
Refrigerator	115	x	6	=	____
Air Conditioner	115	x	7	=	____
Dishwasher	115	x	3	=	____
			Total	=	____

27. The total attendance at a school for 18 days in September was 8208. The attendance for 20 days in October was 8980. How much greater was the average attendance per day in September than in October?

est.______
comp.______
calc.______

CALCULATOR CAPERS

Work each problem to complete the magic square. The sums in the rows, columns, and diagonals are equal.

1. 58 + 29 x 17
2. 1868 - 35 x 42
3. 616 - 1162 ÷ 14
4. 21,056 - 28 x 105 x 7
5. 364 ÷ 14 + 18 x 26
6. 5734 - 82 x 53 - 876
7. 780 - 7452 ÷ 108 - 256
8. 6028 + 57 x 214 - 17,636
9. 27 x 324 - 39 x 209 - 6080 ÷ 38

1	2	3
4	5	6
7	8	9

LESSON 9C

DIVISION- NONZERO REMAINDER

EXERCISES

1. $9\overline{)317}$ est.______ comp.______ calc.______

2. $7\overline{)291}$ est.______ calc.______

3. $6\overline{)856}$ est.______ comp.______ calc.______

4. $8\overline{)623}$ est.______ calc.______

5. $32\overline{)205}$ est.______ comp.______ calc.______

6. $49\overline{)723}$ est.______ calc.______

7. $28\overline{)957}$ est.______ comp.______ calc.______

8. $3\overline{)895}$ est.______ calc.______

9. $19\overline{)438}$ est.______ comp.______ calc.______

10. $68\overline{)4190}$ est.______ calc.______

11. $53\overline{)6283}$ est.______
calc.______

12. $79\overline{)3049}$ est.______
calc.______

13. $193\overline{)5726}$ est.______
calc.______

14. $227\overline{)10558}$ est.______
calc.______

15. $329\overline{)43774}$ est.______
calc.______

16. $559\overline{)36271}$ est.______
calc.______

17. $703\overline{)24102}$ est.______
calc.______

18. $916\overline{)82583}$ est.______
calc.______

APPLICATIONS

19. A printing firm must package 10,000 books in cartons of 44 books each. How many full cartons will be needed? How many books will be left over?

est._______

calc.______

20. A service club is to contact businesses in a fund drive. There are 328 contacts to be divided among 63 members. How many contacts should each member make? How many are left over?

est._______

calc.______

21. The members of a girl scout troop are to sell tickets for a carnival. A total of 500 tickets are distributed to 36 scouts. How many should each scout get? How many are left over?

est._______

calc.______

22. The 234 members of a Boys Club are divided into basketball teams of 7 players each. How many teams are formed? How many boys are left over to be assigned to teams?

est._______

calc.______

23. The length of a board is 130 inches. Find the length of the board in feet and inches.

est._______

calc.______

24. An automobile race is 500 miles in length. The track is 3 miles in circumferenc[illegible]w many full laps (times around) does [illegible] for the race. How many extra miles [illegible]e needed?

est. ______
comp. ______
calc. ______

25. [illegible] rope 58 meters long is to be cut into 13 pieces of equal length. What is the length of each piece? How many meters long is the remaining piece of rope?

est. ______

calc. ______

26. A truck can carry 3 metric tons (3000 kilograms) of gravel. How many full truck loads are needed to haul 22,328 kilograms? How many kilograms of gravel would be left over?

est. ______

calc. ______

CALCULATOR CAPERS

A. Divide and find the remainders. Fill in the magic square with the remainders.

1. $169 \div 29$
2. $1743 \div 74$
3. $1008 \div 35$
4. $3389 \div 43$
5. $1354 \div 49$
6. $1231 \div 28$
7. $1087 \div 39$
8. $15{,}717 \div 109$
9. $2423 \div 53$

1	2	3
4	5	6
7	8	9

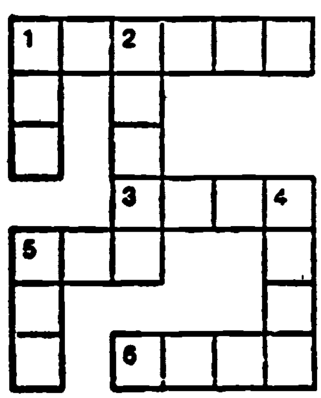
B. Find the remainder in each division problem. With the remainder showing on the display, turn the calculator upside down to read a word. Complete the crossword puzzle.

Across

1. 6,149,786 ÷ 412,213
3. 1,672,456 ÷ 12,328
5. 55,765 ÷ 973
6. 763,882 ÷ 7716

Down

1. 50,551 ÷ 1283
2. 3,911,426 ÷ 50,983
4. 7,414,900 ÷ 7349
5. 135,328 ÷ 1236



APPENDIX C

Teacher's Guide for the Non-Calculator Treatment

INTRODUCTION

As hand-held calculators have become more and more common in everyday usage, questions naturally arise regarding the effect this usage will have on students' mathematics skills. Many mathematics educators feel that students should be allowed to use calculators as an instructional aid in their mathematics curriculum.

Before meaningful decisions can be made regarding the roll hand-held calculators should play in the mathematics curriculum, controlled experimentation is necessary to provide a basis for decision-making. The purpose of this study is to gather information which will aid in predicting the benefits, if any, for the use of the hand-held calculator in Fundamentals of Mathematics classes.

This study, as designed, can be effected to extend over approximately 22 days of instruction. Included in this are two days of testing in the beginning of the study and two days of testing at the end of the study. The testing includes a pre- and posttest on attitudes in mathematics, computation with whole numbers, and problem solving with whole numbers.

The material, designed for approximately 18 lessons, focuses on the four operations with whole numbers. Estimation and problem solving are emphasized throughout. Each teacher will use this material in the class which has instruction without the hand-held calculator.

The teaching guides describe objectives and classroom activities for each lesson. In order for the results of the study to be meaningful, it is important that the participating teachers do essentially the same thing for the same lesson. Thus, it is requested that the activities described for each lesson in the teacher guide be adhered to as closely as possible.

LESSON 1

ROUNDING WHOLE NUMBERS

LESSON OBJECTIVES:

(1) To develop awareness of the importance of rounding numbers for estimation.

(2) To develop skills in rounding numbers to the nearest 10, 100, 1000, etc.

LESSON DURATION:

One day.

CLASSROOM ACTIVITIES:

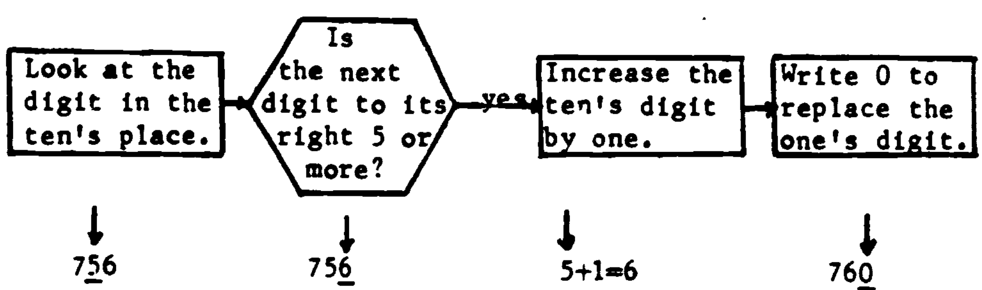
(1) Review place value to millions.

(2) Discuss the need for estimation.

(3) Discuss, as a class activity, the following examples. The flowchart method of explanation is optional.

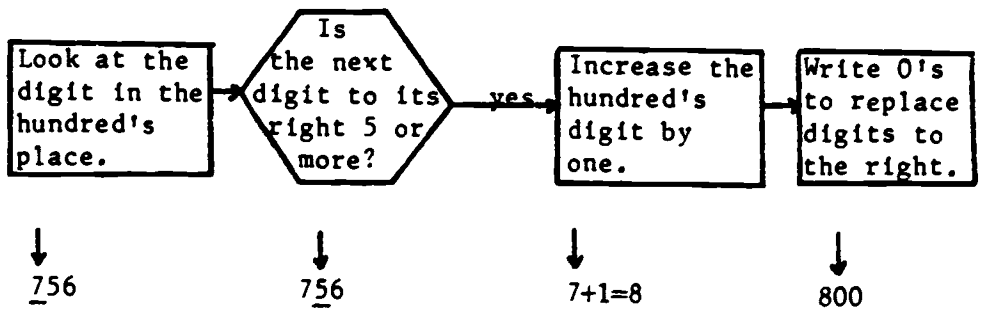
Example 1:

Round 756 to the nearest ten.



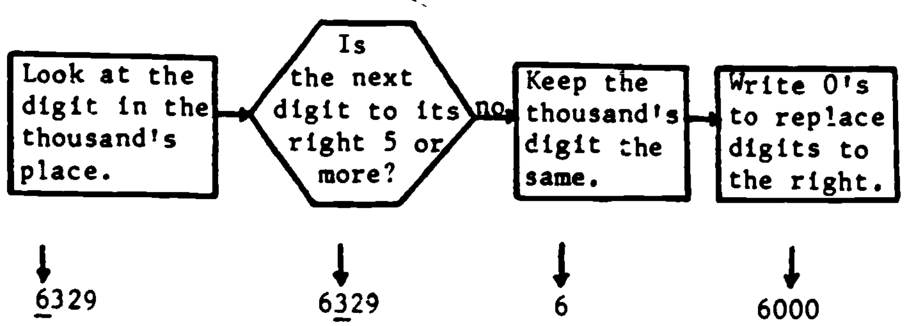
Example 2:

Round 756 to the nearest hundred.



Example 3:

Round 6329 to the nearest thousand.



Here are some other examples

Number	Round to the Nearest	Approximation
874	ten	870
3,195	hundred	3,200
64,970	thousand	65,000
64,970	ten thousand	60,000
25,000	ten thousand	30,000
73,058	thousand	73,000
550,063	hundred thousand	600,000
8,498	thousand	8,000

Example 4:

Round the number in the following sentence to the nearest ten thousand.

The number of persons attending the concert was 17,483

ten thousands	thousands		hundreds	tens	ones
1	7	,	4	8	3

20,000 ← The digit in the ten thousand's place was increased by one.

(5) Distribute the worksheets.

(6) Have students work all exercises.

LESSON 2

ADDITION

LESSON OBJECTIVES:

(1) To develop estimation skills in addition.

(2) To develop computation skills in addition.

(3) To develop problem-solving skills in addition.

LESSON DURATION:

Two days.

CLASSROOM ACTIVITIES:

First Day.

(1) Discuss the meaning of addition and computation techniques in addition.

(2) Discuss and work the following examples by rounding and estimating:

Example 1:

$$\begin{array}{r} 23 \\ +59 \\ \hline \end{array} \qquad 23 + 59 = \underline{\ ?\ }$$

Round to the nearest ten in estimating.

$$\begin{array}{rcr} 23 & \rightarrow & 20 \\ +59 & \rightarrow & +60 \\ \hline & & 80 \end{array} \longleftarrow \text{Estimate}$$

Example 2:

```
 14          14 + 28 + 47 = ___?___
 28
+47
```

Round to the nearest ten in estimating.

$$\begin{array}{rcr} 14 & \longrightarrow & 10 \\ 28 & \longrightarrow & 30 \\ \underline{+47} & \longrightarrow & \underline{+50} \\ & & 90 \longleftarrow \text{Estimate} \end{array}$$

Example 3:

A store sold 127 items on Wednesday, 215 items on Thursday, 254 items on Friday, and 346 items on Saturday. How many items did the store sell in all on these four days?

```
 127         127 + 215 + 254 + 346 = ___?___
 215
 254
+346
```

Round to the nearest hundred in estimating.

$$\begin{array}{rcr} 127 & \longrightarrow & 100 \\ 215 & \longrightarrow & 200 \\ 254 & \longrightarrow & 300 \\ \underline{+346} & \longrightarrow & \underline{+300} \\ & & 900 \longleftarrow \text{Estimate} \end{array}$$

Example 4:

```
 17,283      17,283 + 6,856 + 32,050 = ___?___
  6,856
+32,050
```

Round each number according to its <u>largest</u> place value.

$$\begin{array}{rcrl} 17{,}283 & \rightarrow & 20{,}000 & \text{Rounded to ten thousands} \\ 6{,}856 & \rightarrow & 7{,}000 & \text{Rounded to thousands} \\ \underline{+32{,}050} & \rightarrow & \underline{+30{,}000} & \text{Rounded to ten thousands} \\ & & 57{,}000 & \text{Estimate} \end{array}$$

(3) Have students round and estimate Exercises 1-50.

Second Day.

(1) Discuss and work Examples 1-4. Compare the results with the previous estimations.

(2) Distribute the worksheets.

(3) Have students work Exercises 1, 5, 7, 10, 13, 16, 19, 23, 25, 28, 30, 32, 33, 35, 39, 42, 44, 46, 48, and 50.

(4) If students finish these exercises early, allow them to work on others of their choice for bonus credit.

LESSON 3

SUBTRACTION

LESSON OBJECTIVES:

(1) To develop estimation skills in subtraction.

(2) To develop computation skills in subtraction.

(3) To develop problem-solving skills in subtraction.

LESSON DURATION:

Two Days.

CLASSROOM ACTIVITIES:

First Day.

(1) Discuss the meaning of subtraction and computation techniques in subtraction.

(2) Discuss and work, as a class activity, the following examples by rounding and estimating:

Example 1:

$$\begin{array}{r} 56 \\ -\underline{29} \end{array} \qquad 56 - 29 = \underline{\ ?\ }$$

Round to the nearest ten in estimating.

$$\begin{array}{rcr} 56 & \rightarrow & 60 \\ -\underline{29} & \rightarrow & -\underline{30} \\ & & 30 \leftarrow \text{Estimate} \end{array}$$

Example 2:

$$\begin{array}{r} 73{,}205 \\ \underline{-9{,}476} \end{array} \qquad 73{,}205 - 9{,}476 = \underline{\ ?\ }$$

Round each number according to its <u>largest</u> place value.

$$\begin{array}{rcr} 73{,}205 & \longrightarrow & 70{,}000 \\ \underline{-9{,}476} & \longrightarrow & \underline{-9{,}000} \\ & & 61{,}000 \longleftarrow \text{Estimate} \end{array}$$

Use other examples as needed for understanding before students work individually.

(2) Distribute the worksheets.

(3) Have students round and estimate Exercises 1-37.

<u>Second Day</u>.

(1) Work and discuss Examples 1 and 2. Compare the results with the previous estimations. Discuss other examples as needed for understanding.

(2) Have students work Exercises 1, 5, 6, 9, 11, 14, 16, 17, 19, 21, 23, 25, 26, 29, 30, 33, 34, 35, 36, and 37.

(3) If students finish these exercises early, allow them to work on others of their choice for bonus credit.

LESSON 4

ADDITION AND SUBTRACTION

LESSON OBJECTIVES:

(1) To develop estimation skills in addition-subtraction combination problems.

(2) To develop computation skills in addition-subtraction combination problems.

(3) To develop problem-solving skills in addition-subtraction combination problems.

LESSON DURATION:

Two Days.

CLASSROOM ACTIVITIES:

<u>First Day</u>.

(1) Work and discuss the following examples by rounding and estimating. Emphasize that the order of operations is from left to right.

Example 1:

437 - 192 + 286 = __?__

Round to the nearest hundred.

$$\begin{array}{ccccc} 437 & - & 192 & + & 286 \\ \downarrow & & \downarrow & & \downarrow \\ 400 & - & 200 & + & 300 \end{array}$$

$200 + 300 = 500$ Estimate

Example 2:

$2943 - 856 + 461 - 1017 = \underline{\ ?\ }$

Round each number according to its largest place value.

$$\begin{array}{ccccccc} 2943 & - & 856 & + & 461 & - & 1017 \\ \downarrow & & \downarrow & & \downarrow & & \downarrow \\ 3000 & - & 900 & + & 500 & - & 1000 \end{array}$$

$$\underbrace{3000 - 900}_{2100} + 500 - 1000$$

$$\underbrace{2100 + 500}_{2600} - 1000$$

$$2600 - 1000 \quad \text{Estimate}$$

Discuss other examples as necessary to achieve understanding.

(2) Distribute the worksheets.

(3) Have students round and estimate Exercises 2-32 (even).

<u>Second Day</u>.

(1) Work and discuss Examples 1 and 2. Compare the results with the previous estimations. Discuss other examples as needed for understanding.

(2) Have students work Exercises 2, 4, 7, 12, 15, 17, 19, 21, 23, 24, 25, 26, 29, 30, and 31.

(3) If students finish these exercises early, allow them to work on others of their choice for bonus credit.

LESSON 5

MULTIPLICATION

LESSON OBJECTIVES:

(1) To develop estimation skills in multiplication.

(2) To develop computation skills in multiplication.

(3) To develop problem-solving skills in multiplication.

LESSON DURATION:

Two Days.

CLASSROOM ACTIVITIES:

First Day.

(1) Discuss and work the following examples by rounding and estimating.

Example 1:

$$\begin{array}{r} 18 \\ \times\ \underline{13} \end{array} \qquad 18 \times 13 = \underline{\ ?\ }$$

Round to the nearest ten in estimating.

$$\begin{array}{rcr} 18 & \rightarrow & 20 \\ \times\ \underline{13} & \rightarrow & \times\ \underline{10} \\ & & 200 \leftarrow \text{Estimate} \end{array}$$

Example 2:

$$\begin{array}{r} 48 \\ \times\ \underline{12} \end{array} \qquad 12 \times 48 = \underline{\ ?\ }$$

Round to the nearest ten in estimating.

$$\begin{array}{rcr} 48 & \rightarrow & 50 \\ \times\ \underline{12} & \rightarrow & \times\ \underline{10} \\ & & 500 \leftarrow \text{Estimate} \end{array}$$

Example 3:

$21 \times 36 \times 109 = \underline{\ ?\ }$

Round each number according to its largest place value.

$$\begin{array}{l} 21 \times 36 \times 109 \\ \downarrow \quad\ \ \downarrow \quad\ \ \downarrow \\ \underbrace{20 \times 40}_{800} \times 100 \\ 800 \quad \times 100 = 80{,}000 \leftarrow \text{Estimate} \end{array}$$

Discuss other examples as needed for understanding.

(2) Distribute the worksheets.

(3) Have students round and estimate Exercises 1-34.

Second Day.

(1) Work and discuss Examples 1-3. Compare the results with the previous estimations. Discuss other examples as needed for student understanding of the process and technique of multiplication.

(2) Distribute the worksheets.

(3) Have students work Exercises 2-34 (even).

(4) If students finish these exercises early, allow them to work on others of their choice for bonus credit.

LESSON 6

DIVISION—ZERO REMAINDER

LESSON OBJECTIVES:

(1) To develop estimation skills in division.

(2) To develop computation skills in division.

(3) To develop problem-solving skills in division.

LESSON DURATION:

Two Days.

CLASSROOM ACTIVITIES:

<u>First Day</u>.

(1) Discuss and work, as a class activity, the following examples by rounding and estimating:

Example 1:

$34\overline{)442}$ 442 34 = ___?___

Round each number according to its largest place value.

$34 \longrightarrow 30$ $442 \longleftarrow 400$

$$\begin{array}{r} 13 \leftarrow \text{Estimate} \\ 3\cancel{0}\overline{)40\cancel{0}} \end{array}$$

Example 2:

$24\overline{)10296}$ - $10296 \div 24 = \underline{\ ?\ }$

Round each number according to its largest place value.

$24 \longrightarrow 20$ $10296 \longleftarrow 10000$

$$\begin{array}{r} 500 \longleftarrow \text{Estimate} \\ 2\not{0}\,\overline{)\,1000\not{0}} \end{array}$$

Discuss other examples as needed for understanding.

(2) Distribute the worksheets.

(3) Have students work Exercises 2-34 (even) by rounding and estimating.

<u>Second Day</u>.

(1) Discuss and work Examples 1 and 2 as a class activity.

(2) Distribute the worksheets.

(3) Have students work Exercises 1-8, 10, 12, 19, 21, 22, 25, 26, 28, 30, 32, and 34.

(4) If students finish these exercises early, allow them to work on others of their choice for bonus credit.

LESSON 7

MULTIPLICATION AND DIVISION

LESSON OBJECTIVES:

(1) To develop estimation skills in multiplication-division combination problems.

(2) To develop computation skills in multiplication-division combination problems.

(3) To develop problem-solving skills in multiplication-division combination problems.

LESSON DURATION:

Two Days.

CLASSROOM ACTIVITIES:

<u>First Day</u>.

(1) Discuss and work the following examples by rounding and estimating. Emphasize that the order of operations is from left to right.

Example 1:

$12 \times 26 \div 24 = \underline{\ ?\ }$

Round to the nearest ten in estimating.

$12 \times 26 \div 24$

$\underbrace{10 \times 30} \div 20$

$\underbrace{30\cancel{0} \div 2\cancel{0}}$

15 Estimate

Example 2:

$6003 \div 87 \times 24 \div 36 = \underline{\ ?\ }$

Round each number according to its largest place value.

$$6003 \div 87 \times 24 \div 36$$
$$\downarrow \quad 10\downarrow \quad \downarrow \quad \downarrow$$
$$\underbrace{600\cancel{0} \div \cancel{0}\cancel{0}} \times 20 \div 40$$
$$\underbrace{60 \quad \times 20} \div 40$$
$$\underbrace{120\cancel{0} \quad \div \quad 4\cancel{0}}$$

30 Estimate

Discuss other examples as necessary for understanding.

(2) Distribute the worksheets.

(3) Have students work Exercises 1-33 (odd) by rounding and estimating.

<u>Second Day</u>.

(1) Discuss and work Examples 1 and 2, as a class activity. Discuss other examples as needed.

(2) Distribute the worksheets.

(3) Have students work Exercises 1, 2, 3, 7, 18, 21, 22, 24, 25, 27, 31, and 34.

(4) If students finish these exercises early, allow them to work on others of their choice for bonus credit.

LESSON 8

COMBINED OPERATIONS

LESSON OBJECTIVES:

(1) To develop estimation skills in combined operations problems involving addition, subtraction, multiplication, and division.

(2) To develop computation skills in combined operations probems involving addition, subtraction, multiplication, and division.

(3) To develop problem-solving skills in combined operations problems involving addition, subtraction, multiplication, and division.

LESSON DURATION:

Two Days.

CLASSROOM ACTIVITIES:

First Day.

(1) Discuss and work, as a class activity, the following examples by rounding and estimating. Emphasize that multiplication and division must be done from left to right before addition and subtraction is done from left to right. Show that parentheses may be used to help with the order of operations.

Example 1:

528 + 24 x 97 = ?

Round each number according to its largest place value. Insert parentheses to show that operations are to be done first.

$$528 + 24 \times 97$$
$$\downarrow \qquad \downarrow \qquad \downarrow$$
$$500 + (\underbrace{20 \times 100})$$
$$\underbrace{500 + 2000}$$
$$2500 \leftarrow \text{Estimate}$$

Example 2:

$4086 - 42 \times 28 + 965 = \underline{\ ?\ }$

Round off each number and insert parentheses.

$$4086 - 42 \times 38 + 965$$
$$\downarrow \qquad \downarrow \qquad \downarrow \qquad \downarrow$$
$$4000 - (\underbrace{40 \times 40}) + 1000$$
$$\underbrace{4000 - 1600} + 1000$$
$$\underbrace{2400 + 1000}$$
$$3400 \leftarrow \text{Estimate}$$

(2) Distribute the worksheets.

(3) Have students work Exercises 2-22 (even) and 23-27 by rounding and estimating.

Second Day.

(1) Discuss and work, as a class activity, Examples 1 and 2. Compare the results with the previous estimations. Discuss other examples as needed for understanding

(2) Have students work Exercises 1, 2, 7, 8, 9, 12, 15, 19, 23, 24, 26, and 27.

(3) If students finish these exercises early, allow them to work on others of their choice for bonus credit.

LESSON 9

DIVISION NONZERO REMAINDER

LESSON OBJECTIVES:

(1) To improve estimation skills in division.

(2) To improve computation skills in division.

(3) To improve problem-solving skills in division.

LESSON DURATION:

Two Days.

CLASSROOM ACTIVITIES:

First Day.

(1) Discuss and work, as a class activity, the following example by rounding and estimating.

Example.

$42 \overline{)238}$ $238 \div 42$

Round each number according to its largest place value.

$42 \longrightarrow 40$ $238 \longrightarrow 200$

$$\begin{array}{r} 5 \leftarrow \text{Estimate} \\ 4\emptyset \overline{)20\emptyset} \end{array}$$

Discuss other examples as necessary for studnet understanding.

(2) Distribute the worksheets.

(3) Have students round and estimate Exercises 1-26.

Second Day.

(1) Discuss and work, as a class activity, the example given above. Compare the result with the previous estimation. Discuss other examples as needed for understanding.

(2) Distribute the worksheets.

(3) Have students work Exercises 1, 3, 5, 7, 9, 20, 22, 23, 24, and 25.

(4) If students finish these exercises early, allow them to work on others of their choice for bonus credit.

APPENDIX D

Lessons for the Non-Calculator Treatment

LESSON 1

ROUNDING WHOLE NUMBERS

EXERCISES

Round to the nearest ten.

1.	89	2.	73	3.	45	4.	96
5.	263	6.	578	7.	981	8.	695
9.	4384	10.	5741	11.	3286	12.	9612
13.	70,823	14.	29,576	15.	47,209	16.	76,814

Round to the nearest hundred.

17.	263	18.	578	19.	981	20.	695
21.	4384	22.	5741	23.	3286	24.	9612
25.	70,823	26.	29,576	27.	47,209	28.	76,814

Round to the nearest thousand.

29.	4834	30.	5741	31.	2534	32.	9612
33.	3286	34.	5491	35.	70,823	36.	29,576
37.	47,209	38.	580,000	39.	80,057	40.	555,555

Round to the nearest ten thousand.

41.	70,823	42.	29,576	43.	47,209	44.	580,000
45.	74,800	46.	800,561	47.	84,631	48.	555,555

Round to the nearest hundred thousand.

49. 580,000 50. 555,555 51. 800,561 52. 251,999

53. 109,000 54. 190,009 55. 671,256 56. 781,010

Round the number in each sentence to the given place.

57. The club has 493 dollars in its treasury. (nearest hundred)

58. The distance between two cities is 87 kilometers. (nearest ten)

59. The factory has 3254 workers. (nearest thousand)

60. 268,000 recordings of the song have been sold. (nearest ten thousand)

61. There are 619 pupils in the school. (nearest ten)

62. A family had an income of $17,824 for one year. (nearest ten thousand)

63. Erika's mother bought 83 balloons for the party. (nearest ten)

64. The number of refrigerators produced in one year was 5,982,000. (nearest million)

LESSON 2

ADDITION

EXERCISES

1. 19 + 16

est.______
comp.______

2. 17 + 15

est.______

3. 18 + 19

est.______

4. 13 + 25

est.______

5. 29 + 34

est.______
comp.______

6. 56 + 97

est.______

7. 13 + 28

est. ______
comp.______

8. 89 + 74

est.______

9. $\begin{array}{r} 92 \\ \underline{+47} \end{array}$

est.______

10. $\begin{array}{r} 51 \\ +88 \\ \hline \end{array}$

est.______
comp.______

11. $\begin{array}{r} 29 \\ +76 \\ \hline \end{array}$

est.______

12. $\begin{array}{r} 59 \\ +81 \\ \hline \end{array}$

est.______
comp.______

13. 18 + 15 + 17

est.______
comp.______

14. 19 + 19 + 19

est.______

15. 18 + 13 + 15

est.______

16. 12 + 38 + 87

est.______
comp.______

17. $\begin{array}{r} 23 \\ 19 \\ +42 \\ \hline \end{array}$

est.______

18. $\begin{array}{r} 68 \\ 97 \\ +51 \\ \hline \end{array}$

est.______

19. $\begin{array}{r} 71 \\ 34 \\ +52 \\ \hline \end{array}$

est.______
comp.______

20. $\begin{array}{r} 25 \\ 75 \\ +50 \\ \hline \end{array}$

est.______

21. $\begin{array}{r} 5,286 \\ +7,823 \\ \hline \end{array}$

est.______

22. 25,682
+ 7,981

est.______

23. 12,809
+164,201

est.______
comp.______

24. 17,289
+ 9,858

est.______

25. 8,712
3,196
+41,839

est.______
comp.______

26. 23,408
57,196
+62,100

est.______

27. 78,556
21,008
+39,927

est.______

28. 438,672
+753,995

est.______
comp.______

29. 6 + 29 + 5,397 + 86 + 409

est.______

30. 23,438 + 9,817 + 67 + 53

est.______
comp.______

31. 37 + 5,273 + 569 + 8 est.______

32. 867 + 4,238 + 59 + 3,824 est.______
comp.______

APPLICATIONS

The chart below shows the number of employees in the U.S. Postal Service for a recent year.

Postal Clerks	286,384
City Carriers	212,561
Rural Carriers	50,309
Mail Handlers	43,303
Postal Supervisors	38,102
Postmasters	30,731
Maintenance Service Workers	23,962
Motor Vehicle Operators	6,466
Vehicle Maintenance Workers	5,823
Protection Force	1,919
Postal Inspectors	1,589
Other	5,251

Find the total number of employees in each exercise below.

33. City Carriers and Rural Carriers

est.______
comp.______

34. Protection Force and Postal Inspectors

est.______

35. Postal Supervisors and Postmasters

est.______
comp.______

36. All maintenance workers

est.______

37. Postal Clerks and Mail Handlers

est.______

38. Total number of postal employees

est.______

The chart below shows how many students each mathematics teacher of West End School has for each class period.

	Periods						
	1	2	3	4	5	6	7
G. Brown	25	0	28	19	0	23	26
R. Dodd	21	27	0	31	0	24	28
D. Grove	20	26	32	0	19	0	27
F. Sanchez	17	28	0	26	29	23	0
M. Kimball	24	24	25	18	0	27	0
A. Pierce	30	29	0	15	0	26	27
T. Young	19	23	25	0	31	29	0

39. Find the total number of students in M. Kimball's classes.

est.______
comp.______

40. Find the total number of students in T. Young's classes.

est.______

41. Find the total number of students in D. Grove's classes. est.______

42. Find the total number of students in G. Brown's classes.

est.______

comp.______

43. Find the number of students who take math the first period.

est.______

44. Find the number of students who take math the fourth period.

est.______

comp.______

45. Find the number of students who take math the sixth period.

est.______

46. Find the number of students who take math the second period.

est.______

comp.______

The chart below shows the number of calories in some foods.

Food	Calories
Beef Roast, 3-oz. serving	180
Sirloin Steak, 3-oz. serving	185
Pork Tenderloin, 3-oz. serving	215
Chicken, 3-oz. serving	140
Codfish, 3-oz. serving	145
Tuna, 3-oz. serving (in oil)	170
Green Beans, ½ cup	15
Lettuce, ½ head	35
Celery, 3 stalks	10
Radishes, 4 small	5
Tomato, 1 small	20
Potato (baked) 1 medium	90
Apple, 1 medium	80
Banana, 1 medium	100
Dates, 3 or 4	85
Orange, 1 medium	65
Watermelon, 1 slice	115
Pineapple, ½ cup	40
Strawberries, ½ cup	30
Milk, 1 glass	166
Cola Beverage, 1 glass	105
Coffee, 1 cup with cream	30

In exercises 47 - 50, find the total number of calories in each meal.

47. 3 ounces of chicken
4 radishes
½ cup of green beans
½ cup of strawberries
1 glass of milk

est.______

49. 3 ounces of tuna
3 stalks of celery
4 small radishes
1 medium orange

est.______

comp.______

48. 3 ounces of codfish
½ head of lettuce
1 small tomato
1 slice of watermelon
1 cup of coffee with cream

est.______

50. 3 ounces of roast beef
1 medium baked potato
½ cup of pineapple
1 glass of cola

est.______
comp.______

LESSON 3

SUBTRACTION

EXERCISES

1. 73 - 59

est.______
comp.______

2. 96 - 57

est.______

3. 81 - 59

est.______

4. 67 - 25

est.______

5. 812 - 675

est.______
comp.______

6. 786 - 421

est.______
comp.______

7. 128 - 89

est.______

8. 237 - 148

est.______

9. $\begin{array}{r} 506 \\ \underline{-359} \end{array}$

est.______
comp.______

10. $\begin{array}{r} 713 \\ \underline{-285} \end{array}$

est.______

11. $\begin{array}{r} 999 \\ \underline{-751} \end{array}$

est.______
comp.______

12. $\begin{array}{r} 901 \\ \underline{-698} \end{array}$

est.______

13. $\begin{array}{r} 6432 \\ \underline{-2587} \end{array}$

est.______

14. $\begin{array}{r} 12,417 \\ \underline{-\ 9,528} \end{array}$

est.______
comp.______

15. $\begin{array}{r} 42,037 \\ \underline{-38,928} \end{array}$

est.______

16. $\begin{array}{r} 10,000 \\ \underline{-7,846} \end{array}$

est.______
comp.______

17. $\begin{array}{r} 23,502 \\ \underline{-19,738} \end{array}$

est.______
comp.______

18. $\begin{array}{r} 92,175 \\ \underline{-47,246} \end{array}$

est.______

19. $\begin{array}{r} 328,912 \\ \underline{-117,456} \end{array}$

est.______
comp.______

20. $\begin{array}{r} 3,298,016 \\ \underline{-1,456,729} \end{array}$

est.______

APPLICATIONS

21. In 1950, there were 4,931 golf courses in the United States. There were 10,188 in 1970. How many more were there in 1970?

est.______
comp.______

22. In 1950, there were 6,325 bowling alleys in the United States. By 1970, there were 9,140. How many more were there in 1970?

est.______

23. The Oakland Raiders scored 355 points in a recent season. They had a total of 228 points scored against them. How many more points did Oakland score than their opponents?

est.______
comp.______

24. In a recent year 1,313,000 persons stayed overnight in Yellowstone National Park. That same year 787,000 persons stayed overnight in Grand Canyon National Park. Find the difference between the two numbers.

est.______

25. There were 2664 state parks in the United States in 1960. The number increased to 3245 by 1970. How many more state parks were there in 1970 than in 1960?

est.______
comp.______

The table shows weekly earnings for workers in certain occupations for five years.

Occupations	1970	1971	1972	1973	1974
Professional and Technical	181	189	192	212	228
Managers and Administrators	190	200	214	238	250
Salesworkers	133	141	151	163	172
Clerical	109	115	121	130	140
Craftspeople	157	167	172	195	211
Non-farm - Laborers	110	117	123	138	149

26. How much more per week did a professioanl make in 1974 than in 1970?

est.______
comp.______

27. In 1973, how much more per week did a manager make than a craftsperson?

est.______

28. Find the increase in salesworkers' weekly earnings from 1970 to 1974.

est.______

29. Find the difference between the highest and lowest earnings in the table for 1972.

est.______
comp.______

34. The John Hancock building in Chicago is is 1107 feet high. The World Trade Center in New York is 1250 feet high. Find the difference between their heights.

:0 - 1107 = ? est.____ comp.____

35. In 1960, there were 1,015, 461 acres of city and coun parks in the U.S. In 1970, there were 9,785 acres. How much did the area decrease?

est.____
comp.____

36. The average rainfall in New York is 108 centimeters. In Los Angeles it is 37 centimeters. How much greater is the amount in New York than in Los Angeles?

est.____
comp.____

37. The airline distance from New York to Honolulu by way of San Francisco is 7950 kilometers. The distance from New York to San Francisco is 4118 kilometers. Find the distance from San Francisco to Honolulu.

est.____
comp.____

LESSON 4

ADDITION AND SUBTRACTION

EXERCISES

1. 86 - 19 - 28

2. 314 + 59 - 178 est.________ comp.________

3. 386 - 72 - 83

4. 1228 - 914 + 16 est.________ comp.________

5. 3723 + 1519 - 2086

6. 13,293 - 5,408 + 399 est.________

7. 6[illegible],482 - 12,438 - 17,937

8. 536,928 + 47,586 - 277,923 est.________

9. 228 - 74 + 139 - 213

10. 1073 - 827 - 69 + 526 est.________

11. 158 - 107 + 93 - 29

12. 433 - 208 - 87 + 329 est.________
comp.________

13. 704 + 593 - 217 - 378

14. 326 - 497 + 1091 - 324 est.________

This formula gives the profit of a business based on income and expenses.

Profit = Income - Expenses

$$P = I - E$$

Find the value of P for the given values of I and E.

30. I = $26,428 est.______
E = 19,792 comp._____

31. I = $328,402 est.______
E = 237,539

32. I = $2,472,341 est.______
E = 2,128,574

33. I = $868,115 est.______
E = 753,437 comp._____

15. 137 - 61 - 19 + 28 est._______
comp._______

16. 243 - 76 + 23 + 109 est._______

17. 2056 + 1217 + 5948 - 3279 - 983
est._______
comp._______

18. 278 + 916 - 432 + 187 - 365 - 78
est._______

APPLICATIONS

19. The owner of a hot dog stand buys $54 worth of hot dogs and $18 worth of buns. The discount is $12. Find the total bill.

est.______
comp.______

20. At the beginning of June, the merchandise of a business was valued at $35,728. During the month $21,375 worth of merchandise was sold. Also, $12,529 worth of additional merchandise was purchased. Find the value at the end of June.

35,728 - 21,375 + 12,529 = ___?___
est.______

21. Sales of hamburgers at the Silver Arches Drive-In are shown below. Find how many more hamburgers of all three kinds were sold on Saturday than on Sunday.

	Saturday	Sunday
Regular Hamburgers	593	378
Deluxe Hamburgers	419	255
Cheeseburgers	271	147

593 + 419 + 271 - 378 - 255 - 147 = ___?___
est.______
comp.______

22. The attendance at Cinema I for three nights was 518, 673, and 925. The attendance at Cinema II for the same three nights was 724, 796, and 688. Which cinema had the greater attendance? How much greater was it?

est.______

23. A family has a monthly income of $950. Expenses for one month are listed below. How much does the family have left at the end of the month?

Rent: $250 Food: $190 Clothing: $55

Transportation: $115 Taxes: $170

Recreation: $75 Miscellaneous: $65

est.______

comp.______

24. The table shows the number of certain electronic products sold in the United States in 1965 and 1974. Each number represents 1000 units. For example, in the table 6,245 means that 6,245 thousands or 6,245,000 phonographs were sold. Find how much more the total number in the table for 1974 is than the total for 1965.

	1965	1974
Phonographs	6,245	4,807
Radios	14,082	33,231
Television Sets	11,028	15,280
Tape Recorders	3,445	10,400

est.______

25. At the beginning of September, Wilson School had 678 pupils. During the year, 38 new pupils entered and 49 pupils moved to other schools. Roosevelt School started the year with 713 pupils. During the year, 29 new pupils entered and 57 pupils left. Which school had the greater enrollment at the end of the year. How much greater?

est.______

comp.______

The following items were sold in a school bookstore in the months shown.

	Sept.	Oct.	Nov.	Dec.
Pencils	942	875	628	735
Ballpoint Pens	368	402	295	319
Felt Pens	276	226	198	253

26. How many more pencils than ballpoint pens were sold during the four months?

est._______
comp._______

27. How many more ballpoint pens than felt pens were sold?

est._______

28. How many more writing instruments were sold in September than in October?

est._______

29. The table shows both the business and pleasure mileage of two cars for one year. How many more miles was the first car driven than the second?

	First Car	Second Car
Business	8258 miles	256 miles
Pleasure	4723 miles	5097 miles

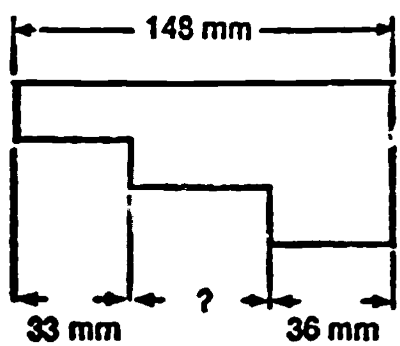
est._______
comp._______

30. The table shows the size in pounds for five offensive linemen on two football teams. Which team has the heavier line? How much heavier?

	Spartans	Bruins
Right Tackle	212 lbs	205 lbs
Right Guard	197 lbs	186 lbs
Center	192 lbs	188 lbs
Left Guard	185 lbs	176 lbs
Left Tackle	207 lbs	209 lbs

est._______
comp._______

31. Find the unknown length in the drawing at the right.



est._______
comp._______

32. In order to reach a vacation site, a couple went 1029 kilometers by plane. They then went a distance by jeep and completed the journey by hiking 38 kilometers. How far did they travel by jeep if the total trip was 1284 kilometers?

est._______

LESSON 5

MULTIPLICATION

EXERCISES

1. 19 x8

est.______

2. 34 x9

est.______
comp.______

3. 45 x7

est.______

4. 58 x37

est.______
comp.______

5. 69 x83

est.______

6. 96 x79

est.______
comp.______

7. 479 x53

est.______

8. 637 x89

est.______
comp.______

9. 719 x266

est.______

10. 12 x 19 x 23

est.__________
comp.__________

11. 27 x 34 x 46 est.________

12. 86 x 25 x 13 est.________
comp.________

13. 215 x 16 x 11 est.________

14. 45 x 29 x 206 est.________
comp.________

15. 34 x 18 x 312 est.________

16. 14 x 17 x 8 x 39 est.________
comp.________

17. 52 x 9 x 83 x 79 est.________

18. 17 x 19 x 34 x 47 est.________
comp.________

APPLICATIONS

19. The teachers in District 20 received salary increases of $390 per year. Find the total cost of the increase for 538 teachers.

    390 x 538 = ? est.______

20. A supermarket received a shipment of 64 cartons of soup. There were 24 cans in a carton. How many cans of soup were in the shipment?

    est.______
    comp.______

21. A family spends $48 per week for food. Find the cost of their food for a year.

    52 x 48 = ? est.______

22. A family budget allows $136 per month toward a retirement plan. How much will be paid into the plan in 15 years?

    est.______
    comp.______

23. A ski resort had a daily average of 628 registrations for the 59 days in February and March. Find the total number of persons registered over the two months.

est._______

24. A scuba diving club chartered a boat for a trip. The cost was $75 per member. Find the total cost for the 52 club members.

est._______
comp.______

25. The auditorium of a school has 72 rows of seats. There are 46 seats in each row. How many seats are in the auditorium?

est._______

26. A school schedules 56 English classes. The average size of each class is 28 students. How many students are enrolled in English classes?

est._______
comp.______

27. On a group flight of 248 passengers, each person is allowed 44 pounds of luggage. What is the maximum amount of luggage there can be on the flight?

est._______

28. Find the length of a 21-mile marathon race in yards. (1 mile = 1760 yards)

est._______
comp.______

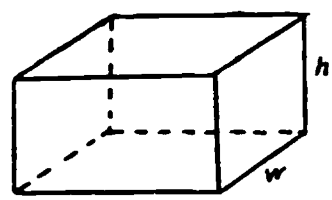
29. A company shipped 1028 cartons. Each carton weighed 14 kilograms. Find the total number of kilograms.

est.______

30. In Mobile, Alabama, the average rainfall per month is 144 millimeters. Find the average yearly rainfall in millimeters.

est.______
comp.______

The formula for the volume of a rectangular solid is shown below.



Volume = Length x Width x Height
V = l x w x h

Find the value of V for the values of l, w, and h.

31. l = 54 feet
w = 29 feet
h = 18 feet
est.____

32. l = 1088 yards
w = 876 yards
h = 95 yards
est.____ comp.____

33. l = 128 centimeters
w = 124 centimeters
h = 96 centimeters
est.____

34. l = 527 meters
w = 390 meters
h = 223 meters
est.____ comp.____

LESSON 6

DIVISION - ZERO REMAINDER

EXERCISES

1. 9) 207 comp.______

2. 8) 272 est.______ comp.______

3. 17) 323 comp.______

4. 13) 234 est.______ comp.______

5. 36) 864 comp.______

6. 38) 722 est.______ comp.______

7. 72) 3240 comp.______

8. 57) 2394 est.______ comp.______

9. 83) 58764

10. 94) 16826 est.______ comp.______

11. $66\overline{)22638}$

12. $65\overline{)16185}$ est.______
comp._____

13. $257\overline{)23644}$

14. $108\overline{)24732}$ est.______

15. $439\overline{)90434}$

16. $1296\overline{)815184}$ est.______

17. $2034\overline{)1153278}$

18. $4375\overline{)3198125}$ est.______

19. A basketball player scored 228 points in 12 games. Find the average number of points scored per game.

228 12 = ?

comp.______

20. A total of 65,364 persons attended the 13 home games of a basketball team. Find the average attendance.

est.______

21. A golfer had a total score of 288 in a 72-hole tournament. What was the golfer's average score per hole?

comp.______

22. The sum of Daphne's bowling scores for 15 games was 2130. What was her average score per game?

est.______
comp.______

23. The total cost to a club of 160 members for a charter flight to Europe was $62,880. What was the cost per member?

24. A student took 12 tests over a semester and earned a total of 996 points. What was the student's average test score?

est.______

25. Proceeds from the sale of a school's yearbook amounted to $7000. If a yearbook cost $8, how many were sold. comp.____

26. A school has 3538 students and 122 teachers. Find the average number of students per teacher.

est.______
comp.______

27. A shipment of books weighs 27,300 pounds. The books are in cartons of 42 pounds each. How many cartons are in the shipment?

28. The first United States manned suborbital space flight reached a height of 601,920 feet. What is this height expressed in miles?

est.______
comp.______

29. One aspirin tablet weighs about 325 milligrams. How many aspirin tablets weigh 4875 milligrams?

comp.______

30. One barrel of crude oil produces about 72 liters of gasoline. How many barrels are needed to produce 11,160 liters of gasoline?

est.______
comp.______

The following formula gives the price per item if the total cost and the number of items are known.

$$\text{price per item} = \frac{\text{total cost}}{\text{number of items}} \quad \text{or } p = \frac{C}{n}$$

Find the value of p for the given values of C and n.

31. C = \$768
n = 128 shirts

32. C = \$2592
n = 96 radios

est.____ comp.____

33. C = \$439,530
n = 345 motors

34. C = \$81,648
n = 729 suits
est.____ comp.____

LESSON 7

MULTIPLICATION AND DIVISION

EXERCISES

1. 24 x 35 ÷ 21 est._______ comp._______

2. 318 x 42 ÷ 63 comp._______

3. 1024 ÷ 64 x 309 est._______ comp._______

4. 1980 ÷ 165 x 429

5. 19313 ÷ 89 x 186 est._______

6. 305592 ÷ 428 x 93

7. 600754 ÷ 77 ÷ 94 est.________
comp.________

8. 206973 ÷ 29 ÷ 61

9. 16920 ÷ 94 x 41 est.________

10. 323 x 76 ÷ 34

11. 167475 ÷ 319 x 1084 est.________

12. 1892856 ÷ 593 ÷ 168

13. 3575 ÷ 13 x 24 ÷ 25 est.________

14. 182 x 57 ÷ 21 ÷ 19

15. 1012 ÷ 22 x 106 ÷ 1219 est.________

16. 1548 ÷ 12 x 43 x 38

17. 2106 ÷ 39 x 118 177 est.________

18. 67 x 438 ÷ 73 x 304 comp.________

19. 127 x 548 ÷ 73 x 304 est.________

20. 21808 ÷ 376 ÷ 29 x 115 x 87

APPLICATIONS

21. Excluding interest, the payment on Jon's car is $96 per month for 48 months. Find his monthly payment if he decides to pay for the car in 36 months.
$96 \times 48 \div 36 = \underline{?}$

est.______
comp.______

22. The cost for 40 Ski Club members on a trip by bus will be $36 each. How much will it cost each person if only 32 members go and the total cost is the same?

comp.______

23. An infantry division contains 13 battalions with 6 companies in each battalion. There are 200 persons in each company. The battalions are grouped into brigades of 3900 persons each. Find the number of brigades.
$200 \times 6 \times 13 \div 3900 = \underline{?}$

est.______

24. A printing company packages 46 books in a carton The cartons are shipped on skids with each skid holding 24 cartons. How many skids will be needed for 20,976 books?
$20976 \div 46 \div 24 = \underline{?}$

comp.______

25. The length of an auto race track is 1320 yards. How many laps (times around) are needed for a race of 300 miles? (Hint: One mile equals 1760 yards.)
$300 \times 1760 \div 1320 =$ ___?

est.________
comp.________

26. A floor with an area of 126 square feet is to be covered with tile. How many pieces of tile will be needed if each tile has an area of 81 square inches? (Hint: A square foot equals 144 square inches.)

A formula for computing the brake horsepower of an automobile is shown below.

$$\text{Brake Horsepower} = \frac{\text{Torque} \times \text{RPM}}{5250}$$

$$H = \frac{T \times R}{5250} \quad \text{or} \quad H = T \times R \div 5250$$

Find the values of H for the given values of T and R.

27. $T = 300$
$R = 4550$

est.________
comp.________

28. $T = 250$
$R = 1890$

29. T = 455 est.________
R = 2250

30. T = 350
R = 2925

The formula for the area of a triangle is shown below.

$$A = \frac{bh}{2} \text{ or } A = b \times h \div 2$$

Find the value of A for the given values of b and h.

31. b = 15 inches est.________
h = 8 inches comp.________

32. b = 224 feet
h = 193 feet

33. b = 1056 meters est.________
h = 537 meters

34. b = 609 centimeters
h = 286 centimeters comp.________

LESSON 8

COMBINED OPERATIONS

EXERCISES

1. $36 + 19 \times 27$

comp.______

2. $15 \times 24 + 187$

est.______
comp.______

3. $728 \times 14 + 221$

4. $25 \times 186 + 89$

est.______

5. $353 + 378 \times 59$

6. $47 \times 139 + 76$

est.______

7. $728 - 18 \times 14$

comp.______

8. $6966 - 5022 \div 54$

est.______
comp.______

9. 8575 - 421 x 9 + 4786

comp.______

10. 53,104 - 743 x 56 + 13,299 est.______

11. 29,101 - 48 x 13 x 29

12. 4078 - 256 x 12 - 94 est.______
comp.______

13. 54,361 - 19,275 ÷ 75 x 201

14. 327,102 - 31,428 ÷ 9 x 87 est.______

15. 945 ÷ 15 + 38 x 19

comp.______

16. 38 + 23 x 45 - 298 est.______

17. 3592 ÷ 449 x 123 - 798

est.______

18. 1008 - 18 x 2924 ÷ 102

19. 38 + 23 x 45 - 297 ÷ 9 comp.____

20. 9288 ÷ 129 + 387 ÷ 43 x 19 est.____

21. 353 x 59 - 278 x 50 - 1080 ÷ 30

22. 13,271 - 147,088 ÷ 29 - 323 x 24 est.____

APPLICATIONS

23. The yearly cost of an insurance policy from Company A is $372. A similar policy has a yearly cost of $348 from Company B. How much less is the monthly cost of a policy from Company B than from Company A?

372 12 - 348 12 = ? est.____
comp.____

24. A store purchased 25 refrigerators for $395 each and 40 color TV sets for $375 each. Find the total cost.

est.____
comp.____

25. A family used 433 kilowatt hours of electricity in one month. They were charged 6 cents for each of the first 50 kilowatt hours and 4 cents for each of the remaining kilowatt hours. Find the amount of the electric bill in cents.

50 x 6 + 383 x 4 = ? est.____

26. Find the total number of watts for these appliances.

est.______
comp.______

Appliance	Volts	x	Amps	=	Watts
Iron	115	x	10	=	______
Refrigerator	115	x	6	=	______
Air Conditioner	115	x	7	=	______
Dishwasher	115	x	3	=	______
			Total	=	______

27. The total attendance at a school for 18 days in September was 8208. The attendance for 20 days in October was 8980. How much greater was the average attendance per day in September than in October?

est.______
comp.______

LESSON 9

DIVISION- NONZERO REMAINDER

EXERCISES

1. $9\overline{)317}$ est.______ comp.______

2. $7\overline{)291}$ est.______

3. $6\overline{)956}$ est.______ comp.______

4. $8\overline{)623}$ est.______

5. $32\overline{)205}$ est.______ comp.______

6. $49\overline{)723}$ est.______

7. $28\overline{)957}$ est.______ comp.______

8. $3\overline{)895}$ est.______

9. $19\overline{)438}$ est.______ comp.______

10. $68\overline{)4190}$ est.______

11. $53\overline{)6283}$ est.______ 12. $79\overline{)3049}$ est.______

13. $193\overline{)5726}$ est.______ 14. $227\overline{)10558}$ est.______

15. $329\overline{)43774}$ est.______ 16. $559\overline{)36271}$ est.______

17. $703\overline{)24102}$ est.______ 18. $916\overline{)82583}$ est.______

APPLICATIONS

19. A printing firm must package 10,000 books in cartons of 44 books each. How many full cartons will be needed? How many books will be left over?

est.______

20. A service club is to contact businesses in a fund drive. There are 328 contacts to be divided among 63 members. How many contacts should each member make? How many are left over?

est.______
comp.______

21. The members of a girl scout troop are to sell tickets for a carnival. A total of 500 tickets are distributed to 36 scouts. How many should each scout get? How many are left over?

est.______

22. The 234 members of a Boys Club are divided into basketball teams of 7 players each. How many teams are formed? How many boys are left over to be assigned to teams?

est.______
comp.______

23. The length of a board is 130 inches. Find the length of the board in feet and inches.

est.______
comp.______

24. An automobile race s 500 miles in length. The track is 3 miles in circumference. How many full laps (times around) does it take for the race. How many extra miles are needed?

est.________
comp.________

25. A rope 58 meters long is to be cut into 13 pieces of equal length. What is the length of each piece? How many meters long is the remaining piece of rope?

est.________
comp.________

26. A truck can carry 3 metric tons (3000 kilograms) of gravel. How many full truck loads are needed to haul 22,328 kilograms? How many kilograms of gravel would be left over?

est.________

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VITA

Billy Lynn Hopkins was born in Grand Saline, Texas, on August 6, 1947, the son of Tressie Edwards Hopkins and Johnnie Glynn Hopkins. After completing his work at the Van High School, Van, Texas, in 1965, he entered North Texas State University at Denton, Texas. He received the degree of Bachelor of Arts with a major in mathematics from North Texas State University in May of 1969. During the following year he was employed as a mathematics teacher in North Mesquite High School, Mesquite, Texas. In September 1970, he entered the Graduate School of North Texas State University. He was awarded the degree of Master of Science in December 1971. During the 1971-72 school year he was employed as a mathematics teacher in Van Junior High School, Van, Texas. In September 1972, he entered the Graduate School of The University of Texas at Austin. He was employed as a mathematics teacher in Reagan High School, Austin, Texas, during the period August 1974, through October 1976. Since that time he has been employed as a consultant in mathematics at the Texas Education Agency at Austin, Texas. In 1970, he married Anita Darlene Rowlett of San Antonio. A son, Bryan Douglas, was born in 1971 and a daughter, Amy Katherine, was born in 1975.

Permanent address: 10003 Floyd
Austin, Texas 78753

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