THE EFFECTIVENESS OF MODERN INSTRUCTIONAL MATERIALS
IN A GENERAL MATHEMATICS CLASS

by

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THE PROBLEM

Introduction

The ninth grade mathematics program at Glenn County Union High School, Willows, California, consists of four basic courses: Algebra I, business mathematics, shop mathematics, and general mathematics. The first three are designed for students who have indicated their preference in these areas and who have demonstrated reasonable facility with basic arithmetic skills. General mathematics is designed for students who lack these basic skills as indicated by achievement test scores and arithmetic grades.

The administration and faculty have considered adopting new instructional materials in an effort to improve student achievement in general mathematics. Consideration had been given to materials which follow the recommendations of curriculum committees involved in the current "modern" mathematics movement. However, there was little evidence that these materials were better suited for the low achiever in mathematics than those traditionally taught at Glenn County Union High School. As a result, school personnel were not content to make a curriculum decision until more definitive evidence was available.

Statement of the Problem

The purpose of this study was to obtain information by experimentation relative to the effectiveness of the new instructional materials versus the traditional materials in a general mathematics class. The writer attempted to: (1) present instructional units involving the elementary arithmetic operations to a control and an experimental class; (2) measure achievement gains with a pre-test and a post-test; (3) determine significant differences in achievement gains between the control and experimental groups; (4) use the results of the study to compare the effectiveness of the new and traditional instructional materials with respect to basic computational skills.

Importance of the Study

An important part of a general mathematics program is the instructional unit on elementary arithmetic operations. Due to the multiplicity of simple addition, subtraction, multiplication, and division involved in solving more elaborate problems, efficiency and facility in the elementary operations is essential. The statistical evidence presented in this study will be an important factor in making curriculum decisions pertaining to the general mathematics program at Glenn County Union High School.

Definition of Terms

Most of the terms will be defined in the context of this report. However, some terms are of sufficient importance that they will be defined here for the benefit of the reader.

Average student. Average student was defined as that student who is capable of performing successfully in the high school, but did not possess the ability to succeed in an accelerated mathematics program.

Below average student. Below average student was used synonymously with the terms "low achiever" and "slow learner" which referred to the student with low innate ability. The writer used these terms interchangeably when making reference to investigations or writings by other authors.

College bound or college capable students. These terms were used interchangeably when referring to students who possessed the capabilities to continue their formal education beyond high school.

Control group. The control group consisted of one class of twenty-one ninth grade students who were subjected to a traditional treatment of the four elementary arithmetic operations on whole numbers, fractions, and decimals. They received a review of the principles of arithmetic operations followed by drill and practical applications in the form of word problems, demonstrations, and projects.

<u>Experimental group</u>. The experimental group was one class of nineteen ninth grade students who were subjected to a new approach to the four elementary operations. This approach differed from the traditional in terminology, some symbolism, and an emphasis on the development of concepts rather than mechanical manipulation.

<u>General mathematics students</u>. The term "general mathematics students" refers to the slow learners and underachievers who were used as subjects in this study. Although most of the subjects had low innate ability, there were several average and above average youngsters whose lack of motivation and interest was one reason for their low achievement record in arithmetic.

<u>Low achiever</u>. Low achiever was used synonymously with the terms "below average student" and "slow learner."

<u>Modern mathematics</u> or <u>new mathematics</u>. These terms were used interchangeably when referring to the recent innovations in the school mathematics curriculum such as those proposed by the School Mathematics Study Group and others.

<u>New curriculum materials</u>. New curriculum materials refers to any texts or instructional materials which reflect the new mathematics. In this study the basal text for the

experimental group was General Mathematics.[1]

Non-college bound students. The term "non-college bound students" refer to both average and below average students whose limited ability will either prevent the continuation of their formal education beyond high school or make success in college highly unlikely. The writer used this term interchangeably when making reference to investigations or writings by other authors.

Slow learner. Slow learner was used synonymously with the term "below average student."

Terminal student. Terminal student was used interchangeably with "non-college bound student."

Under achiever. Under achiever refers to the student who, on the basis of standardized test data, would be expected to achieve better than his academic record indicated.

Limitations of the Study

This study was limited in that (1) the experimental unit was only a small part of the total general mathematics

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[1] Kenneth E. Brown, Daniel W. Snader, and Leonard Simon, General Mathematics (River Forest, Illinois: Laidlaw Brothers, 1963), 512 pp.

program; (2) the writer was the only person involved in the instructional phase of the experiment; (3) sampling requirements were difficult to meet since the control and experimental groups were the only subjects available; (4) other variables which influence achievement, such as emotional disturbance or cultural deprivation, were not easily controlled; and (5) the use of the term "traditional" applies to those teaching methods unique to Glenn County Union High School.

REVIEW OF THE LITERATURE

A review of the literature will reveal to what extent modern mathematics programs recommended by the new curriculum committees affect the average and below average students.

Historical Background

The mathematics education of the average student in the United States up to 1960 was not much different than it had been in 1900.[2] According to a prominant California educator and mathematician, concern for the static school mathematics curriculum was initially felt during World

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[2]Frank A. Reger, "A History of Selected Major Modern Mathematics Programs" (unpublished Master's thesis, Chico State College, Chico, California, 1964), p. 1.

War II when aptitude tests revealed a large number of servicemen were mathematically incompetent.[3]

Later, in the early 1950's, the Mathematics Examiners of the College Entrance Examination Board began to question the validity of the curriculum they were testing. They doubted that the curriculum was aligned with the demands of our technological world.[4] The Board established a commission composed of mathematicians and educators to review the secondary mathematics program and to make recommendations for its modernization and improvement.[5]

In December, 1951, the University of Illinois Committee on School Mathematics was established to investigate the content and teaching of secondary mathematics. Directed by Dr. Max Beberman, the committee began working on the problem by introducing new classroom instructional materials which placed emphasis on the student discovering generalizations for himself.[6]

The Ball State Teachers College established another

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[3]Max Kramer, in an address given to the California Mathematics Council, Northern Section, Seaside, California, December 10, 1965.

[4]National Longitudinal Study of Mathematical Abilities, Information Bulletin No. 6 (March, 1964), p. 2.

[5]*Ibid*.

[6]Reger, *op. cit.*, p. 8.

curriculum committee in the fall of 1956. Secondary instructional materials used by Ball State and Purdue professors in experimental programs were later developed into an entirely new series of text books.[7]

The final impetus for curriculum reform came in 1957 after Russia orbited Sputnik. The quality of mathematics at this time became a matter of national prestige and security. Additional curriculum committees were initiated in response to public demand for better mathematics education.[8]

One of the first curriculum committees formed subsequent to Sputnik was the School Mathematics Study Group which began in the spring of 1958. Directed by Dr. Edward G. Begle of Yale University, the Study Group distributed experimental texts to schools in forty-five states for use during the 1959-60 school year. Constructive criticism and evaluation by teachers and advisors were used to improve the materials. Other influential curriculum committees included the University of Maryland Mathematics Project, the Boston College Mathematics Institute, and the Developmental Project in Secondary Mathematics at Southern Illinois

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[7] Ibid., p. 5.

[8] Kramer, loc. cit.

University.[9]

A research project of major significance was the Greater Cleveland Mathematics Program created in 1958. The materials for this program were developed by the Educational Research Council of Greater Cleveland.[10]

Primary Objective of the New Curriculum Committees

The primary objective of the new curriculum committees was to create ". . . a spirit of inquiry, of discovery, that is instilled in pupils through an inductive approach."[11] Instructional materials designed by the new curriculum committees encouraged students to use concepts already acquired as a means of discovering new concepts.

Criticisms of the New Curriculum Committees

The major criticism of the new curriculum committees was their failure to provide for the average and below average students. In his evaluation of the Report of the

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[9]Harold J. Panko, "The Impact of Mathematics Reform on the Program for Average High School Students in Selected Northern California Schools" (unpublished Master's thesis, Chico State College, Chico, California, 1964), pp. 10-11.

[10]Walter R. Borg, Educational Research (New York: David McKay Company, 1963), pp. 13-14.

[11]"How Does Modern Mathematics Help Us Teach?" The Resourceful Teacher No. 7 (Morristown, New Jersey: Silver Burdett Company, 1964), p. 1.

Cambridge Conference on School Mathematics, Stone commented that the Conference dealt exclusively with mathematics for the college capable individual ". . . just as the whole reform movement has been doing for a decade."[12] Wilson's remarks were also typical of many educators:

> In this first surge of excitement, a great deal of energy has been expended in an effort to provide new courses for the college preparatory student, but very little attention has been devoted to the needs of other types of pupils, especially the so-called terminal students.[13]

Advocates of the New Curriculum Materials for General Mathematics

Although there was little evidence to support the fact that modern mathematics was appropriate for average and below average students, many educators and professional groups recommended that modern programs be made available to these students.

According to Wilson, a mathematics program for the college bound and terminal student should differ only in degree and should include such concepts as number systems, algebraic structure, interesting drill exercises, and

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[12]Marshall H. Stone, "Goals for School Mathematics: The Report of the Cambridge Conference on School Mathematics," The Mathematics Teacher, 58:356, April, 1965.

[13]Jack D. Wilson, "What Mathematics for the Terminal Student?" The Mathematics Teacher, 53:518, November, 1960.

meaningful puzzles and games.[14] Mehl also felt that remedial mathematics should be refreshed with many of the new topics and instructional devices.[15] Adler proposed that slow learners can profit from the abstract concepts present in the new instructional materials provided they are properly taught. He further asserted: ". . . let us not hold back from any children the benefits of the new courses of study. Extend the new programs to all classes on all levels."[16]

Other educators such as Allen,[17] Proctor,[18] and Sobel,[19] also suggested that current mathematics curricula should include a program for students not capable of success in accelerated classes.

The Committee on High School Mathematics recommended

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[14] Ibid., p. 519.

[15] William G. Mehl, "Providing for the Basic Student in the Junior High School," The Mathematics Teacher, 53:359-63, May, 1960.

[16] Irving Adler, "Some Thoughts About Curriculum Revision," The Mathematics Teacher, 56:510, November, 1963.

[17] Frank B. Allen, "The Council's Drive to Improve School Mathematics: A Progress Report," The Mathematics Teacher, 57:370-78, October, 1964.

[18] Amelia D. Proctor, "A World of Hope: Helping the Slow Learners Enjoy Mathematics," The Mathematics Teacher, 58:118-22, February, 1965.

[19] Max A. Sobel, "Providing for the Slow Learner in the Junior High School," The Mathematics Teacher, 52:247-53, May, 1959.

that the same general program procedure be used for all students, except that slower individuals be separated and proceed at a slower rate.[20] The Commission on Mathematics also recommended that curriculum objectives for the slow learner be the same in structure and concept but to a lesser degree in scope.[21]

<u>Research Relative to the Average and Below Average Students</u>

Although more experimentation and research in modern topics and their effectiveness with average and below average students is needed, there has been some work done in this area, especially at the junior high school level. Payne reported that the majority of available evidence indicates modern programs are at least as effective as the traditional for "a wide range of student ability."[22]

<u>Research by individuals</u>. Easterday experimented with thirty-seven eighth grade and forty-one seventh grade low achievers to determine if they could be taught modern

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[20] W. H. Meyer, moderator, "Report of the Committee on High School Mathematics Courses," <u>California Schools</u>, 50:385-97, September, 1960.

[21] Panko, <u>op</u>. <u>cit</u>., pp. 12-13.

[22] Holland Payne, "What About Modern Programs in Mathematics," <u>The Mathematics Teacher</u>, 58:422-24, May, 1965.

mathematics effectively.[23] The two groups consisted of forty-nine boys and twenty-nine girls distributed in equal proportion. The mean intelligence quotients were 100 and 94.1 for the seventh and eighth grades respectively.

Both classes were taught concepts introduced through techniques of the School Mathematics Study Group text EM 101-107. Practice was designed through traditional work sheets. At the end of the school year Easterday administered the California Achievement Test, Form W, and reported a grade level increase of up to three years in reasoning and four years in computational skills. He noted that students with intelligence quotients less than 100 made the largest over-all growth. As a result, Easterday concluded that modern mathematics "can be blended" with traditional materials into a successful subject matter program for low achievers.[24]

Ruddell divided four seventh grade classes into an experimental group which studied new mathematics materials, and a control group given traditional instruction.[25] Each

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[23]Kenneth Easterday, "An Experiment With Low Achievers in Arithmetic," The Mathematics Teacher, 57:462-68, November, 1964.

[24]*Ibid.*, p. 468.

[25]Arden K. Ruddell, "The Results of a Modern Mathematics Program," The Arithmetic Teacher, 9:330-35, October, 1962.

group was divided into two sections, one with a mean intelligence quotient of 135 and another with a mean intelligence quotient of 112. The purpose of this study was to determine if students taught modern mathematics achieve as well as their traditional counterparts.

Ruddell measured the results of his investigation with three tests; (1) The Wide Range Achievement Test in Arithmetic; (2) The Sequential Test of Educational Progress and the School and College Abilities Test; and (3) a pencil and paper test prepared by the investigator.

Upon analyzing the testing data, Ruddell found that children taught a program of modern mathematics will score as high or higher than children taught a program of traditional mathematics. Of importance here is his suggestion that:

> Although the four classes which constituted the sample for this study were formed for an accelerated mathematics program, many of the students in these classes had intelligence and arithmetic pre-test scores more in keeping with a normal group. This would suggest that youngsters with average ability could study a modern mathematics program without suffering any mathematical loss as measured by tests designed for traditional programs.[26]

Modern instructional materials have placed a greater emphasis on intellectual curiosity as a motivational vehicle as opposed to the traditional use of social or practical

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[26] *Ibid.*, p. 335.

arithmetic as the primary learning incentive. Some authors have questioned whether or not the abstract nature of numbers will stimulate a low achiever more effectively than materials based upon present individual interests or the arithmetic needs of a possible future vocation.[27]

Holton attempted to measure the effectiveness of intellectual curiosity as a motivational vehicle with a group of general mathematics students. The sample consisted of 136 ninth grade boys in fourteen classes. On the basis of the Kuder Preference Record, Vocational, Form C, the boys were divided into four high interest and four low interest levels. Holton compared four motivational vehicles at each interest level: (1) farming; (2) automobile; (3) social utility; and, (4) intellectual curiosity. The experimental unit covered mathematical inequalities in the form of linearly programmed instructional textbooks.

In regard to achievement and retention, which were measured by an objective criterion test, Holton found that the four motivational vehicles were equally effective at all interest levels. He concluded that achievement can be improved by any motivational device as long as it conforms

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[27]Boyd D. Holton, "A Comparison of Motivational Vehicles in Teaching General Mathematics Students" (unpublished Doctor's dissertation, The University of Illinois, Urbana, 1963).

to individual interests.[28]

Research by professional groups. As a result of experimentation, the School Mathematics Study Group has prepared texts for junior high school students with a lower level of reading ability. These texts reflect a de-emphasis of the so-called practical applications and place more stress on abstractions to motivate youngsters.[29] The University of Maryland has successfully used its new curriculum materials for average and below average students in the junior high school.[30]

Some important studies are currently underway. The National Longitudinal Study of Mathematical Abilities, initiated in 1962, began a five year study to provide information concerning variables which effect mathematical learning.[31] One of the goals of this study was to determine the effectiveness of the new curriculum materials for below

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[28]Ibid.

[29]Harold J. Panko, "The Impact of Mathematics Reform on the Program for Average High School Students in Selected Northern California Schools" (unpublished Master's thesis, Chico State College, Chico, California, 1964), p. 12.

[30]Ibid.

[31]National Longitudinal Study of Mathematical Abilities, Information Bulletin No. 6 (March, 1964), p. 1

average students.[32] In 1964 Allen reported to the National Council of Teachers of Mathematics that a Committee on Mathematics for the Non-College Bound had been formed. At this time the committee was making long range plans for the improvement of mathematics instruction for terminal students.[33]

Russian Research

Some of the instructional recommendations of the new curriculum committees parallel those of Soviet mathematics educators. As an example, modern teaching guides suggested the introduction of addition and subtraction simultaneously as inverse operations. Russian educators employed this method as an application of Pavlov's famous finding that ". . . differentiation between a positive and a negative stimulus is achieved most effectively when the two are interspersed during conditioning."[34]

Boguslavsky cited one Russian investigation relative to the teaching of addition and subtraction to slow

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[32] Sally Herriot, in a report given to the California Mathematics Council, Northern Section, Seaside, California, December 11, 1965.

[33] Frank B. Allen, "The Council's Drive to Improve School Mathematics: A Progress Report," The Mathematics Teacher, 57:370-78, October, 1964.

[34] George W. Boguslavsky, "Psychological Research in Soviet Education," Science, 125:916, May 10, 1957.

learners. They found little transfer from successful manipulation of blocks to mental operations. On the other hand, if the child was urged to visualize the blocks and then describe his operations aloud, his mental performance was considerably improved. Boguslavsky defined this technique as "imagery."[35]

Present Trends in Northern California Schools

In a recent study Panko determined the extent to which high schools in Northern California were conforming to recommendations of the new curriculum relative to programs for average and below average students.[36] He contacted fifty schools with an average daily attendance of at least three hundred students. These schools operated on a nine-to-twelve grade system.

Approximately 75 per cent of the respondents were in agreement with authoritative curriculum committees and indicated they had been conforming slowly to recommendations of the committees. Seventeen schools were not in agreement with the new curriculum committees. Their reasons varied but in general they felt the recommendations of the committees were unrealistic for slower students and that

[35] Ibid., p. 918.

[36] Panko, op. cit., pp. 1-44.

computational skills should be the primary objective of a remedial mathematics program.

Panko's study did not reveal information concerning the effectiveness of the new materials for slower students. He recommended more research and experimentation in this area.

METHODS AND PROCEDURES

Description of the Population

Glenn County is situated in the center of a rich agricultural area of the Sacramento Valley. The major agricultural product is rice although substantial income is also derived from sheep, beef, dairying, lumber, and seed and nut crops.[37]

The Glenn County Union High School District includes Glenn County Union High School, two elementary schools located in the town of Willows, and four elementary schools which are in surrounding rural areas. The district is relatively wealthy with a 1964-65 assessed valuation of $26,760,760.

Glenn County Union High School possesses a maximum possible accreditation as granted by the Western Association

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[37]Leland Brown, "Annual Crop and Livestock Report, County of Glenn" (Willows, California: Office of the Agricultural Commissioner, 1964), p. 8. (Mimeographed.)

of Schools and Colleges and the University of California. Approximately 45 per cent of this comprehensive four-year high school's graduates enter colleges and universities. The average daily high school attendance for the 1964-65 school year was 487.03. One-fourth of the student population live in rural areas and commute to school by bus.[38]

<u>Description of the Sample</u>

The control and experimental groups used in this study were two classes of general mathematics and were part of the writer's 1965-66 teaching assignment. There were nine male and twelve female students in the control group and six males and thirteen females in the experimental group. All students were in the ninth grade with the exception of one girl in the experimental group who had failed general mathematics the previous year. The average age for all subjects was 175.8 months (14.7 years).

The subjects in both groups had a mean intelligence quotient of 94.9. The California Achievement tests administered in October, 1964, revealed the majority of students below average in arithmetic reasoning and fundamental skills. Eight subjects in the control group failed at

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[38] Erwin A. Decker, "Historical and Current Financial Condition of the Glenn County Union High School District" (Willows, California: Glenn County Union High School District, September, 1964), pp. 1-13. (Mimeographed.)

least one elementary grade as compared to six in the experimental class.

A comparison of age, intelligence quotients, percentile ranks, and grade placement data for each group is given in Appendix A. There was little variation between the two classes although the experimental group exhibited a slightly greater range of mental ability.

Personal data relative to the occupational status of the subject's parents is given in Appendix B. The majority of parents were involved in farming and skilled labor.

Methods Used

Complete randomized sampling was not possible in this experiment since the two groups involved were the only general mathematics classes available. However, individual classroom assignments were made from alphabetized lists by school counselors who did not attempt to group according to ability. A coin flip determined which of the two general mathematics classes would be subjected to the experimental unit. The control group met during the period before lunch and the experimental group met during the last period of the day.

The experiment lasted eight weeks and the instructional units pertained to the four fundamental arithmetic operations on whole numbers, fractions, and decimals. Detailed lesson plans are given in Appendix C.

Instructional materials constituted the independent variable for this study. Although the subject matter content for both the control and experimental groups was essentially the same, the new instructional materials differed from the traditional in concept, terminology, some symbolism, and an emphasis on inductive rather than deductive reasoning. The new instructional materials also shifted emphasis from mechanical manipulations to the development of concepts.

The initial objectives of the new instructional materials were to develop an understanding of the number concept, the distinction between number and numeral, properties of different numeration systems, and the properties of numbers under given operations. A one-to-one matching of members of two sets illustrated the process of counting and an introduction to various numeration systems supplemented the distinction between number and numeral. The face value and place value of our positional decimal system became significant following a discussion of the base-five and base-two systems. Properties of non-negative whole numbers under the four elementary operations were made intuitively apparent by extensive use of the number line. The number line was a major tool in developing concepts leading to the discovery of number properties.

Following a discussion on measurement and the definition of fractions, the experimental group was shown that the structural properties of positive whole numbers held for fractions. Concepts already acquired facilitated the ability to perform the elementary operations on fractions. Finally, decimals were introduced as symbols which could be used as different names for fractions. Related concepts provided an easy and logical transition for the students.

Although the new instructional materials placed major emphasis on acquiring concepts, the student's skill with mechanical manipulation was not neglected. However, during drill sessions the youngsters were made constantly aware of the meanings and conceptual aspects of arithmetic operations through verbal discussions and review demonstrations.

The traditional instructional materials began with the reading of large numbers and continued through the elementary operations on positive whole numbers, fractions, and decimals. Students were presented with "rules" for specific situations followed by a discussion regarding the justification of these rules. Blocks, diagrams, and the ruler used with individual students provided basic concepts.

Drill constituted a major emphasis with the control group. Once the students demonstrated reasonable facility with the mechanical manipulation of numbers, practical applications were stressed through word problems and group and individual projects.

Since many of the newer mathematics programs have been based on intellectual curiosity as the primary motivational vehicle, this technique was used extensively with the experimental group through the inductive development of basic number properties. Motivation for the control group was derived from individual interests and occupational aspirations. Other learning incentives such as praise and reproof, competition, and knowledge of results were utilized equally in both classes.

Variables which are difficult to control in a study of this nature have been discussed earlier under Limitations of the Study. There were no serious discipline problems which could effect achievement gains and no subjects were lost during the experiment. The writer, who had previous teaching experience with the new instructional materials and attended two summers of a National Science Foundation Institute in Mathematics, instructed both the control and experimental groups.

Testing Instruments

The instrument used as a pre-test and post-test was Test 4, Sections D, E, F, and G of the California Achievement Test, Form W. Sections D, E, F, and G consisted of twenty items each and measured facility with addition, subtraction, multiplication, and division respectively. The items involved whole numbers, fractions, and decimals and were closely representative of the objectives of the experimental unit. Problems similar to those used in Sections D, E, F, and G are given in Appendix E.

During the testing periods, students had twenty minutes to complete each section. The pre-test and post-test each took two class periods to complete. Individual scores on all sections were based upon the total number of items correct. Appendix D contains tables of raw scores made by both groups on the pre-test and post-test.

Statistical Procedures

The *F* test for homogeneity of variance and the *t* test for significance of difference between means were applied to each of the twenty-four sets of data pertaining to the two groups in this study. The null hypothesis was employed to determine whether or not an observed difference between two means could be considered significant. The null hypothesis states that there is no difference between the two means and that any observed difference occurred by chance. In this study the null hypothesis was rejected only when it was shown that an observed difference between two means would occur by chance no more than five out of one hundred cases (.05 level of confidence).

Three formulas for t were used in this study. When comparing pre-test and post-test scores between the same groups, research requires the use of a t formula for correlated samples.[39] The writer used a t formula for uncorrelated samples when comparing means between the control and experimental groups.[40]

Furthermore, if the F test indicated the population variance in a particular case was significantly different beyond the .05 level of confidence, a different method for arriving at a t value was used. This method is accomplished through formulas developed by Cochran and Cox.[41]

RESULTS

The analysis of data relative to the pre-test scores of the control and experimental groups are summarized in Table I. No significant difference in the mean pre-test scores was found as a result of the t test. Application of the F test yielded no significant difference in population

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[39]Celeste McCollough and Van Atta Loche, Statistical Concepts: A Program for Self-Instruction (New York: McGraw-Hill Company, 1963), p. 237.

[40]Ibid., p. 240.

[41]William G. Cochran and Gertrude M. Cox, Experimental Designs (New York: John Wiley and Sons, 1950), p. 92.

variance and the two groups were assumed to be homogeneous in regard to arithmetic fundamentals.

TABLE I

SIGNIFICANCE OF DIFFERENCE BETWEEN THE PRE-TEST SCORES OF THE CONTROL AND EXPERIMENTAL GROUPS ON TEST 4 OF THE CALIFORNIA ACHIEVEMENT TEST, FORM W

	n	X	s^2	s	*F*	*P*	*t*	*P*
Control	21	55.38	117.05	10.82	1.19	n.s.	.61	n.s.
Experimental	19	53.21	138.95	11.79				

Table II reveals data relative to the mean scores of the control group on the pre-test and post-test and the experimental group on the pre-test and post-test. The average gain of 7.86 items correct made by the control group was found to be significant beyond the .001 level of confidence. The experimental group had an average gain of 9.73 items correct and the *t* test indicated this difference was also significant beyond the .001 level of confidence. In view of the normal learning curve, the achievement gains indicated in Table II were expected.

No significant difference was found between the control and experimental groups in the analysis of mean scores derived from post-test results even though the control group had a slightly higher mean. Results of the post-test analysis are listed in Table III.

TABLE II

SIGNIFICANCE OF DIFFERENCE BETWEEN THE PRE-TEST AND POST-TEST SCORES OF THE CONTROL GROUP AND THE PRE-TEST AND POST-TEST SCORES OF THE EXPERIMENTAL GROUP ON TEST 4 OF THE CALIFORNIA ACHIEVEMENT TEST, FORM W

		Pre-test			Post-test				
	n	X	s^2	s	X	s^2	s	t	P
Control	21	55.38	117.05	10.82	63.24	59.49	7.71	5.59	.001
Experimental	19	53.21	138.95	11.79	62.95	95.77	9.78	5.35	.001

TABLE III

SIGNIFICANCE OF DIFFERENCE BETWEEN THE POST-TEST SCORES OF THE CONTROL AND EXPERIMENTAL GROUPS ON TEST 4 OF THE CALIFORNIA ACHIEVEMENT TEST, FORM W

	n	X	s^2	s	F	P	t	P
Control	21	63.24	59.49	7.71	1.61	n.s.	.11	n.s.
Experimental	19	62.95	95.77	9.78				

In an attempt to analyze further the differences between the control and experimental groups, t tests were applied to data derived from each of the four sub-sections of the pre-test and post-test. Table IV summarizes results of the control group's pre-test and post-test scores on sections D, E, F, and G. The average gain was positive in all sections except section D, addition. Here the observed difference was zero. However, the observed differences in sections E, F, and G, were found to be significant beyond the .05, .01, and .001 levels of confidence respectively.

TABLE IV

SIGNIFICANCE OF DIFFERENCE BETWEEN THE CONTROL GROUP'S PRE-TEST AND POST-TEST SCORES ON SECTIONS D, E, F, AND G ON TEST 4 OF THE CALIFORNIA ACHIEVEMENT TEST, FORM W

Section		Pre-test			Post-test				
	n	X	s^2	s	X	s^2	s	*t*	*P*
D, add.	21	14.48	8.56	2.93	14.48	11.26	3.36	0	n.s.
E, subtr.	21	14.29	8.46	2.91	15.86	6.25	2.50	2.66	.05
F, multip.	21	13.62	8.74	2.96	15.43	4.65	2.16	3.12	.01
G, divis.	21	13.00	20.70	4.55	17.19	3.47	1.87	5.10	.001

Data in regard to the experimental group's pre-test and post-test scores on sections D, E, F, and G, are given in Table V. Observed achievement gains in all sections were positive and the *t* test revealed each were significantly different beyond the .001 level of confidence except for section F, multiplication. The null hypotheses relative to section F was rejected at the .05 level of confidence. In all four sections the null hypotheses was rejected with a high degree of confidence.

TABLE V

SIGNIFICANCE OF DIFFERENCE BETWEEN THE EXPERIMENTAL GROUP'S PRE-TEST AND POST-TEST SCORES ON SECTIONS D, E, F, AND G ON TEST 4 OF THE CALIFORNIA ACHIEVEMENT TEST, FORM W

Section		Pre-test			Post-test				
	n	X	s^2	s	X	s^2	s	t	P
D, add.	19	13.84	9.70	3.11	16.58	8.71	2.95	5.82	.001
E, subtr.	19	13.32	10.22	3.19	15.95	7.72	2.78	4.61	.001
F, multip.	19	13.32	9.70	3.11	15.00	5.00	2.25	2.21	.05
G, divis.	19	12.73	14.64	3.82	15.42	8.15	2.85	3.99	.001

The t test revealed no significant difference between the pre-test scores of the control and experimental groups on sections D, E, F, and G. Each application of the F test was also negative. This data is given in Table VI and concurs with the results listed in Table I which suggested that the two groups were homogeneous with respect to arithmetic fundamentals. Table VI appears on page 31.

Table VII compares data relative to the control and experimental group scores on each of the four sub-sections of the post-test. The mean of the experimental group on section D, addition, exceeded the control group's mean score on the same section by 2.10 problems correct. Application of the t revealed this difference significant beyond the .05 level of confidence. In contrast, the control

TABLE VI

SIGNIFICANCE OF DIFFERENCE BETWEEN THE PRE-TEST SCORES OF THE CONTROL AND EXPERIMENTAL GROUPS ON SECTIONS D, E, F, AND G ON TEST 4 OF THE CALIFORNIA ACHIEVEMENT TEST, FORM W

	Section	n	X	s^2	s	F	P	t	P
Control	D, add.	21	14.48	8.56	2.93	1.13	n.s.	.67	n.s.
Experimental	D, add.	19	13.84	9.70	3.11				
Control	E, subtr.	21	14.29	8.46	2.91	1.21	n.s.	1.03	n.s.
Experimental	E, subtr.	19	13.32	10.22	3.19				
Control	F, multip.	21	13.62	8.74	2.96	1.11	n.s.	.31	n.s.
Experimental	F, multip.	19	13.32	9.70	3.11				
Control	G, divis.	21	13.00	20.70	4.55	1.42	n.s.	.20	n.s.
Experimental	G, divis.	19	12.73	14.64	3.82				

TABLE VII

SIGNIFICANCE OF DIFFERENCE BETWEEN THE POST-TEST SCORES OF THE CONTROL AND EXPERIMENTAL GROUPS ON SECTIONS D, E, F, AND G ON TEST 4 OF THE CALIFORNIA ACHIEVEMENT TEST, FORM W

		n	X	s^2	s	*F*	*P*	*t*	*P*
Control	D, add.	21	14.48	11.26	3.36				
Experimental	D, add.	19	16.58	8.71	2.95	1.29	n.s.	2.08	.05
Control	E, subtr.	21	15.86	6.25	2.50				
Experimental	E, subtr.	19	15.95	7.72	2.78	1.24	n.s.	.11	n.s.
Control	F, multip.	21	15.43	4.65	2.16				
Experimental	F, multip.	19	15.00	5.00	2.25	1.08	n.s.	.61	n.s.
Control	G, divis.	21	17.19	3.47	1.87				
Experimental	G, divis.	19	15.42	8.15	2.85	2.35	.05	2.31*	.05

*This *t* value was obtained through use of the formula when *F* is significant beyond the .05 level of confidence discussed under *Statistical Procedures*.

group's greater mean score on Section G, division, was significantly higher beyond the .05 level of confidence. There were no significant differences between mean scores on the remaining two sections. The *F* test was not significant in any section except when applied to data obtained from section G, division. In this case the significance of difference between means was evaluated through an application of the Cochran and Cox formula discussed under *Statistical Procedures*.

Data relative to the significance of difference between pre-test-to-post-test gains on Sections D, E, F, and G, by the Control and Experimental groups is presented in Table VIII. This data is similar to the analysis of mean post-test scores of both groups given in Table VII. There were no significant differences between average gains on Sections E, F, and G. However, the difference of 2.74 items gained on Section D, addition, favoring the Experimental group was highly significant beyond the .001 level of confidence.

TABLE VIII

SIGNIFICANCE OF DIFFERENCE BETWEEN AVERAGE GAINS OF THE CONTROL AND EXPERIMENTAL GROUPS ON SECTIONS D, E, F, AND G ON TEST 4 OF THE CALIFORNIA ACHIEVEMENT TEST, FORM W

	Section	n	Ave. gain	s^2	s	F	P	t	P
Control	D, add.	21	0	6.70	2.58	1.64	n.s.	3.70	.001
Experimental	D, add.	19	2.74	4.09	2.02				
Control	E, subtr.	21	1.57	7.25	2.69	1.18	n.s.	1.29	n.s.
Experimental	E, subtr.	19	2.63	6.14	2.48				
Control	F, multip.	21	1.81	7.17	2.68	1.53	n.s.	.14	n.s.
Experimental	F, multip.	19	1.68	11.00	3.31				
Control	G, divis.	21	4.19	14.07	3.75	1.67	n.s.	1.42	n.s.
Experimental	G, divis.	19	2.67	8.45	2.91				

SUMMARY AND CONCLUSIONS

Review of the Problem

This study was initiated to evaluate the effectiveness of the new instructional materials in a ninth grade general mathematics class. One class of twenty-one students designated as the control group, were exposed to a traditional treatment of the experimental unit. Mean achievement scores were compared with the experimental group, a class of nineteen youngsters whose instruction followed the recommendations of the new instructional materials.

Both groups took Test 4 of the California Achievement Test, Form W, as a pre-test and post-test. This test was sub-divided into sections D, E, F, and G which measured computational skills in addition, subtraction, multiplication, and division respectively. Significant differences between mean scores of the control and experimental groups were determined by selected statistical procedures.

Conclusions

For the students, instructional materials, and tests used in this study, the following conclusions were made:

1. The results of the experiment indicated that both groups made significant gains in achievement.

2. The experimental group made significantly higher gains in achievement with regard to the addition of whole

numbers, fractions, and decimals.

3. The control group made significantly higher gains in achievement with regard to the division of whole numbers, fractions, and decimals.

4. The traditional and modern instructional materials were equally effective in regard to the achievement of computational skills with subtraction and multiplication of whole numbers, fractions, and decimals.

Implications of the Study

The conclusions based upon the statistical analysis of this study warrant some discussion regarding their implications. The approach used in presenting addition was novel, different, and more interesting to students in the experimental class and could have been a major factor in producing significant achievement gains. According to Borg, this phenomenon is a result of the Hawthorne Effect.[42]

Several studies have indicated that rote learning was more effective for low achievers than learning by discovery.[43] Although Kersh rejected any implication of

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[42] Walter R. Borg, Educational Research (New York: David McKay Company, 1963), p. 338.

[43] Bert Y. Kersh, "The Motivating Effect of Learning by Directed Discovery," Journal of Educational Psychology, 53:65-71, April, 1962.

the superiority of rote learning, he stated this was due to "retroactive inhibition" caused by the experimental effort to inject meaning into mathematical statements.[44] In the opinion of the writer, retroactive inhibition was one factor which could have accounted for significant differences in achievement gains between the control and experimental groups with respect to division. The experimental class had difficulty transferring the more complex concepts of division to mechanical manipulation. On the other hand, concepts and meanings did not interfere with the control group's transfer from memorization of rules to the actual process of dividing numbers.

Suggestions for Further Study

Studies similar to this should be made to investigate instructional materials at the elementary level of education. It is at this level where the understanding of basic concepts and facility with arithmetic operations is most crucial.

More definitive evidence should be secured in the area of motivation. A majority of past research revealed the effectiveness of praise, competition, knowledge of results, and rewards. However, recent studies with slow learners have not been unequivocal in support of these

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[44] Ibid., p. 70.

devices as learning incentives.[45] More research is also needed to examine the advantages of intellectual curiosity as a motivational vehicle for general mathematics students.

The effectiveness of learning by discovery, a method advocated by the new curriculum committees, should be examined more closely. In reference to studies which indicated that rote learning produced higher achievement gains with the slower students than learning by discovery, Kersh commented that ". . . the fact that meaning injected into rules might interfere with learning doesn't imply that rote learning is superior to learning with understanding but it does indicate we must know more about meaningful learning and how we come by it."[46]

Reports similar to this have contributed to our knowledge of how the traditional and modern materials compare on traditional tests. Few studies have used instruments which measure all the concepts and skills related to a modern program.[47] Consequently, more research should be

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[45] Hani Van De Riet, "Effects of Praise and ReProof on Paired-Associate Learning in Educationally Retarded Children," Journal of Educational Psychology, 55:139-43, June, 1964.

[46] Kersh, op. cit., p. 71.

[47] Emmet D. Williams and Robert V. Shuff, "Comparative Study of SMSG and Traditional Mathematics Text Materials," The Mathematics Teacher, 56:495-504, November, 1963. (Editor's note, p. 504.)

conducted which deals with a modern program in relation to its objectives.

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APPENDIX A

TABLE IX

AGES OF SUBJECTS

Control Group			Experimental Group		
Student			Student		
Boy	Girl	Age in months	Boy	Girl	Age in months
A		190		A	180
	B	194		B	170
C		173		C	186
D		176		D	174
	E	174		E	170
F		176	F		187
	G	177	G		166
	H	177		H	180
	I	170	I		184
	J	174		J	186
K		177	K		174
L		173		L	170
M		169		M	171
	N	178		N	167
O		170	O		170
	P	171	P		191
Q		172		Q	179
	R	175		R	166
	S	172		S	175
	T	181			
	U	172			
Average age: 175.6			Average age: 176.1		
Average age boys: 175.1			Average age boys: 178.6		
Average age girls: 176.3			Average age girls: 174.9		

TABLE X

INTELLIGENCE QUOTIENTS OF SUBJECTS

California Tests of Mental Maturity									
Control Group					Experimental Group				
Student					Student				
Boy	Girl	L	NL	T	Boy	Girl	L	NL	T
A		81	80	81		A	79	81	85
	B	73	87	80		B	84	98	91
C		92	95	94		C	66	71	69
D		79	102	91		D	77	62	70
	E	87	97	92		E	104	104	104
F		80	79	80	F		84	94	89
	G	68	76	72	G		102	95	99
	H	83	86	85		H	90	90	90
	I	90	89	90	I		87	87	87
	J	110	101	106		J	86	102	94
K		113	100	107	K		85	101	93
L		107	101	104		L	85	107	96
M		98	103	101		M	92	114	103
	N	91	100	95		N	110	106	108
O		110	108	109	O		113	110	112
	P	93	104	99	P		98	98	98
Q		112	101	107		Q	115	120	118
	R	105	103	104		R	113	110	112
	S	106	101	104		S	84	86	85
	T	82	96	89					
	U	107	101	104					
Average:		93.7	95.7	94.9	Average:		92.3	96.6	94.9
Average boys:		96.9	96.6	96.8	Average boys:		94.8	97.5	96.7
Average girls:		91.3	95.1	93.2	Average girls:		91.2	96.2	93.7

NOTE: The intelligence quotients given in the table were derived from scores made on The California Tests of Mental Maturity administered in October, 1964.

TABLE XI

PERCENTILE RANKS OF SUBJECTS

Iowa Tests of Educational Development
Quantitative Thinking and Composite Ranks

Control Group Student Boy	Girl	QT	C	Experimental Group Student Boy	Girl	QT	C
A		32	35		A	40	23
	B	40	23		B	12	35
C		40	29		C	69	48
D		69	23		D	18	29
	E	32	13		E	--	--
F		32	29	F		32	35
	G	32	35	G		40	48
	H	48	42		H	18	35
	I	18	29	I		32	42
	J	80	68		J	75	55
K		--	--	K		12	23
L		56	55		L	--	--
M		42	32		M	32	55
	N	56	68		N	40	48
O		48	74	O		75	55
	P	--	--	P		--	--
Q		63	68		Q	40	55
	R	48	55		R	75	82
	S	63	78		S	40	62
	T	48	48				
	U	80	82				
Average:		49	47	Average:		41	46
Average boys:		48	43	Average boys:		38	41
Average girls:		50	49	Average girls:		42	48

NOTE: The percentile ranks given in the table were derived from scores made on the Iowa Tests of Educational Development administered in October, 1964.

TABLE XII

GRADE PLACEMENT DATA

California Achievement Test
Arithmetic Reasoning and Fundamentals

Control Group					Experimental Group				
Student					Student				
Boy	Girl	A-R	A-F	T-A	Boy	Girl	A-R	A-F	T-A
A		5.4	6.4	5.9		A	4.7	5.8	5.3
	B	6.0	7.4	6.7		B	6.4	6.3	6.4
C		6.6	7.9	6.8		C	7.2	6.2	6.7
D		7.7	5.9	6.8		D	7.4	6.4	6.9
	E	6.4	7.3	6.8		E	6.8	7.7	7.3
F		7.6	6.5	7.1	F		7.7	7.3	7.5
	G	6.6	7.7	7.2	G		7.4	7.5	7.5
	H	8.0	7.0	7.5		H	7.4	7.9	7.7
	I	8.2	7.4	7.8	I		6.6	9.1	7.9
	J	7.7	8.0	7.9		J	8.6	8.2	8.4
K		8.2	7.7	8.0	K		8.3	8.8	8.6
L		8.3	7.7	8.0		L	7.9	9.5	8.7
M		8.3	7.6	8.0		M	---	---	8.8
	N	8.2	8.0	8.1		N	8.8	9.0	8.9
O		8.7	8.1	8.4	O		---	---	8.9
	P	8.3	8.4	8.4	P		---	---	---
Q		8.2	8.7	8.5		Q	---	---	---
	R	7.9	9.1	8.5		R	---	---	8.9
	S	8.0	9.3	8.7		S	---	---	9.0
	T	9.0	9.1	9.1					
	U	---	---	9.5					
Average:		7.7	7.8	7.8	Average:		7.3	7.7	7.8
Average boys:		7.7	7.4	7.5	Average boys:		7.5	8.2	8.1
Average girls:		7.7	8.1	8.0	Average girls:		7.2	7.4	7.8

NOTE: The grade placement data given in the table was derived from scores made on the California Achievement Test administered in October, 1964.

APPENDIX B

TABLE XIII

OCCUPATIONAL STATUS OF THE SUBJECT'S PARENTS: CONTROL GROUP

Student Boy	Student Girl	Father's occupation	Mother's occupation
A		*farmer	housewife
	B	mill worker	nurses aid
C		mill worker	housewife
D		milk distributor	housewife
	E	bar tender	housewife
F		mechanic	telephone operator
	G	laboratory technician	waitress
	H	**-----	bank teller
	I	shop foreman	telephone operator
	J	lawyer	housewife
K		farmer	housewife
L		***-----	waitress
M		farmer	housewife
	N	game refuge manager	housewife
O		farmer	housewife
	P	custodian	housewife
Q		policeman	housewife
	R	ranch foreman	housewife
	S	**-----	escrow officer
	T	farmer	housewife
	U	*farmer	housewife

*The student's parents are divorced and he lives with his mother and step-father.
**The student's parents are divorced.
***The student's father is deceased.

TABLE XIV

OCCUPATIONAL STATUS OF THE SUBJECT'S PARENTS: EXPERIMENTAL GROUP

Student Boy	Student Girl	Father's occupation	Mother's occupation
	A	forklift operator	nurses aid
	B	farmer	deputy auditor
	C	farmer	housewife
	D	*retired	housewife
	E	farmer	housewife
F		oil field worker	nurses aid
G		mechanic	housewife
	H	farmer	housewife
I		**gardener	kitchen helper
	J	***-----	private nurse
K		***-----	waitress
	L	house painter	housewife
	M	**farmer	bank teller
	N	farmer	housewife
O		farmer	housewife
P		forest service	housewife
	Q	**-----	housewife
	R	logger	housewife
	S	farmer	housewife

*The student's father and mother are deceased and he lives with legal guardians.
**The student's parents are divorced and he lives with his mother and step-father.
***The student's father is deceased.

APPENDIX C

PROGRESS RECORD OF THE EXPERIMENTAL GROUP

First Week

Procedures and Content

I. Orientation.
  A. Introduction of students.
  B. Oral outline of course objectives.
II. Brief evaluation of student achievement level through question and answer procedure.
III. Administration of pre-test.
  A. Sections D and E.
  B. Sections F and G.
IV. Counting and Computing.
  A. Number concept
    1. One-to-one matching of members of two sets.
    2. Extend the concept of one-to-one matching to explain natural number as a property of sets.
  B. Distinction between number and numeral.
    1. Discuss number as a property of sets and numeral as a symbol which represents that property.
    2. Numbers are ideas of quantity and symbols are names for numbers.

Activities

I. Oral exercises involving early mans' method of counting by matching sets of objects.
II. Exercises.

Second Week

Procedures and Content

I. Properties of different numeration systems.
  A. Egyptian numerals.
    1. Stress the number-numeral concept by pointing out that different numerals may name the same number.
    2. Point out the non-positional aspect of the Egyptian system.

B. Roman numerals.
   1. Stress the number-numeral concept.
   2. Point out the non-positional aspect of the Roman system.

C. Our decimal system.
   1. Compare the non-positional systems with our positional system.
   2. In our decimal system, a symbol has a face value and a place value.
   3. Indicate how numerals may be written as statements which show place value ($237 = 2(100) + 3(10) + 7(1)$).

<u>Activities</u>

I. Exercises.

II. Competition.
   A. Mathematical football.
   B. Elimination tournaments with groups of students.

Third Week

<u>Procedures and Content</u>

I. More about our decimal system.
   A. Re-emphasize the positional aspect of the decimal system and the face value and place value of a numeral.
   B. Stress that place value may be based on any system and that in the decimal system, the place values are based on ten.

II. Base-five system.
   A. Record base-five numerals in terms of counting collections of sets.
   B. Compare the place values of base-five system with base-ten.

III. Base-two system.
   A. Compare the place values of base-two system with base-five and base-ten.
   B. Show the practical applications of base-two system in regard to computing machines.

IV. Test.

Activities

I. Exercises.
II. Competition.
  A. Mathematical football.
  B. Tic-tac-toe.

Fourth Week

Procedures and Content

I. The number line.
  A. Illustrate the number line as a series of points to the right of zero.
  B. Stress that a set of numbers may be matched one-to-one with a set of points which make up the number line.
II. Addition on the number line.
  A. Illustrate addition on the number line by drawing line segments from zero.
  B. Lead a discussion to the discovery of the commutative and associative properties of addition.
III. Subtraction on the number line.
  A. Accentuate that subtraction is illustrated on the number line by moving opposite to the direction moved for addition.
  B. Point out the non-commutativity of subtraction.
IV. Multiplication on the number line.
  A. Illustrate multiplication on the number line in terms of a series of additions.
  B. Use the series of additions concept to illustrate the commutative and associative properties of multiplication.
V. Division on the number line.
  A. Accentuate that division is illustrated on the number line by moving opposite to the direction moved for multiplication.
  B. Illustrate the non-commutativity of division.
VI. Demonstrate the properties of zero and one on the number line.

Activities

I. Exercises.
II. Oral drill.

Fifth Week

Procedures and Content

I. The distributive law for multiplication over addition and subtraction.
   A. Use the number line by asserting that if the sum of two numbers is to be multiplied by a third number, the result may be found by multiplying each addend by the third number and adding the two products.
   B. Use the illustration of the distributive law on the number line as a means of reviewing the concepts of addition and multiplication.

II. Review the four basic arithmetic operations on whole numbers and the special properties of the operations.

III. Meaning of a fraction.
   A. A fraction is a number associated with a set of elements each of which is an equivalent part of some unit.
      1. Divide disks or rectangles into equal parts.
      2. Define numerator and denominator.
      3. Stress that fractions may be considered indicated divisions.
   B. Change fractions to equivalent fractions using the multiplication property of one.

IV. Adding fractions.
   A. Use a ruler or the number line to emphasize that fractions must have the same denominator in order to add.
   B. Define least common denominator.
   C. Use the multiplication property of one in changing fractions to higher terms.
   D. Stress that since fractions are added by adding the numerators which are whole numbers, the addition of fractions has the same properties as the addition of whole numbers.

V. Subtracting fractions.
   A. Use a ruler or the number line to emphasize that fractions must have the same denominator in order to subtract.
   B. Use the multiplication property of one in changing fractions to higher terms.

VI. Multiplying fractions.
   A. Use diagrams to represent the multiplication of fractions.

B. Stress that since the numerators and denominators of the fractions are whole numbers, the multiplication of fractions has the same properties as the multiplication of whole numbers.
C. Use the multiplication property of one to justify changing a whole number to a fraction in cases where a fraction is being multiplied by a whole number.

VII. Dividing fractions.
A. Discuss division of whole numbers as being the inverse of multiplication.
B. Extend the previous discussion to the division of fractions.

<u>Activities</u>

I. Exercises.
II. Oral exercises.
III. Competition.

Sixth Week

<u>Procedures and Content</u>

I. Factoring.
A. Define factors.
1. Illustrate the process of factoring whole numbers.
2. Extend the discussion to the use of factoring fractions and how factors of one may be omitted in reducing, multiplying, and dividing fractions.
3. Show the inverse relationship between reducing fractions and changing fractions to higher terms.
B. Improper fractions and mixed numbers.
1. Define mixed number and improper fraction.
2. Indicate that since any whole or mixed number can be expressed as a fraction, the rules for operations with fractions may be applied to operations with whole and mixed numbers.
C. Operations with improper fractions and mixed numbers.
1. Re-emphasized the properties of addition, subtraction, multiplication, and division.

2. Re-emphasize the use of the distributive property in multiplying mixed numbers.

II. Decimal notation extended.
  A. Stress the extension of place values to include fractional place values for digits appearing to the right of the unit's digit.
  B. Point out that any whole-number place value may be considered to be one tenth of the value of the place to its left.
  C. Extend the previous discussion to introduce fractional place values based on one tenth.

<u>Activities</u>

I. Exercises.
II. Competition.

Seventh Week

<u>Procedures and Content</u>

I. Operations with decimal fractions.
  A. Discuss the correct placement of the decimal point.
    1. In adding, the digits of like place value are put one below the other.
    2. In subtracting, the same procedure holds.
    3. In multiplying, use the fractional place value representation to show where the decimal point must be put in the product.
    4. Relate the division of decimals to a fraction notation and show how the multiplication property of one can be used so that decimals may be divided without regard to the decimal point.
  B. Re-emphasize the reasoning that is used in placing the decimal point in the numeral which represents the result of a computation.

II. Express common fractions in decimal form.
  A. Accent the definition of a common fraction as an indicated division to give meaning to the process of expressing a common fraction as a decimal.
  B. Use the multiplication property of one to convert fractions to equivalent fractions with denominators of 100.
  C. Extend the previous exercise to the process of converting fractions to decimals.

III. Rounding numbers.
  A. Emphasize that rounding a number is a process of "bracketing" the number between two values and selecting one of those values as the better approximation for the number.
  B. Allow the students to select their own rules for rounding numbers through the process of bracketing.

<u>Activities</u>

I. Exercises.
II. Review of concepts and computation.

Eighth Week

<u>Procedures and Content</u>

I. Review.
  A. Concepts.
  B. Drill on computational skills.
II. Administration of post-test.
  A. Sections D and E.
  B. Sections F and G.

PROGRESS RECORD OF THE CONTROL GROUP

First Week

Procedures and Content

I. Orientation.
   A. Introduction of students.
   B. Oral outline of course objectives.
   C. Brief evaluation of student achievement level through question and answer procedure.
II. Administration of pre-test.
   A. Sections D and E.
   B. Sections F and G.
III. Reading large numbers.
   A. Name the place values.
   B. Read statements involving large numbers.
IV. Rounding off whole numbers.
   A. Bracket the number between two values and select one of those values as the better approximation for the number.
   B. Discuss practical applications.

Activities

I. Exercises.
II. Make use of class discussion to acquaint students with each other, the teacher, and the practical applications of reading and rounding whole numbers.

Second Week

Procedures and Content

I. Addition of whole numbers.
   A. Definitions: sum, addend, plus sign, integer.
   B. Place like units under each other.
   C. When carrying is involved check by adding the sum of the units column, the sum of the tens column, etc.
II. Subtraction of whole numbers.
   A. Definitions: minuend, subtrahend, minus sign, remainder or difference.
   B. Place like units under each other.
   C. Check by adding the subtrahend to the remainder.

III. Multiplication of whole numbers.
   A. Review multiplication tables.
   B. Definitions: multiplicand, multiplier, partial products, product.
   C. Check by <u>interchanging</u> the multiplier and multiplicand.

IV. Division of whole numbers.
   A. Definitions: dividend, divisor, quotient, remainder, partial dividend, division symbols.
   B. Describe the long division process.

<u>Exercises</u>

I. Exercises.

II. Games to facilitate drill.
   A. Mathematical football.
   B. Tic-tac-toe.

III. Individual help with multiplication tables and addition and subtraction facts.

Third Week

<u>Procedures and Content</u>

I. Common fractions.
   A. Definitions: fraction (indicated division, part of one or more units), numerator, denominator, common fraction, lowest terms.
   B. Use a ruler and circle to introduce the concept of fractions.
   C. Reducing fractions to lowest terms.

II. Changing improper fractions.
   A. Definitions: proper and improper fractions, mixed numbers.
   B. Point out that a fraction is an indicated division.

III. Changing mixed numbers to simplest form.

IV. Changing fractions to higher terms.
   A. Definition: equivalent fractions.
   B. Use a ruler to facilitate the concept of equivalent fractions.

<u>Exercises</u>

I. Exercises.

II. Mathematical games.

Fourth Week

Procedures and Content

I. Finding the lowest common denominator.
  A. Definitions: lowest common denominator.
  B. Use inspection to find the lowest common denominator.
II. Addition of fractions and mixed numbers.
  A. Use a ruler to introduce the concept of addition.
  B. In adding mixed numbers, first add the fractions, then add the sum to the sum of the whole numbers.
III. Subtraction of fractions and mixed numbers.
  A. Use a ruler to introduce the concept of subtraction.
  B. Borrowing.
IV. Comparing fractions.
V. Changing mixed numbers to improper fractions.

Activities

I. Exercises.
II. Group competition.

Fifth Week

Procedures and Content

I. Multiplication of fractions and mixed numbers.
  A. Use a ruler to introduce the concept of multiplication.
  B. Definitions: cancellation.
II. Division of fractions and mixed numbers.
  A. Invert the divisor and multiply.
  B. Discuss multiplication and division as "opposite" operations to give some insight into the division rule.
III. Finding what part one number is of another.
IV. Finding a number when a fractional part of it is known.
V. Test.

Activities

I. Exercises.
II. Selecting individual and group projects.

Sixth Week

Procedures and Content

I. Reading and writing decimals.
   A. Compare fractions with decimals.
   B. Use a ruler to introduce the concept of decimals.
   C. Name place values.
II. Converting decimals to fractions and fractions to decimals.
III. Addition of decimals.
   A. Compare with the addition of equivalent fractions.
   B. Place like place values under each other.
IV. Subtraction of decimals.
   A. Compare with the subtraction of equivalent fractions.
   B. Place like place values under each other.
V. Comparing decimals.
VI. Multiplication of decimals.
   A. Multiply without regard to the decimal point.
   B. Compare with the multiplication of equivalent fractions to justify the placement of the decimal point in the product.
VII. Division of decimals.
   A. Move the decimal point in the dividend as many places as it was moved in the divisor. Provide reasoning of this operation by referring to the changing of fractions to higher terms (the multiplication property of one).
   B. Check simple division by converting the decimals to fractions.
VIII. Test.

Activities

I. Exercises.
II. Progress reports on projects.

Seventh Week

Procedures and Content

I. Review of fractions and decimals.
II. Individual and group projects.
   A. Drawing blueprints of houses, designed by the students.
   B. Converting standard recipes to accommodate given servings.
   C. Using a micrometer caliper to measure, compare, and record the size of various shop equipment.
   D. Drawing specifications for runways and pits on the new athletic field.
   E. Calculating the length of cables on a rice elevator.
   F. Budgeting for a summer vacation.
   G. Projecting the profit from raising two steers based on estimated expenses and future prices.
   H. Determining grade averages for four Algebra I classes.
   I. Making charts based on the progress of certain stock and determining profit and loss for given investments.

Eighth Week

Procedures and Content

I. Project reports.
II. Review and drill.
III. Administration of post-test.
   A. Sections D and E.
   B. Sections F and G.

APPENDIX D

TABLE XV

RAW SCORES ON THE PRE-TEST AND POST-TEST:
CONTROL GROUP

	Pre-test Sections				Post-test Sections			
Student	D	E	F	G	D	E	F	G
A	11	16	14	19	15	18	17	17
B	14	11	10	13	15	19	14	17
C	12	14	9	9	11	13	11	14
D	9	13	10	7	11	15	13	17
E	17	19	16	17	17	18	19	19
F	14	16	11	11	7	15	16	19
G	17	16	16	20	17	18	18	19
H	17	14	14	7	16	15	14	19
I	17	15	17	17	15	16	15	18
J	11	8	12	6	12	9	14	13
K	16	13	18	14	19	16	19	17
L	16	14	15	12	16	16	17	18
M	18	15	16	15	19	18	17	18
N	10	11	11	11	12	17	14	17
O	16	16	17	18	12	17	14	17
P	17	20	13	19	17	18	17	19
Q	11	13	11	6	8	14	16	13
R	11	11	15	14	15	16	12	17
S	17	13	9	8	17	16	15	16
T	17	16	14	14	18	18	17	19
U	16	16	18	16	15	17	15	18
Total:	304	300	286	273	304	339	324	361
Mean:	14.48	14.29	13.62	13.00	14.48	15.86	15.43	17.19
Total problems correct:			1163			1328		
Mean:			55.38			63.24		

NOTE: The raw scores given in the table represent the number of problems correct on each section of the pre-test and post-test. Each section consisted of twenty items.

TABLE XVI

RAW SCORES ON THE PRE-TEST AND POST-TEST:
EXPERIMENTAL GROUP

	Pre-test Sections				Post-test Sections			
Student	D	E	F	G	D	E	F	G
A	13	14	16	16	17	17	14	17
B	18	15	16	17	18	18	15	16
C	18	16	17	16	19	17	19	18
D	14	13	15	15	19	15	14	15
E	16	12	16	16	18	15	16	18
F	8	6	11	9	11	12	12	11
G	12	11	13	10	16	16	14	17
H	8	11	9	5	8	9	10	8
I	15	13	13	12	19	18	16	16
J	17	15	14	16	17	18	18	18
K	14	14	9	10	17	12	14	15
L	17	16	18	18	17	16	12	15
M	17	17	18	16	20	19	19	19
N	11	11	9	14	14	18	17	14
O	12	16	10	10	17	18	15	15
P	14	16	11	9	11	17	14	12
Q	13	15	12	8	19	18	17	18
R	16	16	17	16	16	18	15	18
S	10	6	9	9	15	12	14	13
Total:	263	253	253	242	315	303	285	293
Mean:	13.84	13.32	13.32	12.73	16.58	15.59	15.00	15.42
Total problems correct:			1011			1196		
Mean:			53.21			62.95		

NOTE: The raw scores given in the table represent the number of problems correct on each section of the pre-test and post-test. Each section consisted of twenty items.

APPENDIX E

SAMPLE QUESTIONS ON TEST 4, SECTION D, OF THE CALIFORNIA ACHIEVEMENT TEST, FORM W

Test 4 - Section D

DIRECTIONS: Do these problems in addition. Then mark the letter of each correct answer. For some of the problems none of the answers given may be correct. If you cannot work a problem, or if you think that none of the answers given is correct, you should mark the letter e. Finish each column before going on to the next. Be sure to reduce fractions to lowest terms. Remember to do your figuring on scratch paper if you are marking your answers on an answer sheet.

(56) 625 +413

a 1012
b 912
c 1018
d 1038
e None

(56) ____

(59) 37 48 50 +84

a 219
b 209
c 129
d 21
e None

(59) ____

(61) \$56.35 3.68 13.62 + 7.41

a \$80.16
b 79.14
c 81.06
d 70.16
e None

(61) ____

(64) 1/5 + 7/20

a 1/2
b 2/5
c 8/20
d 1/4
e None

(64) ____

(65) 61 1/2 14 5/6 +21 2/5

a 96 11/15
b 97 11/15
c 97 1/2
d 98 11/30
e None

(65) ____

(70) 2 1/2 + 2.5

a 4.5
b 5
c 6
d 4
e None

(70) ____

(73) 43.3 + 2.14 + 7

a 43.87
b 43.51
c 63.4
d 50.44
e None

(73) ____

STOP--Now wait for further instructions.

SAMPLE QUESTIONS ON TEST 4, SECTION E, OF THE CALIFORNIA ACHIEVEMENT TEST, FORM W

Test 4 - Section E

DIRECTIONS: Do these problems in subtraction. Then mark the letter of each correct answer. For some of the problems none of the answers given may be correct. If you cannot work a problem, or if you think that none of the answers given is correct, you should mark the letter e. Finish each column before going on to the next. Be sure to reduce fractions to lowest terms. Remember that these are problems in subtraction.

(76) 567 234	a 891 b 801 c 901 d 233 e None (76)	(86) 9 4 2/3	a 13 2/3 b 5 1/3 c 5 2/3 d 4 1/3 e None (86)
(78) 83 67	a 16 b 26 c 150 d 146 e None (78)	(90) 30.6 - 3 3/4	a 26 3/4 b 26.5 c 26.85 d 26.30 e None (90)
(81) $21.64 3.74	a $17.09 b $17.90 c $18.90 d $28.90 e None (81)	(93) 78.06 - 2.3617	a 75.6983 b 76.7983 c 75.6917 d 75.6017 e None (93)
(83) 1/7 1/7	a 1 b 2/7 c 0 d 1/7 e None (83)	STOP--Now wait for further instructions.	

SAMPLE QUESTIONS ON TEST 4, SECTION F, OF THE CALIFORNIA ACHIEVEMENT TEST, FORM W

Test 4 - Section F

DIRECTIONS: Do these problems in multiplication. Then mark the letter of each correct answer. Finish each column before going on to the next. Be sure to reduce fractions to lowest terms.

(96) 344 x 6	a 2044 b 1864 c 2164 d 2064 e None (96)	(110) 54 3/4 x13	a 711.50 b 711 3/4 c 711 1/4 d 711.25 e None (110)
(99) 531 x 25	a 13275 b 3717 c 14275 d 11275 e None (99)	(111) 36.25 x 3 1/2	a 126.875 b 1268 3/4 c 126 3/4 d 126 1/2 e None (111)
(102) 6018 x 307	a 222666 b 1857526 c 1947523 d 1847526 e None (102)	(113) 32.6 x 3.24	a 1057.24 b 105724 c 105.724 d 10.5724 e None (113)
(103) 7 x 1/3	a 7 1/3 b 2 1/3 c 3 1/3 d 2 2/3 e None (103)	STOP--Now wait for further instructions.	

SAMPLE QUESTIONS ON TEST 4, SECTION G, OF THE CALIFORNIA ACHIEVEMENT TEST, FORM W

Test 4 - Section F

DIRECTIONS: Do these problems in division. Then mark the letter of each correct answer. Finish each column before going on to the next. Be sure to express remainders as fractions and reduce fractions to lowest terms.

(116) 6/36	a 16 b 6 c 5 d .6 e None (116)	(131) 5/96 3/4	a 19 1/5 b 19.35 c 19 3/4 d 193.5 e None (131)
(120) 42/8442	a 21 b 201 c 210 d 110 e None (120)	(133) 3/5.34	a .178 b 178 c 17.8 d 1.78 e None (133)
(124) 1/3 ÷ 6	a 1/18 b 2 c 1/2 d 1/9 e None (124)	(134) .06/18.18	a 303 b 3.03 c 33 d 3.3 e None (134)
(128) 5 3/4 ÷ 3/2	a 1.5 b 1 1/3 c 3.5 d 3 5/6 e None (128)		STOP--Now wait for further instructions.

THE EFFECTIVENESS OF MODERN INSTRUCTIONAL MATERIALS IN A GENERAL MATHEMATICS CLASS

by

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B. A., Montana State University, 1960

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Since the Russians orbited Sputnik in 1957, the impact of the "new" or "modern" mathematics movement has been felt throughout the nation. Curriculum committees such as the School Mathematics Study Group have made new instructional materials available at all grade levels of elementary and secondary education.

One of the major criticisms of the new curriculum committees was their failure to provide for average and below average students. The committees prepared most of their instructional materials for college preparatory courses and little effort or research had been directed toward the needs of other types of students.

This study was initiated to obtain information by experimentation relative to the effectiveness of the new instructional materials versus the traditional materials in a ninth grade general mathematics class. The two classes involved in the experiment were part of the writer's 1965-66 teaching assignment at Glenn County High School, Willows, California.

One class of twenty-one students designated as the control group, was exposed to a traditional treatment of the experimental unit. Mean achievement gains were compared with the experimental group, a class of nineteen youngsters whose instruction followed the recommendations of the modern instructional materials.

The experiment lasted eight weeks and pertained to the four fundamental arithmetic operations on whole numbers, fractions, and decimals. Instructional materials constituted the independent variable for this study. Although the subject matter content for both the control and experimental groups was essentially the same, the new instructional materials differed from the traditional in concept, terminology, some symbolism, and an emphasis on inductive rather than deductive reasoning. The modern materials also shifted emphasis from mechanical manipulation to the development of concepts.

The major objectives of the experimental class were to acquire the concepts of counting as a one-to-one matching between members of two sets, the distinction between number and numeral, properties of different numeration systems, and the properties of numbers under given operations. Addition and subtraction, as well as multiplication and division, were introduced simultaneously as inverse operations. Fractions and decimals discussed in terms of alternate names for the same number, provided the students with a meaningful concept of measurement. Illustrations on the number line facilitated concepts relative to the behavior of numbers.

In the control class, students were presented with "rules" for specific situations followed by a discussion and demonstrations regarding the justification of these rules. When youngsters demonstrated reasonable facility with the mechanical manipulation of numbers, practical applications were stressed through word problems and group and individual projects.

Both groups took Test 4 of the California Achievement Test, Form W, as a pre-test and post-test. The test measured arithmetic fundamentals and was closely representative of the objectives of the experimental unit. The *F* test for homogeneity of variance and *t*-tests for significance of difference between means were applied to each set of data pertaining to the control and experimental groups.

As a result of the statistical analysis of the pre-test and post-test scores of both groups the following conclusions were made for students, instructional materials, and tests used in this study:

1. The results of the experiment indicated that both groups made significant gains in achievement.

2. The experimental group made significantly higher gains in achievement with regard to the addition of whole numbers, fractions, and decimals.

3. The control group made significantly higher gains in achievement with regard to the division of whole numbers, fractions, and decimals.

4. The traditional and modern instructional

materials were equally effective in regard to the achievement of computational skills with subtraction and multiplication of whole numbers, fractions, and decimals.