THE USE OF ELECTRONIC CALCULATORS IN A BASIC MATHEMATICS COURSE FOR COLLEGE STUDENTS

DISSERTATION

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The problem with which this investigation was concerned was that of determining relationships between attitude and between achievement of students in those classes in college basic mathematics which utilized electronic calculators during class sessions and students in those classes which did not utilize electronic calculators.

An experimental study was conducted which compared (1) attitudes toward mathematics in groups who used electronic calculators in the classroom and groups who had no calculators available and (2) achievement in mathematics in groups who used electronic calculators in the classroom and groups who had no calculators available. The subjects were ninety-eight students enrolled in four sections of Basic Mathematics at Northwest Oklahoma State University, Alva, Oklahoma. The experiment was conducted during the fall semester of the 1974-1975 school year.

A survey of the literature revealed that few studies have been conducted utilizing electronic calculators in the classroom and those studies have dealt mainly with low-ability mathematics students or business mathematics

students. No conclusions could be drawn from the results of the limited number of experiments completed.

The Semantic Differential for Attitude Toward Mathematics was used to measure mathematics attitudes, and the "Math Survey Test" developed by the mathematics staff at Northwest Oklahoma State University was used to measure mathematics achievement.

Since randomization was not possible, a "non-equivalent control groups" design was used. Analysis of covariance was used for statistical analysis. Attitude pretest and instructor were covariates for the attitude part of the study, and American College Testing Program mathematics score, achievement pretest, and instructor were covariates for the achievement part of the study. The .1 level of significance was adopted for the study.

The following conclusions were drawn with reference to the population studied.

1. Very little difference exists in student achievement when electronic calculators are used in the classroom of college basic mathematics.

2. Students who use electronic calculators in the classroom have better attitudes toward mathematics than students who have no calculators available, although the difference is not significant.

3. Use of electronic calculators in the classroom is of significantly more benefit in improving attitude

toward mathematics for students with higher aptitude in mathematics than for students with lower aptitude in mathematics.

4. Use of electronic calculators in the classroom is of significantly more benefit in improving achievement in mathematics for students with higher aptitude in mathematics than for students with lower aptitude in mathematics.

5. There is little difference in attitude toward mathematics of females who use electronic calculators in the classroom and males who use electronic calculators in the classroom.

6. There is a difference in achievement in mathematics favoring females who use electronic calculators in the classroom over males who use electronic calculators in the classroom, but the difference is not significant.

Based on the findings of the study, the following recommendations were made.

1. Electronic calculators will be more beneficial in improving attitudes toward mathematics for students with high aptitudes in mathematics than for students with low aptitude in mathematics in a college basic mathematics course.

2. Electronic calculators will be more beneficial in improving achievement for students with high aptitude in mathematics than for students with low aptitude in mathematics in a college basic mathematics course.

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CHAPTER I

INTRODUCTION

A basic mathematics course is offered in many two-year and four-year colleges. The purpose of the course varies with different colleges, but the Panel on Basic Mathematics of the Committee on the Undergraduate Program in Mathematics states that a common aim ". . . will be to provide the students with enough mathematical literacy for adequate participation in the daily life of our present society" (5, p. 2). Frequently the course is required for cultural and general education purposes. Basic mathematics is not designed for students who are mathematics and science oriented, but rather for those in other fields that require less mathematical sophistication and rigor.

There is a sizable student population taking such basic mathematics courses. The College Board of the Mathematical Sciences estimates that approximately 200,000 of the 1,068,000 students enrolled in four-year institutions in the fall of 1965 were taking courses of this type, and 150,000 of 348,000 two-year college mathematics students were enrolled in such courses (5, p. 1).

It is a challenge to the teachers of basic mathematics courses to motivate the students. Many students have taken only the minimum requirements for mathematics in public schools, and some have a fear of mathematics and profess to dislike it. In a study by Poffenberger and Norton (12), over 40 per cent of the college students surveyed reported a dislike for mathematics.

The use of a calculator in the classroom could relieve the student of time-consuming computation and eliminate calculation errors. His effort could then be directed to analyzing problems and structuring solutions. More problems could be worked in the class period and less time would be required outside class for completing an assignment. In this way his attitude toward mathematics and his achievement in it could be improved. The lower cost of electronic calculators in the last year has made it feasible to use them as an aid in the classroom.

Statement of the Problem

The problem of this study was the relationships between attitude and between achievement of students in those classes in college basic mathematics which utilized electronic calculators during class sessions and students in those classes which did not utilize electronic calculators.

Purposes of the Study

The purposes of this study were: (1) to determine differences in students' attitudes toward mathematics with classroom use of electronic calculators in a college basic mathematics course, and (2) to ascertain differences in students' achievments in mathematics with classroom use of electronic calculators in a college basic mathematics course.

Hypotheses

To carry out the purposes of this study, the following hypotheses were formulated.

1. The mean score on a mathematics attitude scale will be significantly higher for students in a college basic mathematics course who use electronic calculators in the classroom than for those who do not.

2. In a college basic mathematics course the mean score on a mathematics attitude scale will be significantly higher for females who use electronic calculators in the classroom than for males who use electronic calculators in the classroom.

3. In a college basic mathematics course the mean score on a mathematics attitude scale will be significantly higher for students with lower American College Testing Program (ACT) mathematics scores (between one-half and two standard deviations below the mean) who use electronic calculators in the classroom than for students with higher ACT mathematics scores (between one-half and two standard deviations above the mean) who use electronic calculators in the classroom.

4. The mean score on an achievement test will be significantly higher for students in a college basic mathematics course who use electronic calculators in the classroom than for those who do not.

5. In a college basic mathematics course the mean score on an achievement test will be significantly higher for females who use electronic calculators in the classroom than for males who use electronic calculators in the classroom.

6. In a college basic mathematics course the mean score on an achievement test will be significantly higher for students with lower ACT mathematics scores (between one-half and two standard deviations below the mean) who use electronic calculators in the classroom than for students with higher ACT mathematics scores (between one-half and two standard deviations above the mean) who use electronic calculators in the classroom.

Background and Significance of the Study

Student attitudes toward mathematics have been a major concern of mathematics educators in the last several years. Much of the research has been directed toward what factors are involved in a student's formulation of his attitude toward mathematics.

Attitude toward mathematics and achievement in mathematics seem to be related, although results of studies are conflicting. Neale found the relationship of attitude toward mathematics and achievement ". . . is surely modest in that attitude accounts for only five to fifteen percent of variation in achievement, and attitudes contribute to achievement only in conjunction with intelligence and prior achievement" (11, p. 631). Aiken and Dreger (4) report mathematics attitudes of college students contribute significantly to prediction of achievement for females, but not for males. In the International Study of Achievement in Mathematics (6) attitudes appear to be independent of mathematics achievement. In another study (2) Aiken concludes scores on attitude tests may be better predictors of choice behavior, satisfaction and perseverance rather than achievement.

Favorable attitudes toward school subjects maximize the possibility that a student will willingly learn more about a subject, remember what he has learned, and use what he has learned (7). Romberg (13) states the need to identify procedures that might modify existing attitudes. Anttonen (4) suggests that future studies could make an attempt to change students so that their attitudes toward mathematics would become more positive and thus overcome emotional blocks to mathematics that would lead to better performance and greater comfort in mathematics.

Formation of favorable attitudes toward mathematics is generally considered to be a desirable outcome of instruction in mathematics. Scandura states, "An acceptable attitude toward mathematics is in itself an important aspect of achievement" (15, p. 437). Objective VI of the National Assessment of Educational Progress (10) is appreciation and use of mathematics. This is reflected in a student's enjoyment of mathematics and recognition of the importance and relevance of mathematics to the individual and to society. Attitudes must be given deliberate attention both in curriculum development and curriculum evaluation. Teachers need to give systematic attention to classroom activities that develop desirable attitudes (11).

Students seem to develop increasingly unfavorable attitudes toward mathematics as they progress through elementary and secondary schools. In a longitudinal study Neale (11) reports that fifth and sixth graders' mean scores on an attitude test had declined a full standard deviation when they were retested six years later. Poffenberger and Norton's study (12) shows that by the time students reach college, only 24 per cent of the males and 26 per cent of the females surveyed like mathematics very much while 36 per cent of the males and 64 per cent of the females dislike mathematics. A definite need for ways to develop positive attitudes toward mathematics in college is indicated by these studies.

Many colleges offer a basic mathematics course below the level of college algebra and trigonometry. The course is designed for vocational and occupational programs and low-level liberal arts students. Many students are advised or required to take the course so that they will attain ". . . mathematical literacy for adequate participation in the daily life in our present society" (5, p. 2). A large portion of these students do not take mathematics courses beyond this level. The Committee on the Undergraduate Program in Mathematics (CUPM) of the Mathematical Association of America has made recommendations for course content in the report, "A Course in Basic Mathematics for Colleges" (5).

Mass production has made small electronic calculators feasible for use in the classroom, and the benefits of their use should be investigated. It is possible that these calculators will become an important aid for students in basic college mathematics by relieving routine, time-consuming computation in arriving at an answer to a problem they have set up. Aiken's study (1) indicates that attitude and enjoyment of the use of routine computation, the use of symbols, and working word problems are related. Elimination of routine computation might improve the attitudes toward mathematics of students, especially those who dislike computation.

If classroom use of small electronic calculators should have a favorable effect on achievement or attitudes toward mathematics, then colleges will have a valuable aid in making education more effective and relevant.

Limitations

This study was limited to those students enrolling in the basic mathematics course at Northwest Oklahoma State University, Alva, Oklahoma, in the fall semester of 1974. This limitation was imposed because of the expense involved in providing calculators and the time involved for a supervisor to oversee the experiment.

Procedures for Collecting Data

Permission was obtained from the dean of students at the institution to utilize his files for this study. All entering freshman students are required to submit scores on the *American College Testing Program* (ACT) before they may enroll. The data were eliminated from this study for those students who: (1) did not have ACT scores, or (2) were in the noncalculator group and had access to personal calculators.

The calculator that was used in this study is the Remington 665. The 665 is a small battery-operated electronic calculator with fifty-hour batteries. It performs addition, subtraction, multiplication, and division, with twelve-digit capacity for multiplication and division. Replacement batteries were readily available in local stores. Assurance was made by the distributor that for the duration of the study immediate replacement would be made in case of a malfunctioning calculator. Additional information on the Remington 665 can be found in Appendix B.

Each student in the calculator group had a calculator on his desk each class period. Ten minutes of the first class period were used to familiarize the student with operation of the calculator. Each day the same lesson presentation was made to both calculator and noncalculator sections with no use of the calculator in the presentation. Twenty-five minutes of the fifty-minute period were used for presentation, and the remaining time was used for students to work on the assignment and obtain individual help as needed. Not all topics were conducive to use of a calculator--in approximately 60 per cent of the lessons calculators could have been used to an advantage.

Four sections of basic mathematics were offered at the institution in the fall semester of 1974: one section at 8:00 a.m., two sections at 11:00 a.m., and one section at 2:15 p.m. Each class period was fifty minutes and classes met three times a week. Enrollment was limited to thirty students in each section.

Meserve and Sobel's Introduction to Mathematics (13) was the textbook used, and the material covered was the same for all sections.

The sections were taught by two teachers; each teacher had one section with calculators available and one section without calculators available. The instructors were experienced college teachers and each had taught the course without calculators fifteen times or more in previous semesters. Neither teacher had previously used calculators as an aid in teaching. The teachers were in agreement on the units to be covered and met each Friday afternoon to confer on the progress of the sections.

The students in the two 11:00 a.m. sections were assigned at random from those choosing basic mathematics at this hour, but randomization for the other sections was not possible because students arranged their own schedules. The teacher who had calculators available for the 11:00 a.m. section was decided by the flip of a coin, and his other section did not have calculators available.

Students filled out a questionnaire on the first day of class. They were pretested with the Semantic Differential for Attitudes Toward Mathematics on the first day of class, and the posttest was administered at the last regular class period. The test on achievement was "Math 1113 Credit by Examination," a ninety-minute test. It was divided into two parts for administration the second and third class periods; it was given as the final examination for the posttest. The title of the test was changed to "Math Survey Test" to justify early administration to the students and prevent misunderstanding.

The following data were compiled, parts of which were later punched into data processing cards: (1) name, (2) identification number, (3) sex, (4) ACT mathematics score, (5) Semantic Differential Attitude pretest score, (6) "Math Survey Test" pretest score, (7) Semantic Differential Attitude posttest score, (8) "Math Survey Test" posttest score, (9) section number, and (10) teacher.

Procedures for Analysis of Data

At the conclusion of the semester, the data were punched into cards for data processing.

Since some sections of basic mathematics were determined by normal enrollment, the "non-equivalent control group design" recommended by Campbell and Stanley (14, p. 366) was used. Analysis of covariance was used to test the significance of the difference among the adjusted means.

For hypotheses one, two, and three, the attitude pretest score and the instructor were the covariables, and the criterion variable was the attitude posttest score. A two-by-two factorial design was used for hypothesis one with one classification as calculator-noncalculator and the other classification male-female. For hypothesis two a one-way analysis of covariance was used dividing the calculator students into male-female classification. For hypothesis three a one-way analysis of covariance was used dividing the calculator students into high ACT-low ACT classification.

For hypotheses four and five the achievement pretest score, ACT mathematics score, and instructor were the covariables, and the criterion variable was the achievement posttest score. For hypothesis six the achievement pretest score and instructor were covariables, and the criterion variable was the posttest achievement score. A two-by-two factorial design was used for hypothesis four with one classification as calculator-noncalculator and the other classification male-female. For hypothesis five one-way analysis of covariance was used dividing the calculator students into male-female classification. For hypothesis six one-way analysis of covariance was used dividing the calculator students into high ACT-low ACT classification.

Appropriate F ratios were calculated from the data to test the six hypotheses. McDonald and Raths state, "More and more researchers are taking a hard look at the sacred cows in decision making--the .01 and .05 levels. . . . At times even the .2 and .3 levels of significance might be appropriate" (8, p. 323). Since making a Type II error was not of serious consequence in this study, the .1 level of significance was adopted.

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CHAPTER II

SURVEY OF THE LITERATURE

In order to present a comprehensive survey of the literature related to the problem of finding the relationship between attitude and between achievement of students in classes in college basic mathematics which utilized electronic calculators during class sessions and students in classes which did not utilize electronic calculators, the relevant research was organized into the following categories: (1) attitude toward mathematics; (2) the relationship of attitude toward mathematics and achievement in mathematics; (3) calculation aids in the mathematics classroom.

Attitude Toward Mathematics

Formation of favorable attitudes toward mathematics is generally considered to be a desirable outcome of instruction in mathematics. Neale (31) stated that something called "attitude" seems to play a crucial role in learning mathematics. According to Scandura (40), a positive attitude toward mathematics is an important goal in itself in addition to the possible role attitude might play in causing students to learn mathematics. Mager (24), Neale (31), and Anttonen (10) expressed similar feelings about attitude toward mathematics.

Measurement of attitude toward mathematics is a relatively new development. Much of the early research, in the 1950's, was directed toward constructing instruments that would measure this attitude with an acceptable degree of validity and reliability. Aiken describes attitude as ". . . a learned predisposition or tendency on the part of an individual to respond positively or negatively to some object, situation, concept, or another person" (3, p. 321). He classifies methods of obtaining measures of attitude into (1) observation, (2) interview, and (3) self-report, including questionnaires, attitude scales, and essays. The most reliable is the self-report technique.

Romberg (38) reports that many of the published research studies dealing with attitude toward mathematics have used the Likert-type instrument by Dutton and Blum (18), the _Math Attitude Scale_ developed by Aiken (5), or a semantic differential devised by the individual researchers themselves.

Dutton (17) was an early leader in developing techniques for measuring attitude. He first used a Thurstone scale, and the most favorable attributes included a recognition of the importance of arithmetic, real enjoyment of problems worked with understanding, pleasure in the challenge of arithmetic problems, and appreciation of arithmetic's being practical, definite, and logical. Unfavorable attributes included not being secure in the subject, being afraid of word problems, and fear of the subject in general. Later Dutton and Blum (18) refined the instrument into a Likert-type scale.

Aiken and Dreger (9) devised a Math Attitude Scale to investigate the relationship of attitudes and performance in mathematics. Aiken later refined it into the Revised Math Attitude Scale (5) to include some broader personality variables. To construct the instrument, Aiken had 310 college students write paragraphs describing their attitudes toward mathematics. He then formed a Likert-type scale of twenty items, ten positive and ten negative. It was found to be a reliable instrument with a test-retest reliability coefficient of .94. A test of independence between scores of the attitude scale and scores on items designed to measure attitude toward academic subjects in general suggested that attitudes specific to mathematics were being measured.

A semantic differential for attitude toward mathematics was constructed by McCallon and Brown (25) in 1971. From a sample of sixty-eight college students, correlation between this instrument and the Math Attitude Scale was .90. It was concluded that this semantic differential is as effective in measuring attitude toward mathematics as the Math Attitude Scale, and in addition, students possessing favorable or unfavorable attitudes differed to a greater extent on the semantic differential.

There is still much to be done on revising and refining instruments to measure attitudes toward mathematics. Romberg (38, p. 481) comments that mathematics attitude studies have not been fruitful in general and suggests the following as possible reasons: (1) researchers obtain attitude scores on pencil-paper tests which are beset with validity, internal consistency, and score stability problems; (2) too many times a single global measure of attitude toward mathematics is used; and (3) no attempt is made to identify procedures to modify existing attitudes.

A study by Evans (19) indicated that four attitude scales, the Dutton-Thurstone, the Dutton-Likert, the Anttonen-revised Hoyt, and the Semantic Differential, all sampled the same constructs. Smith (42) found a significant correlation between the Dutton and Aiken scales. In a recent study (8) Aiken provided a start toward correcting the criticism of attitude being measured by a single global dimension. Objective VI, "Appreciation and Use of Mathematics," of the mathematics objectives of the National Assessment of Educational Progress (28) is defined in terms of two subcategories: (1) recognizing the importance and relevance of mathematics to the individual and to society, and (2) enjoyment of mathematics; Aiken considers that the attitude dimension assessed by instruments used in many current studies involves mainly Objective 2, while Objective 1 is neglected. He constructed a ten-item V-scale to measure Objective 1 to be used in conjunction with an E-scale to measure Objective 2. Both scales had moderately high internal-consistency reliability, and he recommended further research on providing separate measures of the enjoyment and perceived value of mathematics. The International Study of Achievement in Mathematics (22) considered three attitude dimensions: (1) mathematics as a fixed, formal system versus a developing field, (2) mathematics for a few versus mathematics learned by many, and (3) mathematics necessary for national development versus mathematics regarded as a luxury. Whether these categories are valid criteria for measuring attitude toward mathematics and, if so, whether there are more are questions yet to be resolved.

Romberg's third criticism of mathematics attitude studies challenges mathematics educators with the task of improving students' attitudes toward mathematics. This same need was also on lists of needed research by the National Conference of Needed Research in Mathematics Education (34), Romberg and DeVault (39), Roberts and Dickson (37), and Riedsel and Burns (36). Neale emphasized the need with the following comment.

> If certain attitudes are important objectives of mathematics instruction, then such attitudes must be given deliberate and separate attention both in

> curriculum development and curriculum evaluation. Teachers need to give systematic attention to classroom activities that develop desirable attitudes (31, p. 631).

Aiken (6) offered the following possibilities for techniques to improve mathematics attitudes: (1) more effective counseling, (2) enrichment programs, (3) provision for successful experiences for all, (4) special courses and teaching methods, (5) mathematical games, and (6) exposure to people who use mathematics on the job. Pack (32) proposed that the nature of present tests could contribute to poor attitudes. Traditionally these tests are designed to "spread people out." Romberg (38) suggested considering mastery learning and criterion-referenced tests rather than comprehensive and norm-referenced tests. A study by Small, Holton, and Davis (41) indicated that detailed checking of homework compared with a cursory checking had no effect on attitude or achievement. Techniques for improving attitudes toward mathematics remain unresolved by current research.

Aiken has been one of the leaders in investigating attitudes toward mathematics, and many of the studies involve sex differences. Aiken and Dreger (9) found that attitude toward mathematics contributed significantly to the prediction of achievement in mathematics for females, but not for males when achievement was based on final course grades. They also found that mathematics attitudes were related to remembered impressions of former mathematics teachers, and this relationship was stronger for females than for males. In a later study of college freshmen (4), Aiken found the mean mathematics attitude score of males was significantly greater than that of females. In a study preparing for multivariable investigation of several groups (7), he concluded there were greater interest and achievement in mathematics by males in high school and college.

Students' attitudes toward mathematics seem to decline as they progress from elementary school through college. Aiken (3) reported a very definite attitude toward arithmetic as early as the third grade and that the attitudes were more positive than negative. In a longitudinal study (31), Neale found that attitudes toward mathematics of students remained fairly constant up to the fifth or sixth grade and then started to decline. He reported a decline of a full standard deviation in fifth and sixth grade students when they were retested as eleventh and twelfth grade students six years later. Poffenberger and Norton (35) reported that 36 per cent of the males and 64 per cent of the females in a college survey disliked mathematics, while 24 per cent of the males and 26 per cent of the females liked mathematics very much. Roberts and Dickinson (37) found that college students on the engineering track had significantly more positive attitudes (at the .01 level) than students enrolled in terminal mathematics programs.

Relationship of Attitude Toward Mathematics and Achievement in Mathematics

There are basically two reasons that mathematics instructors try to develop positive attitudes toward mathematics: (1) a positive attitude toward mathematics is an important goal in the education system; and (2) attitudes could possibly be related to achievement in mathematics. It is the second of these reasons with which this part of the review will be concerned.

In many studies involving relatively small groups there seems to be significant positive correlation between attitude toward mathematics and achievement in mathematics, though it is not high. Neale reported, "Evidence from a variety of studies indicated remarkably constant correlation between attitude toward mathematics and standardized mathematics achievement test scores" (31, p. 634). Most correlation coefficients ranged between .2 and .4. When he considered attitude as one of the predictors of achievement, attitude contributed only 5 to 15 per cent of variation in achievement. Anttonen (10) found that attitude scores contributed something over and above ability test scores to prediction of achievement in mathematics at the high school and college levels. Studies by Aiken (2, 4, 7) and Burbank (12) gave more evidence of significant correlation between attitude and achievement in mathematics even though it was low. Aiken (2) cautioned teachers and researchers not to assume a causal relationship; achievement seems to have as much effect on attitude as attitude has on achievement. Neale (31) gave a similar caution but did not check on causality.

Cristaniello conducted a study (15) that showed when students were divided into high, middle, and low groups on the basis of attitude toward mathematics, the correlation between mathematics ability and mathematics achievement was higher for the middle group than for high or low. Aiken found somewhat contradictory results in a study involving high school and college students (4). He found only very positive or very negative attitudes affect achievement--the middle range does not. Aiken conjectured that correlation between attitude and achievement may vary with ability level and proposed more research on the subject.

Aiken has also considered sex as a covariable with attitude in the prediction of achievement in mathematics (4, 7, 9). In one of the studies (9) he found mathematics attitudes contributed significantly to prediction of achievement for females in college but not for males when achievement was measured by final course grades. He urged multivariable investigation of several groups with the results analyzed separately by age and by sex (7). A study on sex differences in mathematics for ninth grade students in New Jersey was conducted by Keller (23). She found no significant differences by sex in attitudes toward mathematics or achievement in mathematics at the .05 level. Attitude and achievement in mathematics were significantly related in both males and females.

Husén's study (22) found attitude to be independent of mathematics achievement. Students who were high on attitudinal dimensions were not necessarily those who scored well on the achievement tests. A possible reason for these contradictory results is that Husén used unusual dimensions of attitude. His study considered these attitudinal dimensions: (1) mathematics as a fixed system versus a developing field, (2) mathematics for a few versus mathematics learned by many, and (3) mathematics necessary for national development versus mathematics regarded as a luxury. Attitude studies in which some correlation was found with achievement were based on the two dimensions recommended by the National Assessment of Educational Progress (28): (1) recognition of the importance and relevance of mathematics to the individual and to society, and (2) enjoyment of mathematics.

The need for a broad study of the relationship of attitude toward mathematics and mathematics achievement was expressed by Dessart and Frondsen with this comment.

> At this time there is no body of research evidence indicating that attitude and achievement are correlated in a significantly positive manner and, furthermore, such a correlation would not imply causation (16, p. 1190).

Computation Aids in the Classroom

Many teachers and students have questioned the high instructional and testing priority currently assigned to speed and accuracy in arithmetic computation. To find the existing attitudes toward practice for computation in schools, the Mathematics Teacher Editorial Panel surveyed a sample of teachers, mathematicians, and laymen (45). Some of the results of that survey are included in the following statements: (1) Weakness in computational skill acts as a significant barrier to learning of mathematical theory and applications--61 per cent agreed, 39 per cent disagreed; and (2) Availability of calculators will permit treatment of more realistic applications of mathematics, thus increasing student motivation--96 per cent agreed, 4 per cent disagreed.

Prior to the development and refinement of electronic calculators, the expense and inconvenience of using electric mechanical calculators limited their use in the classroom. Cantor (13) reported a study of experimental text materials in which students used electric calculating machines in the laboratory period. When comparable groups were routinely tested at the end of the study, the students who had worked with calculators showed significantly greater improvement in arithmetic skills than did the others. Advani (1) used electric calculators in an experiment on improving achievement and attitude of twelve- to fifteen-year old students with learning and behavior problems. He reported significant improvement in achievement, but there was no control group with which they could be compared. Most students responded favorably to a questionnaire about the use of calculators, although a few thought the calculators were noisy and interrupted concentration. Beck (11) taught a mathematics class in which mechanical calculators were used and reported her observations. She concluded that students enjoyed using the calculators and formed better work habits. Van Atta observed that "many problems which cannot be done by the pupil alone can be done by the pupil plus a calculator" (44, p. 651).

The Instructional Affairs Committee of the National Council of Teachers of Mathematics (NCTM) issued the following position statement which was adopted by the NCTM Board of Directors at its September, 1974, meeting.

> 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 (30).

NCTM encouraged teachers to experiment with the use of electronic calculators in the classroom and report the results to *The Mathematics Teacher*. A similar request was made by McKellips in the *Oklahoma Council for Teachers of Mathematics Bulletin* (26). The National Association of

Secondary School Principals urged teachers to begin experimental classwork with pocket calculators and advised administrators to make funds available for purchase of such equipment for classroom use (29).

A few studies on the use of electronic calculators have been completed, and some are currently in progress. Haga (20) conducted a study involving business mathematics students in 1970. He selected 123 students who were weak in decimals, fractions, and percentages for placement in classes where electronic calculators were used regularly. Student performance in these areas improved significantly, though there was no control group with which to compare them. In a doctoral study (33) Page compared the achievement of a group that used calculators as a tool in solving business problems with a group that solved business problems and used calculators following the course. The group using calculators in the course showed significantly greater gains in problem-solving capability.

Cech (14) investigated the use of desk calculators on attitude and achievement in mathematics. His subjects were low-achieving ninth grade students with IQ scores ranging from seventy-five to ninety-five and achievement scores two or more years below grade level. He reported the use of calculators for this type student made no significant difference in attitude toward mathematics nor in achievement based on computational skills. A possible reason cited for this lack of difference was the host of social, academic, and psychological pressures on this type student. Cech suggested use of calculators to improve computational skills might be unsound, but recommended further study on using calculators to solve meaningful problems and to illustrate mathematical principles.

In an attempt to determine what reasonable role calculators may play in schools, the New York State Education Department arranged for a trial study (43) of such calculators in two schools during the 1973-1974 school year. Each sixth grade student of one class in each school was issued a calculator for classroom use throughout the school year. Control groups were established, and pretesting and posttesting utilized the New York State Mathematics Tests for Grade 6. This test includes mathematics computation, concepts, and problem solving. Frank S. Hawthorne, chief of the Bureau of Mathematics Education, was in charge of the project and reported its purposes in The Arithmetic Teacher (21). The study was designed to investigate the calculator's contribution to mathematics achievement by possibly eliminating unnecessary calculation that consumes precious time and destroys interest for the students. Also, use of the calculator could make it possible for a student to check the accuracy of his answer providing immediate verification, an important motivational factor. The experiment is completed and the data have been gathered, but no report of the analysis has been published.

Menlo College has established a computation center for use by the mathematics, science, and business students. The center is equipped with Hewlett-Packard 45 calculators, and students are taught through daily use of the calculators. The program is not a controlled study, so no statistical data of an experimental nature are available. The six professors whose classes are involved feel that students are learning more about the "why" of the material learned because of the logic system of the calculator. They report the speed of the calculators has allowed students to cover more material with far more realistic problems that do not have "neat" answers (27).

Summary

Mathematics educators recognize that attitude toward mathematics is an important goal of instruction and could possibly be a means of increasing mathematics achievement. The Dutton Scale, the Revised Math Attitude Scale, and the Semantic Differential for Attitude Toward Mathematics are three instruments that are widely used in measuring mathematics attitudes. It is recognized that continued study is needed for broadening the dimensions of the attitude instruments. In several limited studies there seemed to be a low but significant correlation between attitude and achievement in mathematics. Because other studies showed no correlation between attitude and achievement, a larger study, perhaps nationwide, is recommended. Since electronic calculators have become feasible for use in the classroom only in the last two or three years, reported research has been limited. Many organizations and mathematics educators are encouraging experimental work on use of electronic calculators in the classroom.

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CHAPTER III

EXPERIMENTAL DESIGN AND EXPERIMENTAL PROCEDURES

The purpose of this chapter is to describe the experimental study which was conducted. The chapter is divided into four subsections: the setting of the study, instruments used in the study, procedures used to collect the data, and the procedures used for statistical treatment of the data.

The Setting of the Study

The experiment was conducted during the fall semester of the 1974-1975 school year at Northwest Oklahoma State University, Alva, Oklahoma. Alva, Oklahoma, has a population of approximately 7,000 and is located in northwest Oklahoma. Alva is a rural community with most of its residents having an agricultural background. Northwest Oklahoma State University is a state-supported and fully accredited four-year university. The enrollment at the institution during the fall term of 1974-1975 was approximately 1,800. Complete programs of study are available in many major areas. The university offers a Master of Teaching degree in its graduate school. The school was originally conceived as a teachers college, but now liberal arts degrees are offered. Approximately half of the students are enrolled in the school of education. Many of the students who attend Northwest Oklahoma State University live in rural communities in northwest Oklahoma, and approximately 40 per cent commute to school daily.

The subjects for the study were students enrolled in the four sections of Basic College Mathematics, Math 1113, taught at Northwest Oklahoma State University in the fall semester of the 1974-1975 school year. Basic College Mathematics is an elective course, but all students are required to complete four credit hours of science, four credit hours of foreign language, or three credit hours of mathematics to satisfy general education requirements for a degree. Many students choose Math 1113 to fulfill this requirement.

Basic College Mathematics was designed to include fundamental concepts of elementary mathematics as recommended by the Committee on the Undergraduate Program in Mathematics of the Mathematical Association of America in the booklet, A Course in Basic Mathematics for Colleges (5). An outline of the content recommended is in Appendix D. The text for the course was Introduction to Mathematics by Meserve and Sobel (7). The following chapters of the text were taught in the fall semester of 1974-1975: Chapter 2--An Introduction to Sets; Chapter 4--Systems of Numeration; Chapter 5--Mathematical Systems; Chapter 6--Sets of Numbers; Chapter 7--An Introduction to Algebra; Chapter 9--An

Introduction to Probability; and Chapter 10--An Introduction to Statistics. An outline of these chapters is presented in Appendix C.

Instruments

Hypotheses three and six required classifying the subjects according to aptitude and ability in mathematics. The instrument chosen for this classification was the American College Testing Program (ACT) examination in mathematics.

The American College Testing Program was initiated in 1959 and has been widely accepted as an aid for guidance in colleges. Over a million students take the tests annually, and it is required for entrance into colleges and universities in sixteen states. Three new forms of the test are published annually. In a review (3, p. 612) Wallace reports, "Validation of the ACT has been very extensive with consistently good results." The mathematics usage part of the ACT consists of forty items in arithmetic, algebra, and geometry to be taken in fifty minutes. Findley (4, p. 3) states the ACT program is based on well-conceived and well-built tests. The reliability for Form 4-AC was reported to be .89 based on the odd-even reliability estimate.

The Semantic Differential for Attitude Toward Mathematics developed by McCallon and Brown (6) was utilized for measuring mathematics attitudes (see Appendix A). This instrument consists of fifteen items, each with seven intervals between the poles. In scoring, the seven points on each scale are weighted with integers one through seven in the direction of unfavorable-favorable. The score for the test was the sum of the item scores. The instrument was compared to the Math Attitude Scale constructed by Aiken and Dreger (2). From a sample of sixty-eight college students, correlation between the two instruments was r = .90. It was concluded that the semantic differential is as effective a measure of mathematics attitude as the Math Attitude Scale. In addition, people possessing favorable and unfavorable attitudes differed to a greater extent on the evaluative scales of the semantic differential, thus lending construct validity to the instrument. Correlation was significant at the .001 level.

From extensive examination of reliable sources, no appropriate published instrument was found to measure achievement in college basic mathematics. The best available instrument found was the "Math 1113 Credit by Examination" constructed by the mathematics department of Northwest Oklahoma State University, Alva, Oklahoma (see Appendix A).

To construct the test, the chairman of the mathematics department submitted a request to the seven members of the department asking for: (1) specific objectives that each teacher tried to achieve in Math 1113, and (2) two or three problems that would test for each objective specified. This information was compiled with problems following each objective listed. All members met to discuss and evaluate common objectives of the course and the submitted problems. The final result was a test of fifty items. The items represented seventeen of the fifty-seven suggestions for a two-semester course in the pamphlet, A Course in Basic Mathematics for Colleges, by the Committee on the Undergraduate Program in Mathematics of the Mathematical Association of America (5). Topics covered in the examination that are not specifically mentioned in the pamphlet are: (1) sets and simple set operations, (2) prime factorization of integers, and (3) functional notation. In the introduction to the committee's outline are these comments.

> In this section we present an outline of one sequence of the topics which the panel feels is appropriate for use in implementing the purposes of the course. It should be re-emphasized that coverage of these topics is in itself neither necessary nor sufficient for the course to fulfill the spirit of the panel's recommendations (5, p. 9).

The credit by examination instrument was developed in the spring of 1972 and has been administered since the fall of 1972. In the opinion of the mathematics department it has adequately and consistently tested for the objectives of the basic mathematics course.

A self-report questionnaire was constructed to gather information about each subject (see Appendix A). This information was utilized to eliminate from the study the data of any subject of the noncalculator group who has access to a calculator.

Collection of the Data

In this section the nature of the experimental study is presented and the procedures for executing the experiment are described. The purposes of the study were to determine differences in students' attitudes toward mathematics with classroom use of electronic calculators and to ascertain differences in students' achievements in mathematics with classroom use of electronic calculators. Students in the sections which had electronic calculators available in the classroom comprised the experimental group, and students in the sections which did not have electronic calculators available formed the control group.

Each student in the experimental group had a calculator on his desk each class period. Ten minutes of the first class period were used to familiarize the student with operation of the calculator. Each day the same lesson presentation was made to both experimental and control groups with no use of the calculator in the presentation. Twenty-five minutes of the fifty-minute period were used for lesson presentation, and the remaining time was used for students to work on the assignment and obtain individual help as needed. Not all topics were conducive to use of a calculator--in approximately 60 per cent of the lessons calculators could have been used to an advantage. Students in the classes with calculators available were free to use the calculators or not, as they chose; however, the teachers observed that all students made use of the calculators during certain lessons. Students in the calculator sections were allowed to use calculators on examinations.

Four sections of Math 1113 were offered at the Institution in the fall semester of 1974: section 1 at 8:00 a.m., two sections (sections 2 and 3) at 11:00 a.m., and section 4 at 2:15 p.m. Each class period was fifty minutes and classes met three times a week. Enrollment was limited to thirty students in each section, and these sections all developed into classes of normal size. In Table I is the distribution of students in the four sections at the beginning of the term.

The sections were taught by two teachers; each teacher had one section with calculators available and one section without calculators available. The instructors, Tom Ikard and Warren Nichols, were experienced college teachers, and each had taught the course without calculators many times in previous semesters. Neither teacher had previously used calculators as an aid in teaching. The teachers agreed on the units to be covered and met each week to confer on the progress of the sections.

The students in the two 11:00 a.m. sections were assigned at random from those choosing basic mathematics at that hour, but randomization for other sections was not possible. By toss of a coin section 3 had calculators available; section 1 was the other class that had calculators available.

TABLE I

NUMBER ENROLLED IN MATH 1113

	Male	Female	Total
Section 1, 8:00 a.m. (Nichols)	15	12	27
Section 2, 11:00 a.m. (Nichols)	15	15	30
Section 3, 11:00 a.m. (Ikard)	15	14	29
Section 4, 2:15 p.m. (Ikard)	10	15	25
Totals	55	56	111

Some of the students in the original enrollment were not included in the data used for analysis. All students who withdrew from the course during the semester, who did not have ACT scores on file in the dean's office, or who were in the control group and had calculators available were eliminated from the study. The students in the control group who had calculators available were determined by a questionnaire filled out the first class session (see

Appendix A). The distribution of the students used in the study is in Table II.

TABLE II

DISTRIBUTION OF STUDENTS IN THE STUDY

	Male	Female	Total
Section 1, 8:00 a.m. (Nichols)	13	10	23
Section 2, 11:00 a.m. (Nichols)	15	14	29
Section 3, 11:00 a.m. (Ikard)	13	12	25
Section 4, 2:15 p.m. (Ikard)	7	14	21
Totals	48	50	98

ACT mathematics scores for all students enrolled in Math 1113 were obtained from the dean's office. Students filled out a questionnaire and were pretested with the Semantic Differential for Attitude Toward Mathematics on the first day of class. The posttest for attitude was given at the last regular class period. The test on achievement was "Math 1113 Credit by Examination," a ninety-minute test. For the pretest it was divided into two parts for administration the second and third class periods; it was given as the final examination for the posttest. The title of the test was changed to "Math Survey Test" to justify early administration to the students and prevent misunderstanding. The data for the study can be found in Appendix E.

Procedures for Treatment of the Data

Data processing was performed by the Data Processing Center at North Texas State University, Denton, Texas, utilizing an IBM 360 model 50 computer. Two programs were used from the center's statistical library: ST019--analysis of covariance, two-way design; and ST014--analysis of covariance, one-way design.

The hypotheses of the study were:

1. The mean score on a mathematics attitude scale will be significantly higher for students in a college basic mathematics course who use electronic calculators in the classroom than for those who do not.

2. In a college basic mathematics course the mean score on a mathematics attitude scale will be significantly higher for females who use electronic calculators in the classroom than for males who use electronic calculators in the classroom.

3. In a college basic mathematics course the mean score on a mathematics attitude scale will be significantly higher for students with lower <u>American College Testing Program</u> (ACT) mathematics scores (between one-half and two

standard deviations below the mean) who use electronic calculators in the classroom than for students with higher ACT mathematics scores (between one-half and two standard deviations above the mean) who use electronic calculators in the classroom.

4. The mean score on an achievement test will be significantly higher for students in a college basic mathematics course who use electronic calculators in the classroom than for those who do not.

5. In a college basic mathematics course the mean score on an achievement test will be significantly higher for females who use electronic calculators in the classroom than for males who use electronic calculators in the classroom.

6. In a college basic mathematics course the mean score on an achievement test will be significantly higher for students with lower ACT mathematics scores (between one-half and two standard deviations below the mean) who use electronic calculators in the classroom than for students with higher ACT mathematics scores (between one-half and two standard deviations above the mean) who use electronic calculators in the classroom.

A two-by-two factorial design was used for hypotheses one and four, with one classification being calculator-noncalculator groups and the other classification being male-female groups. This design was used to check for interaction and to observe any sex differences in attitude and achievement that Aiken reported in his study (1). A one-way design was used for hypotheses two, three, five, and six.

Analysis of covariance was used for all hypotheses to control statistically for any initial differences which might confound differences between groups. A summary of the classifications and variables for each hypothesis is in Table III.

TABLE III

CLASSIFICATIONS AND VARIABLES FOR HYPOTHESES

Hypothesis	Classification(s)	Covariables	Criterion Variable
1	Calculator and Noncalculator groups Male and Female groups	Instructor and Attitude pretest	Attitude posttest
2	Calculator Male and Calculator Female groups	Instructor and Attitude pretest	Attitude posttest
3	Calculator High ACT and Calculator Low ACT groups	Instructor and Attitude pretest	Attitude posttest
4	Calculator and Noncalculator groups Male and Female groups	ACT, Instructor and Achievement pretest	Achievement posttest
5	Calculator Male and Calculator Female groups	ACT, Instructor and Achievement pretest	Achievement posttest
6	Calculator High ACT and Calculator Low ACT groups	Instructor and Achievement pretest	Achievement posttest

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CHAPTER IV

ANALYSIS OF DATA

The results of statistical analysis of test data concerning attitude toward mathematics and achievement in mathematics are presented in this chapter. Data processing was performed by the Data Processing Center at North Texas State University, Denton, Texas. The level of significance is reported for each hypothesis when tested in the null form and the .1 level of significance was the point of rejection for each null hypothesis.

The total number of students in the study was ninety-eight. Table IV indicates the number of observations by calculator-noncalculator classification and by male-female classification.

TABLE IV

NUMBER OF OBSERVATIONS

	Calculator	Noncalculator	Row
Male	26	22	48
Female	22	28	50
Column	48	50	98

The attitude pretest means and the unadjusted posttest means are in Table V.

TABLE V

ATTITUDE PRETEST MEANS AND UNADJUSTED POSTTEST MEANS*

	Calculator	Noncalculator	Row
Male	59.6538 (66.8461)	66.6818 (69.0454)	62.8750 (67.8542)
Female	59.9091 (65.3636)	60.4143 (63.7143)	60.2200 (64.4400)
Column	59.7708 (66.1667)	63.2000 (66.0600)	61.5204 (66.1122)

*Unadjusted posttest means are in parentheses.

Research hypothesis one was: The mean score on a mathematics attitude scale will be significantly higher for students in a college basic mathematics course who use electronic calculators in the classroom than for those who do not. The hypothesis was tested in null form, and the results of analysis of covariance with attitude pretest score and instructor as covariates, and attitude posttest score as the criterion variable are shown in Table VI.

The F score needed for the calculator-noncalculator main effect at the .1 level of significance was $F(1,92) = 2.78$. The F score obtained was $F(1,92) = 1.0500$. Therefore the null form of hypothesis one was accepted at the .1 significance level and research hypothesis one was rejected.

TABLE VI

ANALYSIS OF COVARIANCE TABLE FOR HYPOTHESIS ONE

(N = 98)

Source	Sum of Squares	DF	Mean Squares	F	p
Sex (rows)	55.1263	1	55.1263	.5822	.4474
Calculator (columns)	99.4230	1	99.4230	1.0500	.3082
Interaction	.0080	1	.0080	.0001	.9927
Within	8711.7329	92	94.6927	. . .	. . .

Research hypothesis two was: In a college basic mathematics course the mean score on a mathematics attitude scale will be significantly higher for females who use electronic calculators in the classroom than for males who use electronic calculators in the classroom. There were forty-eight subjects in the calculator group. The attitude pretest mean for this group was 59.7708, and the unadjusted posttest mean was 66.1667, with respective standard deviations of 14.1064 and 12.0574. The attitude pretest means, unadjusted posttest means, and standard deviations by male-female classification are contained in Table VII. The hypothesis was tested in null form, and the results of analysis of covariance with attitude pretest score and instructor as covariates, and attitude

TABLE VII

UNADJUSTED ATTITUDE DATA FOR CALCULATOR GROUP BY MALE-FEMALE CLASSIFICATION

Group	Number of Observations	Variable	Mean	Standard Deviation
Male	26	Pretest attitude	59.6538	13.1025
		Posttest attitude	66.8461	10.5895
Female	22	Pretest attitude	59.9091	15.5224
		Posttest attitude	65.3636	13.8067

posttest score as the criterion variable are shown in Table VIII. The adjusted attitude posttest means were 66.9056 for males and 65.2934 for females. The F score needed for a significant difference in the means at the .1 level was F(1,44) = 2.83, and the F score obtained was F(1,44) = .2746. Therefore the null form of hypothesis two was accepted at the .1 significance level and research hypothesis two was rejected.

TABLE VIII

ANALYSIS OF COVARIANCE TABLE FOR HYPOTHESIS TWO

Source	Sum of Squares	DF	Mean Squares	F	p
Within	4952.4531	44	112.5557	. . .	. . .
Difference	30.9063	1	30.9063	.2746	.6029
Total	4983.3594	45	. . .	. . .	. . .

Research hypothesis three was: In a college basic mathematics course the mean score on a mathematics attitude scale will be significantly higher for students with lower American College Testing Program (ACT) mathematics scores (between one-half and two standard deviations below the mean) who use electronic calculators in the classroom than for students with higher ACT mathematics scores (between one-half and two standard deviations above the mean) who use electronic calculators in the classroom. There were eighteen subjects in the groups classified by ACT mathematics score, eight in the lower group and ten in the higher group. The attitude pretest mean and the unadjusted attitude posttest mean for the eighteen subjects were 61.1111 and 66.8330 respectively, with respective standard deviations of 13.5989 and 10.3824. The attitude pretest means, unadjusted posttest means, and standard deviations by groups are in Table IX.

TABLE IX

UNADJUSTED ATTITUDE DATA FOR CALCULATOR GROUP BY ACT CLASSIFICATION*

Group	Number of Observations	Mean	Standard Deviation
High ACT	10	<u>67.3000</u> (71.5000)	<u>10.3824</u> (5.7203)
Low ACT	8	<u>53.3750</u> (61.0000)	<u>13.6898</u> (9.5319)

*Pretest data are underlined and unadjusted posttest data are in parentheses.

The adjusted attitude posttest means were 62.6321 for the lower group and 70.1943 for the higher group. The hypothesis was tested in null form, and the results of analysis of covariance with attitude pretest and instructor as covariates, and attitude posttest as criterion variable are in Table X. The F score needed for significance is

TABLE X

ANALYSIS OF COVARIANCE FOR HYPOTHESIS THREE

Source	DF	Sum of Squares	Mean Squares	F	p
Total	15	933.1440			
Within	14	748.6919	53.4780		
Difference	1	184.4521	184.4521	3.4401	.0844

F(1,14) = 3.11, and the F score obtained was F(1,14) = 3.4491. The difference in the means was significant, but the direction was reversed. Therefore research hypothesis three was rejected.

Research hypothesis four was: The mean score on an achievement test will be significantly higher for students in a college basic mathematics course who use electronic calculators in the classroom than for those who do not. The ACT means, the achievement pretest means, and unadjusted achievement posttest means are in Table XI. The hypothesis was tested in null form, and the results of analysis of

TABLE XI

UNADJUSTED ACHIEVEMENT DATA FOR HYPOTHESIS FOUR*

	Calculator	Noncalculator	Row
Male	15.9615 (3.1154) 16.1923	15.5909 (4.9545) 17.7273	15.7917 (3.9583) 16.8958
Female	14.5455 (3.6818) 16.9545	16.5357 (4.0714) 17.5714	15.6600 (3.9000) 17.3000
Column	15.3125 (3.3750) 16.5417	16.1200 (4.4600) 17.6400	15.7245 (3.9286) 17.1020

*ACT means are on the first line, achievement pretest means are in parentheses, and unadjusted achievement posttest means are underlined.

covariance with ACT mathematics pretest score, achievement pretest score, and instructor as covariates, and achievement posttest score as the criterion variable are shown in Table XII. The F score needed for the calculator-noncalculator main effect at the .1 level of significance is $F(1,91) = 2.79$. The F score obtained was $F(1,91) = .2528$. Therefore the null form of hypothesis four was accepted at the .1 significance level and research hypothesis four was rejected.

Research hypothesis five was: In a college basic mathematics course the mean score on an achievement test will be significantly higher for females who use calculators in the classroom than for males who use electronic calculators in the classroom. For the forty-eight subjects

TABLE XII

ANALYSIS OF COVARIANCE TABLE FOR HYPOTHESIS FOUR

Source	Sum of Squares	DF	Mean Squares	F	p
Sex (rows)	17.3963	1	17.3963	.8463	.3600
Calculator (columns)	5.1964	1	5.1964	.2528	.6163
Interaction	12.0336	1	12.0336	.5854	.4462
Within	1870.5068	91	20.5550	. . .	. . .

in the calculator group the means for ACT mathematics, achievement pretest, and unadjusted achievement posttest were 15.3125, 3.3750, and 16.5417 respectively; the standard deviations were 5.0662, 4.4560, and 7.8874 respectively. Each of these means by male-female classification are contained in Table XIII. The hypothesis was tested in null

TABLE XIII

UNADJUSTED ACHIEVEMENT DATA FOR CALCULATOR GROUP BY MALE-FEMALE CLASSIFICATION

Group	Number	Variable	Mean	Standard Deviation
Male	26	ACT mathematics	15.9615	5.2724
		Achievement pretest	3.1154	4.9261
		Achievement posttest	16.1923	8.0896
Female	22	ACT mathematics	14.5455	4.8179
		Achievement pretest	3.6818	3.9205
		Achievement posttest	16.9545	7.8101

form and the results of analysis of covariance with ACT mathematics, achievement pretest and instructor as covariates, and achievement posttest as the criterion variable are in Table XIV. The adjusted achievement means were 15.7926 for males and 17.4269 for females. The F score needed for a significant difference in the means at the .1

TABLE XIV

ANALYSIS OF COVARIANCE TABLE FOR HYPOTHESIS FIVE

Source	Sum of Squares	DF	Mean Squares	F	p
Total	1064.0852	44	. . .	. . .	. . .
Within	1033.8049	43	24.0420	. . .	. . .
Difference	30.2803	1	30.2803	1.2595	.2680

level was $F(1,43) = 2.84$ and the F score obtained was $F(1,43) = 1.2595$. Therefore the null form of hypothesis five was accepted at the .1 significance level and research hypothesis five was rejected.

Research hypothesis six was: In a college basic mathematics course the mean score on an achievement test will be significantly higher for students with lower ACT mathematics scores (between one-half and two standard deviations below the mean) who use electronic calculators in the classroom than for students with higher ACT mathematics scores (between one-half and two standard deviations above the mean) who use electronic calculators in the classroom. There were eighteen subjects in the groups classified by ACT mathematics score, eight in the lower group and ten in the higher group. The achievement pretest mean and the unadjusted achievement posttest mean for the eighteen subjects were 5.1667 and 18.3889 respectively, with respective standard deviations of 5.7317 and 8.7524. The achievement pretest means, unadjusted posttest means and standard deviations by low ACT-high ACT classification are in Table XV. The adjusted achievement

TABLE XV

UNADJUSTED ACHIEVEMENT DATA FOR CALCULATOR GROUP BY ACT CLASSIFICATION*

Group	Number of Observations	Mean	Standard Deviation
High ACT	10	<u>7.0000</u> (22.4000)	<u>6.4979</u> (6.6366)
Low ACT	8	<u>2.8750</u> (13.3750)	<u>3.8336</u> (8.8146)

*Achievement pretest means are underlined and unadjusted posttest means are in parentheses.

posttest means were 14.7847 for the lower group and 21.2723 for the higher group. The hypothesis was tested in null form and the results of analysis of covariance with achievement pretest score and instructor as covariates, and achievement posttest score as the criterion variable are in Table XVI. The F score needed for significance was F(1,14) = 3.11 and the F score obtained was 3.9097. The

TABLE XVI

ANALYSIS OF COVARIANCE TABLE FOR HYPOTHESIS SIX

Source	Sum of Squares	DF	Mean Square	F	p
Total	740.8806	15			
Within	579.1472	14	41.3676		
Difference	161.7334	1	161.7334	3.9097	.0680

difference in the means was significant at the .1 level, but the direction was reversed. Therefore research hypothesis six was rejected.

CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purposes of this study were to determine differences in students' attitudes toward mathematics with classroom use of electronic calculators in a college basic mathematics course and to ascertain differences in students' achievements in mathematics with classroom use of electronic calculators in a college basic mathematics course. In order to provide a reference for research related to the purposes, a comprehensive summary of research literature related to attitudes toward mathematics, the relationship of attitudes and achievement in mathematics, and the use of computational aids in the mathematics classroom was presented.

An experimental study was conducted which compared (1) attitudes toward mathematics in groups who used electronic calculators in the classroom and groups who had no calculators available, and (2) achievement in mathematics in groups who used electronic calculators in the classroom and groups who had no calculators available. The subjects of the experiment were ninety-eight students enrolled in four sections of Basic Mathematics at Northwest Oklahoma

State University, Alva, Oklahoma. The experiment was conducted during the fall semester of the 1974-1975 school year. Basic Mathematics is a course designed for students who do not seek a major or minor field in either science or mathematics. Two of the four sections of Basic Mathematics were taught at 11:00 a.m. and the other sections at 8:00 a.m. and 2:15 p.m. Two instructors participated in the study, and each instructor taught one section with calculators available and one section without calculators available.

The Semantic Differential for Attitude Toward Mathematics was used to measure mathematics attitudes, and the "Math Survey Test" developed by the mathematics staff at Northwest Oklahoma State University was used to measure mathematics achievement.

Since randomization was not possible, a "non-equivalent control groups" design was used. Analysis of covariance was used for statistical analysis. Attitude pretest and instructor were the covariates for the attitude part of the study, and American College Testing Program mathematics scores, achievement pretest, and instructor were the covariates for the achievement part of the study. The .1 level of significance was adopted for the study.

Findings

Hypothesis one was: The mean score on a mathematics attitude scale will be significantly higher for students in a college basic mathematics course who use electronic calculators in the classroom than for those who do not. Hypothesis one was rejected at the .1 level of significance. The F score for the calculator group versus the noncalculator group was 1.05 which is much too low for the F score of 2.78 needed for significance. Even though not significant, the difference in the attitude means did favor the calculator group; the attitude means for the calculator group increased 6.3595 and for the noncalculator group increased 2.8600.

Hypothesis two was: In a college basic mathematics course the mean score on a mathematics attitude scale will be significantly higher for females who use electronic calculators in the classroom than for males who use electronic calculators in the classroom. Hypothesis two was rejected at the .1 level of significance. The F score for the difference in the attitude means of male and female students who used calculators in the classroom was only .2746, and the F score required for significance was 2.83. The adjusted posttest attitude means were 66.9056 for the males and 65.2934 for the females, a difference of only 1.6122.

Hypothesis three was: In a college basic mathematics course the mean score on a mathematics attitude scale will be significantly higher for students with lower _American College Testing Program_ (ACT) mathematics scores (between one-half and two standard deviations below the mean) who use electronic calculators in the classroom than for students with higher ACT mathematics scores (between one-half and two standard deviations above the mean) who use electronic calculators in the classroom. Hypothesis three was rejected at the .1 level of significance. The F score found for the difference in the attitude means was 3.4491, and the F score for significance was 3.11. There was a significant difference in the means at the .1 level, but in favor of the higher ACT group. The adjusted attitude posttest means were 62.6321 for the lower ACT group and 70.1943 for the higher ACT group.

Hypothesis four was: The mean score on an achievement test will be significantly higher for students in a college basic mathematics course who use electronic calculators in the classroom than for those who do not. Hypothesis four was rejected at the .1 level of significance. The F score for the calculator and noncalculator groups was .2528, and the F score required for significance was 2.79.

Hypothesis five was: In a college basic mathematics course the mean score on an achievement test will be significantly higher for females who use calculators in the classroom than for males who use electronic calculators in the classroom. Hypothesis five was rejected at the .1 level of significance. The F score for the male and female groups was 1.2595, and the F score required for significance was 2.84. The adjusted posttest achievement scores were 15.7926 for males and 17.4269 for the females, a difference of 1.6343 favoring the females.

Hypothesis six was: In a college basic mathematics course the mean score on an achievement test will be significantly higher for students with lower ACT mathematics scores (between one-half and two standard deviations below the mean) who use electronic calculators in the classroom than for students with higher ACT mathematics scores (between one-half and two standard deviations above the mean) who use electronic calculators in the classroom. Hypothesis six was rejected at the .1 level of significance. The F score found for the difference in achievement means was 3.9097, and the F score required for significance was 3.11. There was a significant difference in the means at the .1 level, but in favor of the higher ACT group. The adjusted achievement posttest means were 14.7847 for the lower ACT group and 21.2723 for the higher ACT group, a difference of 6.4876.

The results from testing hypotheses three and six did indicate significant differences in attitude means and achievement means for the higher ACT group over the lower ACT group when electronic calculators are used in the classroom. The research literature revealed very few studies involving use of calculators in mathematics classes. Cech's study (3) was conducted with subjects that were low-achieving ninth graders, and Advani's study (1) involved students with learning and behavior problems, indicating the use of calculators in the classroom might benefit students with low aptitude in mathematics more than students with high aptitude in mathematics. Aiken (2) found that mathematics attitude and enjoyment of the use of routine computation, the use of symbols, and working word problems were related. Therefore hypotheses three and six were formulated to conjecture that use of electronic calculators in the classroom would benefit students with lower mathematics aptitude more than students with higher mathematics aptitude. This study indicates researchers should give attention to use of calculators in the classroom for students with high mathematics aptitude.

Conclusions

Consistent with the purposes of this study and based on the analysis of the results of the experiment, the following conclusions are offered with reference to the population studied.

1. Very little difference exists in student achievement when electronic calculators are used in the classroom of college basic mathematics.

2. Students who use electronic calculators in the classroom have better attitudes toward mathematics than

students who do not have calculators available, although the difference in attitude is not significant.

3. Use of electronic calculators in the classroom is of significantly more benefit in improving attitude toward mathematics for students with higher aptitude in mathematics than for students with lower aptitude in mathematics.

4. Use of electronic calculators in the classroom is of significantly more benefit in improving achievement in mathematics for students with higher aptitude in mathematics than for students with lower aptitude in mathematics.

5. There is little difference in attitude toward mathematics of females who use electronic calculators in the classroom and males who use electronic calculators in the classroom.

6. There is a difference in achievement in mathematics favoring females who use electronic calculators in the classroom over males who use electronic calculators in the classroom, but the difference is not significant.

Recommendations Based on the Findings of the Study

Based on the findings of this study, the following recommendations are made.

1. Electronic calculators will be more beneficial in improving attitudes toward mathematics for students with

high aptitudes in mathematics for college basic mathematics.

2. Electronic calculators will be more beneficial in improving achievement for students with high aptitude in mathematics for college basic mathematics.

Suggested Areas for Further Research

There are several questions regarding calculators with which mathematics educators need to be concerned. Some of these questions are: (1) Should a student who has his own calculator be allowed to use it in class and on tests when other students do not have access to a calculator? (2) Should calculators be provided for all students in mathematics classes? (3) At what grade levels are calculators beneficial? (4) For what types of courses are calculators beneficial? (5) From the newsletter of Menlo College (4) professors report more subject matter can be completed in courses when calculators are used by the students; should teachers revise syllabuses for classes where calculators are available in the classroom? (6) Can the calculator be used as a teaching device rather than merely as a computational aid? (7) Does a student who has access to a calculator in the classroom enjoy the class more than one who does not have a calculator available?

To provide some of the answers to these questions, the following suggestions are made for further research:

1. Investigation of "enjoyment of the course" as well as attitudes toward mathematics and achievement in mathematics in studies concerning use of calculators.

2. Restructuring of existing courses of college basic mathematics for the use of electronic calculators as a teaching device as well as a computational device.

3. Experiments with amount of course material that can be successfully presented with use of calculators compared with the amount presented without use of calculators.

4. Substantiation of the results of this study with different populations.

5. Studies concerning use of calculators in the classroom at elementary and secondary school levels.

6. Experiments using a calculator laboratory rather than classroom use of a calculator.

7. Experimentation using electronic calculators in other college mathematics courses.

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3. Cech, Joseph P., "The Effect of the Use of Desk Calculators on Attitude and Achievement with Low-achieving Ninth Graders," The Mathematics Teacher, LXV (February, 1972), 183-186.

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APPENDIX A

INSTRUMENTS

MATHEMATICS

Name______________________________________I.D. No.______________________

Check the proper blank to indicate your feeling about mathematics.

Example:

Happy_____:_____:__X__:_____:_____:_____:_____Sad

* *

Pleasant_____:_____:_____:_____:_____:_____:_____Unpleasant

Bad_____:_____:_____:_____:_____:_____:_____Good

Hard_____:_____:_____:_____:_____:_____:_____Soft

Afraid_____:_____:_____:_____:_____:_____:_____Unafraid

Active_____:_____:_____:_____:_____:_____:_____Passive

Valuable_____:_____:_____:_____:_____:_____:_____Worthless

Strong_____:_____:_____:_____:_____:_____:_____Weak

Love_____:_____:_____:_____:_____:_____:_____Hate

Fast_____:_____:_____:_____:_____:_____:_____Slow

Comfortable_____:_____:_____:_____:_____:_____:_____Uncomfortable

Awful_____:_____:_____:_____:_____:_____:_____Nice

Enjoyable_____:_____:_____:_____:_____:_____:_____Unenjoyable

Light_____:_____:_____:_____:_____:_____:_____Heavy

Varied_____:_____:_____:_____:_____:_____:_____Repetitive

Secure_____:_____:_____:_____:_____:_____:_____Insecure

QUESTIONNAIRE

Directions: Please complete the following information for our records.

NAME ____

LAST FIRST MIDDLE INITIAL

Student identification number ______________________________

Year graduated from high school ____________________________

Mathematics courses taken in high school:

(1) ______________ (2) ______________ (3) ______________

(4) ______________ (5) ______________ (6) ______________

Proposed college major ______________________________________

Do you have access to an electronic calculator? ____________

MATH SURVEY TEST

Name________________________________

Instructions: Do all work on the test paper. Designate (underline) your answers very clearly when blanks are not provided. You should work as many exercises as possible; therefore, do not spend long periods of time on any particular exercise. The problems are not presented in order of difficulty, so you may want to skip around and do those that you recognize most easily.

1. Given that the universal set is $\{a, b, c, 1, 4, 5, 7\}$,

   $A = \{b, 1, 5, 7\}$, and $B = \{a, 1, 4,\}$, find:

   (a) A complement = ________________________________

   (b) $A \cup B$ = ________________________________

   (c) $A \cap B$ = ________________________________

2. In a group of 30 students, 15 take algebra, 22 take geometry, 14 take trigonometry, 11 take both algebra and geometry, 8 take geometry and trigonometry, 5 take algebra and trigonometry, and 3 take all 3 subjects. How many take only geometry?

Answer________________

In problems 3 and 4 capital letters will represent points, small letters will represent lines, two letters with an arrow above will represent rays, and two letters with a bar above will represent a line segment.

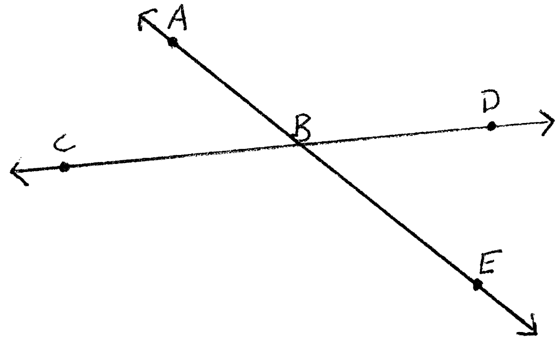
3. Refer to the accompanying figure to find the following sets of points:

   (a) $\overrightarrow{CD} \cap \overrightarrow{DB}$ = ________________

   (b) $\overrightarrow{BA} \cup \overrightarrow{BD}$ = ________________

   (c) $\overline{BC} \cup \overline{BD}$ = ________________

   (d) $\angle ABC \cap D$ = ________________



4. Refer to circle c intersected by line m:

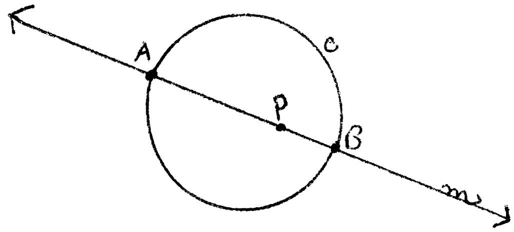
(a) $m \cap c$ = __________

(b) $P \cap m$ = __________

(c) $P \cap c$ = __________

(d) $\overline{AB} \cap c$ = __________

(e) $A \cap c$ = __________



5. Give an example of each of the following:

(a) A rational number that is not an integer.__________

(b) A real number that is not a rational number.__________

(c) An integer that is not a whole number.__________

(d) Two counting numbers that are relatively prime but not prime.__________

(e) Two sets which are equivalent but not equal.__________

6. List the prime numbers between 20 and 40:__________

7. List the prime factors of 220:__________

8. Find two rational numbers between $\frac{4}{13}$ and $\frac{5}{13}$:__________

9. Find the greatest common factor and the least common multiple of 68 and 76:

g.c.f. = __________

l.c.m. = __________

10. Change $124_{(five)}$ (base five) to a base ten numeral:

11. A number written in base ten notation is $76_{(ten)}$. Write this number in base five notation.

12. The sum of 13 and 34 is 102 in a certain base. What is the base?

13. Give the area formulas for the following regions:

(a) Circular region____________________

(b) Triangular region__________________

(c) Trapezoidal region_________________

14. In right triangle DEF, D = 90°, side FD is 12 inches and side EF is 13 inches. How long is side ED?

15. Write the equation of the line with the same slope as $2y - 3x = 5$ which passes through the point (0,5).

16. Write the equation of a circle whose center is at the origin and whose radius is two units.

17. For the graph of $4x - 2y = 12$, find the slope and y-intercept.

slope = ____________________

y-intercept = ____________________

18. A(0,3), B(2,4), and C(0,8) are the vertices of a triangle. Show that triangle ABC is a right triangle.

19. Jane has five dresses, three hats, and four pairs of shoes. Assuming that she can wear any combination of these, how many different outfits can she assemble?

20. A coin is tossed three times. What is the probability that all three tosses are heads?

21. Solve the formula $S = \frac{a}{1 - r}$ for r.

22. Simplify the expression $\left(\frac{3}{4} + \frac{7}{5}\right) + \left(\frac{-2}{3} \div \frac{5}{7}\right) + 1$

23. Write the complex fraction $\frac{1 + \frac{1}{x}}{1 - \frac{1}{x}}$ as a single fraction in lowest terms.

24. Find all values of x that will make the following a true statement.

$$x^2 - 3x - 10 = 0$$

25. Factor the trinomial $8x^2 - 9 - 21x$ into the product of two binomials.

26. Solve the following equations simultaneously for <u>both</u> x and y.

$2x + 2y = 8$

$3x - 3y = 18$

x = ______________

y = ______________

27. If $f(x) = x^2 - 2x + 3$, find f(2), f(-1), and f(0).

f(2) = ______________

f(-1) = ______________

f(0) = ______________

28. Graph on a number line the solution set for real numbers x.

$$\{x \mid x + 3 > 5\} \cap \{x \mid x - 2 < 7\}$$

29. Solve the inequality $7 - 2x < 13$ and sketch the solution set on a number line.

APPENDIX B

THE REMINGTON 665 CALCULATOR

FEATURES OF THE REMINGTON 665

PERSONAL ELECTRONIC CALCULATOR

* Positive action keyboard
* Large digitronic display, easy to read
* More than 5 times battery life than comparable machines
* 12-digit capacity for multiplication and division
* Add-subtract-multiply-divide
* Floating decimal
* Automatic constant
* Clear and correct keys
* Handsome case included
* Battery-operated
* AC adapter--optional

Color: black and white

Shipping weight: one pound

Suggested list price: $59.95

APPENDIX C

OUTLINE OF CHAPTERS TAUGHT IN

COLLEGE BASIC MATHEMATICS

OUTLINE OF CHAPTERS TAUGHT IN COLLEGE BASIC MATHEMATICS

Introduction

The purpose of Appendix C is to present an outline of the chapters from the text, Introduction to Mathematics, taught in College Basic Mathematics for the 1974-1975 fall semester.

Outline of Chapters

I. An Introduction to Sets (Chapter 2)

- A. Set Notation
- B. Subsets
- C. Equivalent Sets
- D. Sets of Numbers
- E. Intersection and Union
- F. Sets of Points

II. Systems of Numeration (Chapter 4)

- A. Egyptian Numeration
- B. Other Methods of Computation
- C. Decimal Notation
- D. Other Systems of Numeration
- E. Base Five Notation
- F. Computation in Base Five Notation

G. Other Number Bases

H. Binary Notation

III. Mathematical Systems (Chapter 5)

A. An Abstract System

B. The Distributive Property

C. Clock Arithmetic

D. Modular Arithmetic

E. Two by Two Matrices

IV. Sets of Numbers (Chapter 6)

A. The Set of Counting Numbers

B. Prime Numbers

C. Applications of Prime Factorizations

D. Equivalence and Order Relations

E. The Set of Whole Numbers

F. The Set of Integers

G. The Set of Rational Numbers

H. The Set of Complex Numbers

V. An Introduction to Probability (Chapter 9)

A. Counting Problems

B. Definition of Probability

C. Sample Spaces

D. Computation of Probabilities

E. Odds and Mathematical Expectation

F. Permutations

G. Combinations

VI. An Introduction to Statistics

A. Uses and Misuses of Statistics

B. Collecting and Presenting Data

C. Measures of Central Tendency

D. Measures of Dispersion

E. Binomial Distributions

APPENDIX D

CUPM RECOMMENDATIONS FOR COURSE CONTENT

CUPM RECOMMENDATIONS FOR COURSE CONTENT

Introduction

The purpose of Appendix D is to present a sample course outline for Mathematics E as recommended by the Committee for the Undergraduate Program in Mathematics in the booklet, A Course in Basic Mathematics for Colleges. The one year course proposed by the committee is referred to as Mathematics E. The committee emphasized that the following outline is merely a sample that could be enriched or abridged as the individual colleges see fit.

Outline of Mathematics E

I. Flow Charts and Elementary Operations

A. Brief introduction to the nature and structure of digital computers. Specimens of computer programs and computer output but no real programming until Part V. Flow charting as a preliminary device for communicating with the computer.

B. Flow charts. Further illustrations of flow charts by nonmathematical examples including loops and branches. Sequencing everyday processes.

C. Addition and multiplication of whole numbers. Addition and multiplication as binary operations. The commutativity and associativity properties, illustrated by everyday examples. Multiplication as repeated addition, illustrated by examples. Drill in these operations. Flow charts for these operations, notion of variable, equality and order symbols. Introduction of the number line as an aid in illustrating the above and to provide for the introduction of the coordinate plane.

D. The distributive property and base 10 enumeration. Distributive law done very intuitively and informally by examples on 2 or 3 digit numbers in expanded form. Illustrate these two topics by means of simple multiplication.

E. Orders of magnitude and very simple approximations. Relate order of magnitude to powers of 10. Motivate approximations to sums and products by means of simple examples. Lower and upper bound for approximations, no percentage errors. Introduction of the symbol $\approx$.

F. Subtraction of whole numbers. Three equivalent statements: $a + b = c$, $a = c - b$, and $b = c - a$. Commutativity and associativity fail for subtraction, operation not always possible. Multiplication distributes over subtraction. Approximations as in I-E. Drill.

G. Exact division of whole numbers. Three equivalent statements for a and b not zero: ab = c, b = c/a, a = c/b. Division is not always possible, division is noncommutative and nonassociative. Flow charting. Computational practice.

H. Division with remainder. Informal discussion of division with remainder. Flow chart process as handled by a computer. Approximations as in I-E.

I. English to mathematics. Translations of English sentences taken from real life situations into algebraic symbolism.

II. Rational Numbers

A. Extending the number line to the negatives. Absolute value and distance.

B. Rational operations on the integers. To be derived from as novel plausibility arguments as possible but not from the field axions. Drill in these operations.

C. Fractions with the four rational operations. Special case of the denominator 100 as percentage. Simple ratio and proportion. Drill in manipulations with fractions.

D. Decimals. Use base 10 notation with negative exponents. Relation between fractions and decimals via division. Many practical applications and practice.

E. Round-off and truncation errors. Significant digits and scientific notation.

F. More on English to mathematics. Use the new ideas developed in this Part. More flow charting with examples drawn from interest computations and financial problems, including the use of the computer.

III. Geometry I

A. Introduction to geometric ideas. Informal discussion of points, planes, segments, lines, angles, parallel and perpendicular lines.

B. Geometric figures. Circles, triangles, special quadrilaterals, notion of congruence.

C. Use of basic instruments. Ruler, protractor, compasses, T-square. Error in measurements.

D. Conversion of units.

E. General introduction to linearity and proportion. Many examples. Notion of similarity.

F. The coordinate plane. Points and ordered pairs, road maps, etc.

G. The graph of $y = mx$. Slope.

IV. Linear Polynomials and Equations

A. English to mathematics. A few word problems leading to one linear equation in one unknown as motivation for algebraic manipulation. Solve some equations by trial and error. Devise flow charts for trial and error solutions.

B. Transformations of one equation in one variable. Both identities such as $2X + 3X = 5X$ and $3(X + 2) = 3X + 6$ as well as transformations such as if $4X + 5 = 11$, then $4X + 3 = 9$.

C. Flow chart for solving $ax + b = c$. Include a variety of other forms.

D. Applications. Word problems drawn from many different areas.

E. Situations leading to one equation in two variables. (Motivation for next section.)

F. Transformations of one equation in two variables. Leading for example to the form $y = mx + b$, being careful not to restrict the names of the variables to x and y.

G. Graphs of linear equations in two variables. Slope of $y = mx + b$. Relation of $y = mx + b$ to $y = mx$.

H. Solutions of two linear equations in two variables. Graphical and analytical methods, applications.

V. The Computer

A. General discussion of the computer. Ability of a computer to respond to well-defined instructions. Illustrate with simple programs. Brief discussion of error due to truncation. Memory, operations, speed, with reference to the available equipment.

B. Uses of the computer in modern society. Many different applications with limitations of the computer stressed.

C. Elementary instruction in programming. Language appropriate to the institution, writing programs from flow charts.

D. Varied applications. Drawing from material already presented, including more sophisticated financial problems. Run programs on computers when available.

VI. Nonlinear Relationships

A. Some examples of nonlinear relationships. Repeated doubling, and exponential growth of populations. Compound interest.

B. The graph of $y = x^2$. Concept of square root and graphical evaluation of square root. Use of tables and approximation of square roots by averaging.

C. Pythagorean theorem and distance formula. Very brief discussion of irrational numbers and the fact that lines and curves have no gaps.

D. The graph of $y = ax^2$. Applications.

E. The graph of $y = ax^2 + bx = x(ax + b)$. Roots and intercepts, maximum and minimum, applications.

F. Graphing of $y = ax^2 + bx + c$. Use vertical translation from $y = ax^2 + bx$. Note that there may be 0, 1, or 2 roots of the corresponding quadratic equation.

G. Approximation of roots. Use of the computer.

H. Inverse, joint and combined variation. Applications.

I. Suitable bounds for accuracy and estimates. Products and quotients, relative and percentage error, graphical illustrations.

VII. Geometry II

A. Areas and perimeters of plane figures. Rectangles, triangles, parallelograms and circles. No extensive involvement with theorems and proofs. Perhaps compute area of irregular regions by use of rectangles and Monte Carlo methods.

B. Surface areas and volumes. Use of formulas for areas and volumes of spheres, cylinders, parallelepipeds.

C. Applications. Consumer problems, pollution problems, conversion of units.

D. Elementary constructions. Use of straight edge and compasses. Include special triangles like isosceles right triangles, 30-60 right triangles, etc.

E. Further extension of work on similar figures.

VIII. Statistics

A. The role of statistics in society. Problems of interpretation of charts, graphs, percentages.

B. Descriptive statistics. Various kinds of graphs; mean, median and mode; range and standard deviation; quartiles and percentiles.

C. The normal distribution. Informal discussion.

D. Statistics and the consumer. Informal discussion of bias: choosing samples. Flow chart and computing should be used whenever appropriate.

IX. Probability

A. Empirical probability. Mortality tables, long run relative frequencies.

B. A priori probability. Tossing coins, rolling dice, selecting discs from box. Experiments in which relative frequencies are compared with theoretical probabilities.

C. Elementary counting principles. Emphasis on devising a procedure for listing of outcomes of an experiment, the procedure suggesting a principle or formula for obtaining the count.

D. Further a priori probability. Independent trials of an experiment. Examples selected from everyday experiences such as athletics.

E. Informal decision theory with examples.

APPENDIX E

THE RAW DATA

THE RAW DATA

Student Number	Sex	Section Number	ACT Math Score	Attitude Pretest	Achievement Pretest	Attitude Posttest	Achievement Posttest	Teacher Number
1.	M	1	14	60	0	76	16	1
2.	M	1	21	54	0	67	21	1
3.	F	1	12	56	11	61	25	1
4.	F	1	14	73	0	85	13	1
5.	M	1	16	65	0	72	6	1
6.	M	1	15	24	6	63	25	1
7.	F	1	14	77	3	85	21	1
8.	F	1	13	65	2	80	23	1
9.	M	1	17	73	3	75	22	1
10.	M	1	21	67	4	62	14	1
11.	M	1	14	57	1	68	13	1
12.	M	1	16	71	5	56	13	1
13.	M	1	11	60	1	58	10	1
14.	F	1	9	24	1	53	7	1
15.	F	1	17	38	7	39	27	1
16.	M	1	16	81	0	73	11	1
17.	F	1	13	63	3	62	11	1
18.	F	1	14	60	1	55	15	1
19.	M	1	25	75	5	75	29	1
20.	F	1	17	71	1	85	15	1
21.	M	1	17	69	1	55	25	1
22.	F	1	10	60	6	60	26	1
23.	M	1	24	73	0	72	31	1
24.	F	2	16	64	2	70	17	1
25.	M	2	6	77	2	65	6	1
26.	F	2	15	57	3	70	16	1
27.	F	2	24	62	13	67	31	1
28.	F	2	7	70	0	55	11	1
29.	M	2	22	60	2	73	28	1
30.	M	2	16	69	10	76	22	1

31.	F	2	16	56	1	61	18	1
32.	F	2	27	81	21	80	28	1
33.	F	2	8	47	2	51	15	1
34.	M	2	24	72	9	82	23	1
35.	F	2	25	72	6	79	31	1
36.	M	2	10	76	0	77	16	1
37.	M	2	23	72	5	75	24	1
38.	M	2	14	59	2	58	1	1
39.	F	2	9	43	1	51	12	1
40.	F	2	24	64	3	75	21	1
41.	M	2	18	59	1	58	16	1
42.	F	2	14	58	5	57	11	1
43.	M	2	11	61	1	70	7	1
44.	F	2	12	56	0	71	21	1
45.	F	2	18	45	3	65	16	1
46.	M	2	23	67	9	73	27	1
47.	M	2	16	78	8	87	25	1
48.	M	2	21	81	23	78	34	1
49.	M	2	17	67	5	77	20	1
50.	M	2	12	65	0	51	13	1
51.	F	2	17	68	2	57	15	1
52.	M	2	20	70	3	86	23	1
53.	M	3	25	83	21	78	30	2
54.	M	3	11	57	3	59	13	2
55.	M	3	17	60	3	51	24	2
56.	M	3	7	50	0	48	0	2
57.	M	3	15	51	1	51	14	2
58.	M	3	5	58	1	74	5	2
59.	M	3	16	43	3	84	16	2
60.	F	3	14	64	1	56	12	2
61.	F	3	15	43	2	53	12	2
62.	F	3	20	75	4	73	15	2
63.	F	3	19	54	7	69	27	2
64.	F	3	29	85	13	79	34	2
65.	F	3	14	61	10	57	7	2
66.	F	3	10	71	1	71	16	2
67.	M	3	14	47	0	78	11	2
68.	M	3	19	53	7	80	17	2
69.	M	3	13	51	1	55	11	2
70.	F	3	14	57	1	77	15	2
71.	M	3	8	49	0	78	10	2
72.	M	3	24	71	15	74	24	2
73.	F	3	18	68	7	65	16	2
74.	F	3	17	66	10	69	22	2
75.	M	3	14	49	0	56	10	2
76.	F	3	4	25	0	36	2	2
77.	F	3	13	62	0	68	12	2

78.	M	4	10	59	3	54	18	2
79.	F	4	16	54	1	39	16	2
80.	F	4	23	64	2	69	18	2
81.	F	4	21	45	10	56	28	2
82.	F	4	19	51	10	55	20	2
83.	F	4	12	60	1	69	10	2
84.	M	4	18	69	1	77	16	2
85.	M	4	9	66	0	68	7	2
86.	F	4	19	75	2	72	17	2
87.	M	4	18	59	5	71	21	2
88.	F	4	17	68	3	61	15	2
89.	F	4	17	66	9	68	22	2
90.	M	4	8	39	1	30	9	2
91.	F	4	11	57	2	48	6	2
92.	M	4	19	72	15	68	24	2
93.	F	4	14	59	1	65	14	2
94.	F	4	12	62	3	70	13	2
95.	F	4	14	66	2	68	12	2
96.	F	4	12	74	6	82	21	2
97.	M	4	8	70	4	65	10	2
98.	F	4	24	49	0	53	17	2

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