INFORMATION TO USERS

This material was produced from a microfilm copy of the original document. While the most advanced technological means to photograph and reproduce this document have been used, the quality is heavily dependent upon the quality of the original submitted.

The following explanation of techniques is provided to help you understand markings or patterns which may appear on this reproduction.

1. The sign or "target" for pages apparently lacking from the document photographed is "Missing Page(s)". If it was possible to obtain the missing page(s) or section, they are spliced into the film along with adjacent pages. This may have necessitated cutting thru an image and duplicating adjacent pages to insure you complete continuity.

2. When an image on the film is obliterated with a large round black mark, it is an indication that the photographer suspected that the copy may have moved during exposure and thus cause a blurred image. You will find a good image of the page in the adjacent frame.

3. When a map, drawing or chart, etc., was part of the material being photographed the photographer followed a definite method in "sectioning" the material. It is customary to begin photoing at the upper left hand corner of a large sheet and to continue photoing from left to right in equal sections with a small overlap. If necessary, sectioning is continued again — beginning below the first row and continuing on until complete.

4. The majority of users indicate that the textual content is of greatest value, however, a somewhat higher quality reproduction could be made from "photographs" if essential to the understanding of the dissertation. Silver prints of "photographs" may be ordered at additional charge by writing the Order Department, giving the catalog number, title, author and specific pages you wish reproduced.

5. PLEASE NOTE: Some pages may have indistinct print. Filmed as received.

Xerox University Microfilms

300 North Zeeb Road
Ann Arbor, Michigan 48106

76-24,394

WEAVER, Joseph Robert, 1935-
THE RELATIVE EFFECTS OF MASSED VERSUS
DISTRIBUTED PRACTICE UPON THE
LEARNING AND RETENTION OF EIGHTH
GRADE MATHEMATICS.

The University of Oklahoma, Ed.D., 1976
Education, mathematics

Xerox University Microfilms, Ann Arbor, Michigan 48106

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

THE RELATIVE EFFECTS OF MASSED VERSUS DISTRIBUTED PRACTICE UPON THE LEARNING AND RETENTION OF EIGHTH GRADE MATHEMATICS

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF EDUCATION

BY

JOSEPH R. WEAVER

Norman, Oklahoma

1976

THE RELATIVE EFFECTS OF MASSED VERSUS
DISTRIBUTED PRACTICE UPON THE
LEARNING AND RETENTION OF
EIGHTH GRADE MATHEMATICS

APPROVED BY

Thomas J. Hill

Harold Huneke

[illegible]

Gerald Kowitz

DISSERTATION COMMITTEE

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation for all those who have contributed to the completion of his formal study, represented by this doctoral dissertation. Special thanks are due Dr. Thomas J. Hill, Chairman of the dissertation committee, who helped define the topic and who patiently guided the author through several months of work. Appreciation is also expressed to the other members of the dissertation committee, Dr. Robert F. Bibens, Dr. Harold V. Huneke, and Dr. Gerald T. Kowitz.

For their hard work and cooperation I owe a debt of gratitude to the teachers who participated in the study: Mr. Stan Bryant, Mrs. Maxine Cory, Miss Frances Leonard, Mrs. Leta Moore, and Mrs. Kay Wilson. Appreciation is extended to Mrs. Jean Arther, chairperson of the mathematics department of Hefner Junior High School, Mrs. Lillian Smith, chairperson of the Western Oaks Junior High School mathematics department, the principals of the two schools, and the administrators of the Putman City Public Schools for their support and cooperation.

Finally, I wish to thank my family. Without their understanding, encouragement, and love the dissertation would not have materialized. My wife, Neva, has been an intellectual stimulus as well as companion and friend; my sons Bob,

Dick, and Scott, have provided inspiration and confidence. To my parents, Rev. and Mrs. E. N. Weaver, I am eternally grateful for their teaching and example and the faith they have shown in me.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

THE RELATIVE EFFECTS OF MASSED VS. DISTRIBUTED PRACTICE UPON THE LEARNING AND RETENTION OF EIGHTH GRADE MATHEMATICS

CHAPTER I

THE PROBLEM

Introduction and Background of the Study

Educators generally agree that practice is an important factor in the initial learning and the retention of concepts and skills. The need for repetition to insure mastery of subject matter has been established in the philosophical and psychological literature [Ahrens (1957), Hilgard and Bower (1966)]. Research has shown that simply varying the amount of practice has no noticeable effect on retention [Bayless (1963), Reynolds and Glaser (1964), and Cierpilowski (1971)].

Laing and Peterson (1973) described four organizational patterns for assigning practice exercises in mathematics. First, the practice most commonly used in textbooks and by teachers is the vertical pattern or massed practice method in which one or more concepts or skills are introduced and the bulk of experience with them is concentrated in one or two assignments given immediately following the presentation of the new topic. Second, the distributed practice method extends the student's experience with a given topic over a longer period of time than the massed practice method. This pattern, which intersperses practice with intervals of rest, permits additional time for the initial learning of new concepts and provides review of previous concepts and skills. Third, the semi-oblique organizational pattern is a method in which students begin exploring a topic before the work on the previous topic has been concluded. Fourth, the oblique pattern is one in which the teacher provides exploratory work on future concepts, immediate practice over the concepts under discussion today, and reinforcement of concepts previously discussed.

While each of these organizational patterns has obvious advantages and disadvantages, very little research has been conducted on the relative merits of these patterns for classroom instruction. The problem related to the efficacy of distributed versus massed practice has concerned educators for a long time. The research on this problem involves both human and animal studies. The animal studies reported by Brogden (1951) indicate a general trend favoring distributed practice over massed practice. However, attempting to generalize such studies to a human population is questionable since the subjects are obviously different and the learning tasks involved do not particularly resemble those in which humans are engaged. In most of the experiments involving humans, rote memorization of non-meaningful material was studied, and as a result the practical implications of these studies are questionable.

In spite of a dearth of conclusive research on distributed practice in mathematics, several educators have suggested this method as a technique for assigning homework. Dodes (1953), writing in the Twenty-first Yearbook of the National Council of Teachers of Mathematics, discussed a technique developed by Sidney Berman that provided for a homework assignment immediately after a topic is introduced and then distributed further practice with the topic over an arbitrary period of time. In a later National Council Yearbook, Lankford (1959) gave examples from algebra and arithmetic which showed how the distributed assignment procedure could be applied. Further support for the distributed practice procedure came from Hillman (1967) and from Johnson and Rising (1967) who advocated brief practice at spaced intervals. Theoretical foundations for the procedure were described by Peterson (1971).

Laing and Peterson (1973) listed the following as the main purposes of the distributed practice pattern:

1. To permit additional time for the initial learning of new concepts.
2. To provide experience in problem solving where the concept involved has not been predetermined by the textbook context in which the concept is presented.
3. To incorporate review of previous concepts and skills into daily lessons.

One of the disadvantages inherent in the massed practice pattern is that it does not provide experiences in discriminating among different concepts and problem types. With most textbook exercises a student can be successful by blindly applying the procedure exhibited by the sample problems. Thus, the learner does not need to discriminate among potentially useful methods that could be employed in solving a particular problem. A distributed practice procedure should help to overcome this weakness in the assignment procedure.

Investigations that have studied the relationships among practice, learning, and retention will be discussed in the review of literature. However, three studies of the effects of distributed practice on the learning and retention of mathematical concepts will be discussed here because they provide a background for the research reported in this dissertation. The three studies are the investigations of Urwiller (1971), Laing (1970), and Camp (1973). A modification of the methods of Laing and Camp was used in the present study.

Urwiller (1971) investigated the effects of distributed practice on the achievement, retention, and attitude toward mathematics of second-year algebra students. Each of the twenty teachers who participated in the study taught at least one class using a distributed assignment procedure and at least one class using a massed assignment procedure.

Urwiller constructed two assignment packages--massed and distributed--using the prepared distributed practice assignment schedule from the teachers commentary for Modern Algebra and Trigonometry: Structure and Method (1965) as a guide. The distributed package was a revision of the published distributed practice listing; the massed package assigned homework exercises on a particular topic in one or more consecutive assignments. The packages included identical homework exercises and each package detailed the exact exercises that were to be assigned from each section of the textbook.

Commercially prepared instruments were used by Urwiller as pretests and posttests and found no significant difference between the two groups in achievement, retention, or attitude.

A careful reading of Urwiller's study reveals at least three weaknesses. First, it is not clear how the massed and distributed treatments were assigned to each instructor's classes. Without this information it cannot be determined whether the results were affected by the order in which the treatments were presented.

A second weakness lies in the procedure followed to construct the assignment packages. According to Urwiller, the published distributed practice guide was developed by Berman and was based on the following procedure:

> . . . Suppose topic A is taught on day one. Problems are assigned from this topic. On the second day, another problem from topic A is assigned. Now one day is skipped. On the fourth day, another problem from topic A is assigned. Now two days are skipped. On the seventh day, another is assigned. Now three days are skipped. On the

> eleventh day another is assigned. Now four days are skipped. On the sixteenth day another is assigned.
> This interval is lengthened until it reaches 5 to 10 days, depending on the importance and difficulty of the topic. Then the topic is reassigned once every week or two [Dodes, 1953, p. 323].

However, a close look at Urwiller's distributed assignment guide indicates that no fixed procedure was followed to construct the homework packages.

To illustrate how practice with topics was distributed in Urwiller's experiments, Camp (1973) randomly selected fifteen lessons (though only 14 are shown in his table) from Urwiller's distributed assignment guide and charted the distribution of problems from each lesson for the first sixteen days. The results appear in Table 1. The table reveals that the distribution of problems was not uniquely determined by the number of problems assigned and that the distribution period was of rather short duration. In six cases, all of the problems were assigned over consecutive days rather than spaced according to the linear relation that was supposed to determine the rest periods. Since a fixed procedure was apparently not used to construct the distributed assignment schedule, and since in some cases Urwiller's distributed practice classes received relatively massed practice on topics, it is questionable whether his results can contribute much to the understanding of the effects of distributed practice in complex learning situations.

There is one other possible weakness in Urwiller's procedure. It is doubtful whether the Cooperative Mathematics

Test, Algebra II was a valid measure of what the students learned during the experimental period. The test was designed to be simply a global inventory of the skills usually developed in second-year algebra courses and lacks items that measure the student's knowledge of trigonometry. It was not constructed to measure the range of concepts and skills developed in a course based on one particular textbook.

TABLE 1

DISTRIBUTION OF PROBLEMS FROM RANDOMLY SELECTED SECTIONS OF URWILLER'S DISTRIBUTED ASSIGNMENT GUIDE (from Camp, 1973, p. 20)

Lesson	Number of Problems	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
8	7	5	2														
114	7	2	2	2					1								
101	8	3	1	2	2												
109	8	2	3	2	1												
32	8	2	2	1	1	1			1								
72	9	2	3		2	1	1										
108	9	3	5	1													
56	9	5	3	1													
51	11	7	3					1									
89	13	7	4	1				1	1								
41	13	5	3	2	1				1	1							
6	15	9	2						1			1	1				1
131	16	10	2	1					1			2					
119	24	12			6	2				2		2					

Laing (1970) investigated the effects of two assignment schedules, massed and distributed, on the initial learning and the retention of topics in eighth-grade mathematics. Each of ten teachers administered each schedule to one of two comparable eighth-grade mathematics classes. All classes received identical homework assignments except for the way the practice was distributed. A chapter on geometry was used to accustom students to the assignment procedures, and the following two chapters, on decimals and rational numbers, served as experimental topics.

Laing defined a distributed practice function based on two other functions. The function $y = 2^x$ was used to determine the length of the rest periods between practices, in school days. The function given in Table 2 was used to determine how the problems assigned to a massed class were to be assigned to a distributed class. Laing then prepared uniform assignments for each teacher to use in giving homework to his classes.

Tests were administered immediately after completing each experimental chapter. These provided initial learning data. A test given three weeks after the completion of the second chapter provided retention data. No significant differences between the two groups were obtained on any of the tests and there was no significant interaction between treatment and general mental ability. However, when differences in non-verbal IQ and computational ability were taken into account, differences in the means of the two groups consistently favored the distributed practice group.

The major weakness of Laing's study was that the two experimental chapters developed related topics. As a result, concepts introduced in the first chapter were repeated in the second chapter and possibly contaminated the massed treatment.

TABLE 2

DISTRIBUTION OF ASSIGNED PROBLEMS ON TOPIC A
(from Laing, 1970, p. 15)

Day	Number of Problems	Day	Number of Problems
1	$[.5N_A]$	12	max $([.05N_A], 1)$
2	max $([.3N_A], 1)$	13	0
3	0	14	0
4	max $([.1N_A], 1)$	15	0
5	0	16	0
6	0	17	0
7	max $([.05N_A], 1)$	18	0
8	0	19	0
9	0	20	0
10	0	21	max $([.05N_A], 1)$
11	0		

Note: N_A represents the number of problems assigned to a massed class on topic A; $[x]$ = greatest interger less than or equal to x.

One other possible reason for the failure of the two treatments to yield significantly different results is that the distribution function may not have extended the student's experience with a topic over a long enough period of time. Fewer than half of the assignments were distributed to the twenty-first day, and only two assignments extended to the thirty-eighth day.

In spite of these weaknesses Laing's study is well designed with a major strength being the use of a distribution function which allowed the experimenter to uniquely determine the number of homework problems to assign to the distributed group in terms of the number assigned to the massed practice group.

Camp (1973) modified Laing's distribution function and used Laing's study as the basis for his own investigation. Camp investigated the relative effects of massed and distributed practice on the initial learning and the retention of two topics in introductory algebra. The sample for the study consisted of ninth grade algebra classes whose teachers were using the same textbook. Each of the eleven teachers participating in the experiment taught two classes--a massed class and a distributed class--that were randomly assigned to the treatment groups. A general ability test was administered to all classes to stratify each class into high, middle, and low ability levels.

Two chapters--one on operations with polynomial expressions and one on linear equations and graphs--were treated and tested in the experimental phase of the study. Initial learning tests were administered immediately after each chapter and retention tests were given immediately after two subsequent chapters had been completed.

Camp used the same function, f: $x \longrightarrow 2^x$, that Laing used to determine the length of the rest interval in the distributed practice schedule. However, he modified the function that Laing used to determine the number of problems to be assigned to a distributed class. His purpose in the modification was to extend a student's practice with a topic over a longer period of time than Laing's function would have done. Table 3 shows the function that Camp used for determining the number of problems to assign to the distributed classes.

No significant differences were found between treatment groups on any of the tests. However, on the polynomials initial learning test, the mean score of the distributed practice group was higher, at each ability level, than the mean score of the massed practice group. On the graphs initial learning test, the difference consistently favored the massed practice group. The mean score of the distributed practice group was higher, at each ability level, than the mean score of the massed practice group on both the polynomials and the graphs retention tests.

Camp suggests that a possible explanation for the inconsistent results on the initial learning tests was that

TABLE 3

THE DISTRIBUTED PRACTICE FUNCTION
(from Camp, 1973, p. 33)

Day	N = Number of Problems Assigned to M Class
1	$\max([.5N], 1) = x_1$*
2	$\max([.2N], 1) = x_2$
4	$\max([.15N], 1) = x_3$
7	$\max([.1N], 1) = x_4$
12	$\max([.05N], 1) = x_5$
21	$\max([.05N], 1) = x_6$
38	$N - \sum_{i=1}^{j} x_i = x_7$**

Note: * $[x]$ means the greatest integer less than or equal to x.

** For a given N, whenever $\sum_{i=1}^{j} x_i = N$, then $x_{j+1} = x_{j+2} = x_7 = 0$.

in the polynomial chapter the topics were primarily skill-oriented but in the graphs chapter the topics were not as skill-oriented. Camp concludes that "the results from the learning tests suggest, therefore, that distributed practice may be slightly more efficient than massed practice for promoting the learning of skill-oriented mathematics only." Another possible explanation for the inconsistent results was that the teachers tended to assign more problems on each polynomial topic than they did on graph topics and thus the results could have been influenced more by the number of practice problems per topic than by the type of practice procedure.

One possible weakness in Camp's study which could account for the non-significant differences between the treatment groups on both retention tests was that the distributed practice procedure may have assigned too much practice in the early stages of learning. Thus, the distinction between the homework experience of the treatment groups may not have been sharp enough during the early stages of learning.

Another possible cause for the lack of significant differences on retention tests in both Laing's and Camp's studies may lie in the choice of the function $f: x \rightarrow 2^x$ to determine the number of days of rest between assignments. The length of each rest interval after the fifth assignment is sufficiently long to allow significant forgetting.

Based upon a study of the literature on massed vs. distributed practice it was the conclusion of this investigator that a study should be conducted that slightly modified the procedures used by Camp. The changes made were the following: 1) a distribution function was used that distributes more homework problems in the later assignments rather than concentrating most of them in the first two assignments as in Laing's and Camp's studies; 2) a function was used to determine rest intervals, between assignments, that would provide approximately the same amount of rest in the early stages as the function $f: x \rightarrow 2^x$ but shorten the length of the rest intervals in the later stages of the experiment; and 3) an attempt was made to insure that teachers involved in the experiment did not assign more exercises per topic in one of the experimental chapters than they did in the other.

Purpose of the Study

The purpose of this study was to design a procedure for distributing practice over several assignments and to compare the initial learning and the retention of two experimental groups--a massed (M) group and a distributed (D) group whose treatment is the same except for the manner in which homework practice is assigned. Practice on a particular topic for the M group was consolidated in one or more consecutive assignments, whereas the D group was given the *same* problems spaced over several assignments with intervals of rest between assignments.

Plan of the Study

The procedures employed by Camp were modified and used as a model for the present study. The principal changes were in the distribution function used.

The sample for the study consisted of eighth grade mathematics classes whose teachers were using the same textbook. Each of the teachers participating in the experiment taught at least two paired classes--a massed class and a distributed class--that were randomly assigned to treatment groups. Data obtained from performance on a general ability test was used to stratify each class into three ability levels: low, middle, and high.

During the experimental phase of the study two chapters from the textbook Holt School Mathematics, Grade 8 by Nichols, et al. (1974) were treated and tested. One of the chapters was on percents and the other was on real numbers.

By modifying the functions used by Camp, a distribution function was defined in terms of two other functions. The first was the function $f: x \rightarrow [\frac{1}{4}x^2]$, where $x = 1, 2, 3. . ..$ This function was used to determine the length of time, in school days, between assignments. The second function used to define the distribution function is given in Table 3A. A distribution chart (Figure 1) was provided to assist the teachers in assigning homework to their classes during the experimental phase of the study.

Initial learning tests, constructed by the investigator, were administered immediately upon completion of each chapter. A retention test, constructed by the investigator, and covering both chapters was administered approximately three months after the completion of the second experimental chapter.

Hypotheses and Questions

Data from initial learning tests and retention tests were used to test the following hypotheses:

1. At each ability level, there is no significant difference in the initial learning of students receiving distributed practice and students

receiving massed practice.

2. At each ability level, there is no significant difference in the retention of learning between students receiving distributed practice and students receiving massed practice.

Additionally, the following questions will be investigated:

1. Does distributed practice have different effects on students at three different levels of ability?

2. What is the relationship among treatment, performance on the initial learning tests, and performance on the retention tests?

TABLE 3A

THE DISTRIBUTED PRACTICE FUNCTION

Day	N = Number of Problems Assigned to M Class
1	$\max([.4N], 1) = N_1$
2	$\max([.2N], 1) = N_2$
4	$\max([.15N], 1) = N_3$
7	$\max([.15N], 1) = N_4$
12	$\max([.1N], 1) = N_5$
19	$\max([.05N], 1) = N_6$
29	$N - \sum_{i=1}^{j} N_i = N_7$

Note: $[x]$ means the greatest integer less than or equal to x. For a given N, whenever $\sum_{i=1}^{j} N_i = N$, then $N_{j+1} = N_{j+2} = N_7 = 0$.

Number of Problems Assigned to M Class / Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	1	1	1	1	2	2	2	3	3	4	4	4	5	5	6	6	6	7	7	8	8	8	9	9	10	10	10	11	11	12
2		1	1	1	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	4	4	4	4	4	5	5	5	5	5	6
4			1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	3	3	3	3	3	3	3	4	4	4	4
7				1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	3	3	3	3	3	3	3	4	4	4	4
12						1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	3
19							1	1	1	1	1	1	1	1	1	1	1	1	1	·	1	1	1	1	1	1	1	1	1	1
29									1		1	2	2	1		1	2	3				1	1	2	1	2	1	1	2	

Figure 1.--Distribution Chart To Be Used in Assigning Homework Practice

The eighth grade mathematics students in the sample used in this study attended two junior high schools in the Putnam City, Oklahoma school district. In these schools, the top ten percent and the lowest ten percent of the students in mathematics ability as determined by achievement records and teacher recommendations are placed in special classes. Thus, the students in the sample came from the middle eighty percent of the eighth graders of the two schools based on past achievement in mathematics.

Organization of the Report

Results of the study will be presented through tables and discussion. Chapter I presents the background of the study and an overview of the problem. Chapter II contains a review of related research. The experimental procedures and a description of the sample, experimental materials and instruments used are discussed in Chapter III. Chapter IV contains the analysis of data and the summary, conclusions and recommendations resulting from the study are found in Chapter V.

CHAPTER II

REVIEW OF RELATED LITERATURE AND RESEARCH

The relative merits of distributed versus massed practice have interested researchers for a long time. However, many of the studies on the subject involve animals and in most of the experiments involving humans, rote memorization of non-meaningful material was studied. This chapter contains a review of some of the literature relevant to the study. The survey attempts to identify what has been discovered about the relationships among practice, learning, and retention. A summary of three studies of the effects of distributed practice on the learning and retention of mathematical concepts was presented in Chapter I. Therefore, this chapter will concentrate on other studies that used meaningful materials to be learned and retained.

The Efficacy of Practice

Practice has long been an important part of the instructional strategy employed by mathematics teachers. Much discussion has occurred among mathematics educators and researchers with regard to the amount and type of drill activities that are necessary to insure learning and retention of concepts and skills.

Ausubel (1968) indicates the need for practice in the learning process as one of the principal factors influencing the cognitive structure.

> Although much significant meaningful learning obviously occurs during initial presentation of the instructional material, both overlearning as well as most long-term retention in classrooms and similar settings, presuppose multiple presentations or trials (practice); and both learning process and outcome customarily encompass various qualitative and quantitative changes that take place during these several trials. Learning and retention, therefore, ordinarily imply practice (1968, p. 273).

He further describes the most immediate effect of practice as increasing the stability and clarity of new meanings which, in turn, strengthens their dissociability in the cognitive structure. Practice also enhances the learner's responsiveness to subsequent presentations of the same material by "sensitizing" him to the potential meanings inherent in the material.

The Effects of Repetition

Educators, students, and learning theorists agree that repetition is a necessary condition for acquiring and maintaining certain concepts and skills ("Homework," 1958; Ahrens 1957; Hilgard and Bower, 1966). In giving some rules potentially useful for education, Hilgard and Bower observed: "Frequency of repetition is still important in acquiring skill, and in bringing enough overlearning to guarantee retention [p. 562]."

Stroud (1942) theorizes that drill is advantageous when pupils engage in practice at the point of error. If successive practices are exact duplicates of each other then learning, defined as a change in performance in the course of practice, does not occur.

Stroud's conclusions does not necessarily imply that repetition serves no useful purpose in the learning of meaningful materials. However, it does suggest that consideration may need to be given to the amount and type of repetition utilized in the mathematics classroom.

According to Ebbinghaus (1913), Luh (1922), and Slamecka (1959), given the necessary conditions for learning, retention can usually be improved with increased repetition. However, studies by Cierpilowski (1971), Gagne' (1962), and Reynolds and Glaser (1964) have shown that the number of practice repetitions may not be the critical factor in improving retention.

Cierpilowski studied the effects of repetition on the "relearning" and retention of facts. Two hundred twenty-nine junior high school students were administered an acquisition trial during which they were presented a list of twenty fact-like statements about a fictional geographic area. After each sentence was given, a question was presented long enough for the subjects to write a correct response to the question. After all twenty facts and questions were presented, an acquisition test of all twenty items was administered. Subjects were given one of nine review treatments immediately after the acquisition test. The variations in the review treatments stemmed from three levels of repetition (1, 3, 5) and three levels of total time (20, 40, or 60 seconds). The review was followed immediately by a "relearning" test. An unannounced "delayed retention" test was administered ten days later. The data from the relearning test showed "relearning" increasing with increasing total-time but decreasing with increasing repetitions. Variations in review had no significant effect on retention.

Gagne' experimented with the effects of various levels of repetition and guidance in an addition of integers program that had been analyzed according to a learning hierarchy. He found no significant differences in learning or retention due to amount of repetition. However, the data did support Gagne's hypothesis that the learning of a task at one stage of a hierarchy is substantially dependent upon the mastery of corresponding subordinate tasks.

Reynolds and Glaser (1964) studied the effects of repetition in the learning of technical terms in biology. Seventy-five junior high school students studied programmed materials on ten topics containing three degrees of repetition. One topic, mitosis, was selected as the experimental unit. This unit introduced eleven new terms and required the subject to learn their meanings and usage in describing the mitosis process. With this unit as a standard, two new units were written which developed the same material but differed from it in the number of stimulus and response repetitions of each term. In one of the new units each term was repeated half as many times as in the original unit; in the other new unit each term was repeated one and one-half as many times as in the original unit. The results indicated that the variations in repetition had only transitory effects upon retention. These results confirmed the conclusions of Welborn and English (1937).

The studies on repetition indicate that the amount may not be a critical factor in learning and retention. Some practice is needed to produce retention, but beyond a certain number of repetitions, increased practice seems to have no facilitating effect.

The Effects of Review

Just as practice can be effective in building a student's proficiency in solving a particular type of problem during its initial learning, review provides an opportunity to re-establish this level of proficiency, and improve its retention after a period of forgetting has occurred. In describing the advantages of delayed review, Ausubel (1966) emphasized that

> prior forgetting presumably has a facilitating effect on meaningful learning and retention because, as a result of both trying and failing to remember material, the learner tends to become aware of negative factors in the learning and retention situations that promote forgetting, that is, of areas of instability, ambiguity, confusion, and lack of discriminability . . .. Thus forearmed, he can take the necessary steps during the relearning session to strengthen particularly weak components of the learning task, to resolve existing confusion and ambiguity, and to increase discriminability between previously learned ideas and related new propositions. [Ausubel, 1966, p. 197]

Butler and Wren (1965) suggest that an effective review facilitates retention of material by emphasizing the interrelationship of previous topics and that such a review concerns itself with thought and meaning rather than habit formation which may be the primary result of pure repetition.

Shunert (1951) studied the relative effectiveness of different frequencies of review with ninth grade algebra classes. He concluded that the classes that reviewed the material more than once each month performed better than those classes which reviewed no more than once every six weeks.

Peterson, Ellis, Toohill, and Kloss (1935) compared ten psychology classes on immediate recall and long-term retention of history passages under three review conditions--no review, one review, and two reviews. The results showed a high positive correlation between the number of reviews and the amount of material retained, but the increments added by the reviews disappeared more rapidly than did the initial learning.

In the studies by Shunert, and Peterson, et. al., the forgetting intervals over which retention instruments were administered to the control and review groups were not equivalent. Thus, the groups with more frequent reviews had studied the material more recently when the retention tests were administered. Therefore, these studies do not provide an adequate measure of the effects of review on long-term retention.

Using the same population mentioned earlier, Peterson, Ellis, Toohill, and Kloss (1935) studied the effects of early and late review on a retention test. Each group reviewed by studying the original text material. The first group reviewed the material three weeks after initial learning or seven weeks before the retention test. The second group reviewed seven weeks after initial learning or three weeks before the retention test. When no significant differences were found between the two groups, the experiment was repeated with reviews at two and nine weeks after initial learning. Again, the results showed no significant differences between the two groups. Thus, the investigators interpreted these results as a matter of compensation. They concluded that the advantages of a review close to initial learning offset the advantages of a review closer in time to the retention test.

Ausubel (1966) compared the effects of early and delayed reviews on long-term retention by using equivalent forgetting intervals for two treatment groups. There was no significant difference between the performances of the two groups on the retention instrument.

The studies on the efficacy of review seem to indicate that review does facilitate retention and that increasing the number of reviews may increase the amount of material retained. However, there is no clear advantage of either early or late review when long-term retention is the dependent variable.

Distributed Versus Massed Practice

The efficacy of distributed practice has been studied by researchers for more than sixty years. Ebbinghaus (1913) showed that, in some cases, lists of nonsense syllables are learned more efficiently when practice is distributed than when it is massed. Since then, learning theorists have attempted to identify conditions under which distributed practice improves learning and retention. However, most of the investigations have been in laboratory situations and thus, most of what we know about distributed practice comes from experiments using non-meaningful learning tasks.

There is considerable support among mathematics educators for the use of distributed practice in the mathematics classroom. Hillman (1967) recommended the use of a form of distributed assignment schedule in which homework exercises involve review of previous topics which support those topics currently being studied in class. Butler and Wren (1965) state:

> In accordance with established principles of drill and review, the items should be distributed throughout the program in such a way that practice upon any particular element will not be too greatly concentrated but will recur at increasing intervals and in decreasing amounts [1965, p. 151].

In reviewing the research related to distributed practice it is apparent that there is no common definition of distributed practice. Generally, investigators have considered any practice procedure that includes rest periods between practice trials, a distributed procedure. The length of time between practice employed by researchers in their experiments varies from a few seconds to several days.

Rote Learning and Retention of Non-Meaningful Material

There have been a number of studies comparing the relative efficacy of distributed and massed practice in memorizing paired-associate and serial lists of nonsense syllables (Ebbinghaus, 1913; Cain and Wiley, 1939; Tsao, 1948; Underwood, 1961). The majority of these studies have shown that distributed practice is more effective than massed practice in facilitating retention.

Underwood (1961) describes variables imbedded in lists of nonsense syllables that interact with distributed practice. For example, the rate of presentation interacts with the practice schedule to the extent that as the rate is increased, the more distributed practice facilitates acquisition. Underwood found that for fixed rest intervals, the longer the list to be memorized, the greater the facilitating effect of distributed practice. Ausubel (1963) found that distributed practice is relatively more effective for memorizing longer than shorter lists of syllables and for items in the middle rather than towards the ends of the lists. Underwood (1961) concluded that unless a critical variable such as amount of interference, or length of rest period is involved, the positive effects of distributed practice are not found.

Some researchers have investigated the facilitating effects of distributed practice in terms of special theories. Hovland (1940) tested the differential forgetting theory, which claims that during a rest period incorrect responses tend to be forgotten while correct responses are retained. Hovland hypothesized that this theory would predict more rapid acquisition under distributed practice and better retention under massed practice.

In Hovland's investigation, sixteen lists of nonsense syllables were learned by thirty-two college students who served as their own controls. Trials were separated by six seconds under the massed practice condition, and two minutes separated each trial under the distributed condition. Distributed practice proved to be more efficient for learning, and contrary to Hovland's hypothesis, recall was better under distributed practice at each of the four retention intervals.

Madsen (1963) investigated the consolidation theory which maintains that neural activity continues for some time after practice with a learning task, and this continuing activity strengthens the trace or neural pattern associated with the task. Thus, distributed practice should have the effect of activating the pattern for a long period of time, while massed practice may not allow enough time for the consolidation process to fix the pattern adequately in memory.

Madsen had subjects of high, middle, and low ability learn a list of ten paired associates to one perfect recitation. Each ability group was divided in half; one half learned the list under distributed conditions, the other half under massed conditions. In general, the distributed group required fewer trials to reach the criterion, and the low ability group did significantly better under the distributed condition than under the massed condition. Madsen explained that low ability students often require a long period of time for consolidation and therefore benefit from distributed practice; high ability students do not require as long a period for consolidation and thus are not adversely affected by massed practice. Other studies designed to investigate the possible interactions of distributed practice and general ability have not confirmed Madsen's claim (Dent and Johnson, 1964; Barmeister and Berry, 1967; Mordock, 1968; Laing, 1970; Camp, 1973).

Rote Learning and Retention of Meaningful Material

Many of the studies of the effects of distributed practice on the rote learning and retention of meaningful material agree with the results of investigations of the interaction of distributed practice and the learning and retention of non-meaningful material. Ellis (1960) reported the major difference seems to be that distributed practice is relatively more effective for the rote learning and retention of non-meaningful material.

Gordon (1925) compared the effects of spaced and unspaced memorizing using four college psychology classes. Each class received six readings of the same poem with different spacings between readings. Results indicate that massed readings were more effective for initial learning while distributed readings were better for delayed recall.

Bumstead (1964) described his 1930 experiment in which he compared rates of memorizing various 50-line passages from Milton's Paradise Lost under different conditions of spaced practice. The rate of acquisition favored longer rather than shorter rest intervals.

Cook (1934) hypothesized that on a task requiring some "insight" to produce a solution, massed trials facilitate the insight but the solution is best fixed through distributed practice. To test this hypothesis, he had two groups of subjects complete puzzles under massed and distributed conditions. Results showed that massed practice was more economical at first, but that with increased repetition, the distributed practice group required less time to complete these tasks. This advantage was also evident on delayed retention tests administered two and four weeks after practice ended.

Cook's hypothesis that massed practice is more economical in earlier stages of learning and distributed practice more economical in later stages was based on what many investigators have confirmed as the general characteristics of the curve of forgetting: forgetting is rapid at first and then tapers off. To translate this into an instructional procedure one would need to mass practice immediately after an exposure to a task to facilitate insight and then distribute practice to help it become a part of the cognitive structure.

Ash (1950) conducted two experiments which assessed the relative effects of spaced and unspaced presentations of a film series. A group of seven classes viewed two films on different subject matter. Four classes did not view the film and served as a control group. Three classes viewed both films during a single hour session, two classes viewed the films during one-half hour sessions on two separate days and two other classes viewed the films during 15-minute sessions on four separate days. Retention tests were administered to the treatment groups at the end of one week and then two weeks after the middle of the treatment week. These tests showed no significant difference between the groups viewing the films over different intervals. Ash conducted a similar experiment with ten companies of Navy recruits with equivalent results. In both experiments, timing of the retention tests did not permit equivalent forgetting intervals across the three treatment groups. Thus the results of this study are somewhat questionable.

Oseas and Underwood (1952) conducted an experiment in which four groups of college students learned size and shape concepts under one of four inter-trial intervals: 6, 15, 30, and 60 seconds. The distributed practice conditions (15, 30, and 60 seconds) produced slightly faster acquisition although no significant differences were shown among the groups on a retention instrument administered 24 hours after treatment.

Fishman, Keller, and Atkinson (1968) investigated the effects of distributed practice on computerized spelling drills. The researchers compared the effects of distributed and massed practice on the acquisition rate and the long-term retention of 29 fifth graders. Results of the study indicate that massed practice produced faster learning, but distributed practice produced significantly better results on delayed retention tests administered 10 and 20 days later.

Ingle, Remstad, Gephart, and Lampsa (1969) studied the effects of spaced and unspaced trials on the memorization of poetry. Students in paired classes memorized "Old Ironsides" under one of two conditions: 10 minutes a day for four consecutive days, or 40 minutes of concentrated study on one day. There were significant differences in favor of distributed practice on initial learning but no significant differences were found on a retention test administered three days after the students' last exposure to the material. These results imply that there was more forgetting under distribution of practice which contradicts the conclusions of Fishman _et_. _al_.

The results of the studies in this subsection indicate that there is no clear evidence of the superiority of either massed or distributed practice on the rote learning and retention of meaningful materials. The major problem seems to be that the meaning of distributed practice differs so widely from study to study that the important characteristics of the practice condition have not been identified. There needs to be more research conducted in which small variations in distribution procedure are studied.

Meaningful Learning and Retention of Meaningful Material

Only four experiments have been reported on the relative effects of massed and distributed practice on learning and retention in classroom situations. Three of these studies (Urwiller, 1971; Laing, 1970; and Camp, 1973) were reviewed in detail in Chapter I. One other study will be reviewed in this subsection.

Reynolds and Glaser (1964) reported the results of a second experiment on the effects of spacing periodic reviews of biology concepts taught to two eighth grade science classes by programmed instruction. The classes had equivalent mean IQ's and had not been exposed to biology instruction during the school year.

One class received massed practice with the experimental topic, mitosis, while the other class received the same information and review but spaced over several topics in biology rather than presented in a concentrated study. Learning and retention tests were administered when the amount of time following the last exposure to the experimental material was the same for both groups. Questions concerning concepts from other biology topics were included on the learning and retention tests as control items.

No significant differences were found between the two groups on the control items on either the learning test or the retention test. However, for the items on mitosis, there were consistent significant differences in favor of the spaced practice group. The investigators concluded that the spacing of review has a facilitating effect upon the learning of material in a programmed sequence.

The small number of studies of the relative effects of massed and distributed practice on meaningful learning and retention of meaningful materials have produced no consistent results. Since the treatments varied among the studies, conclusions about the relative merits of massed and distributed practice are at best tentative.

CHAPTER III

THE EXPERIMENT

The design of the experiment and the procedures used are described in this chapter. This information should be useful to the reader as he evaluates the study and to the investigator who seeks to do further research on the effects of massed and distributed scheduling of assignments.

Sample

Selection

During the spring of 1974, permission was obtained from the assistant superintendent of schools in Putnam City, Oklahoma to involve teachers and pupils of the school district in the experimental phase of the study. Principals and mathematics department chairpersons in three of the junior high schools were visited and the purposes and design of the experiment were explained. Through these interviews it was determined that the eighth grade mathematics classes would be the most appropriate classes to use in the experiment and that Holt School Mathematics, Grade 8 by Nichols, et al. was the textbook that would be used the following year by a majority of the classes.

The eighth grade mathematics classes were chosen for use in the experiment for the following reasons: 1) most of the eighth graders would have already spent one year at their particular school and would not be in the process of learning school policies and procedures; 2) there would be more eighth graders than ninth graders who would be using the same mathematics textbook; 3) tests of general ability would be administered by the school to all eighth graders and test results would be available to the investigator; and 4) most of the eighth graders would return to the same school in the ninth grade and would be available for retention testing.

Of the teachers who were identified as those who would be using the Holt textbook, seven were identified who would be teaching at least two classes of comparable ability during the 1974-75 school year. These teachers all indicated a willingness to participate in the study.

In September 1974, the department chairpersons were contacted by telephone. Because the teachers were involved in writing performance objectives as part of the second phase of the Oklahoma Accountability Plan, it was decided that the experimental phase should be conducted during the spring semester of the 1974-75 school year.

Letters were sent to the seven teachers in February, 1975 giving details of the experiment. At that time one of the teachers replied that she could not participate in the investigation. After the experiment began in March, one other teacher decided that she would rather not participate. Two of the instructors who participated in the experiment were teaching five sections of eighth grade mathematics. Each of these teachers agreed to use two pairs of classes in the experiment. Thus the resulting sample consisted of 14 eighth grade mathematics classes taught by the five remaining teachers.

Description

In the eighth grades of the junior high schools that participated in the experiment, approximately the highest ten percent in mathematics achievement and the lowest ten percent in mathematics achievement were placed in special classes. The students who participated in the experiment were chosen from the middle eighty percent since these students constituted the largest group using the same textbook.

The 350 students tested ranged in IQ from 75 to 128 with a median IQ of 103 as measured by the Short Form Test of Academic Aptitude, Level 4. The classes ranged in mean IQ from 99.4 to 106.3 and in class size from 24 to 33.

Treatments

Treatments to Classes

The classes of each instructor were paired according to size and general ability. Each instructor was asked to teach one of the paired classes under a distributed (D) practice condition and the other under a massed (M) practice condition. The classes were randomly assigned to the D-M order or the M-D order. The resulting sample of teachers, classes and treatments is given in Table 4.

TABLE 4

ASSIGNMENT OF TREATMENTS

Teacher	D Class	M Class
1	Period 4	Period 1
2(a)	Period 1	Period 2
2(b)	Period 5	Period 6
3(a)	Period 1	Period 2
3(b)	Period 4	Period 6
4	Period 5	Period 6
5	Period 3	Period 5

Massed and Distributed Practice

The distribution function used in the experiment was defined in terms of two other functions. The first was the function $f: \rightarrow [\frac{1}{4}x^2]$, where $x = 1, 2, 3, \ldots$, which was used to determine the length of time, in school days, between assignments. The second function, used to determine the number of problems to assign, is given in Table 5.

Each instructor was free to choose the number and type of problems from the textbook to be assigned to his classes The only requirement was that whatever homework problems were given to an M class in the form of concentrated practice must be given to the D class in the form of distributed practice, as defined by the function given in Table 5.

TABLE 5

THE DISTRIBUTED PRACTICE FUNCTION

Day	N = Number of Problems Assigned to M Class
1	$\max([.4N], 1) = N_1$
2	$\max([.2N], 1) = N_2$
4	$\max([.15N], 1) = N_3$
7	$\max([.15N], 1) = N_4$
12	$\max([.1N], 1) = N_5$
19	$\max([.05N], 1) = N_6$
29	$N - \sum_{i=1}^{j} N_i = N_7$

Note [x] means the greatest integer less than or equal to x.

For a given N, whenever $\sum_{i=1}^{j} N_i = N$, then $N_{j+1} =$

$N_{j+2} = N_7 = 0$.

The Distribution Chart

A Distribution Chart (Figure 1), based on the function given in Table 5, was constructed for teachers to use in assigning homework practice to their classes. To illustrate how the chart was used, consider the following example. Suppose Teacher X decided to assign 20 problems on a given topic to his M class. He would locate the column headed 20 on the chart to determine how the problems should be distributed over several assignments to his D class. According to the chart, on Day 1 (the day the topic was introduced) he would assign 8 of the 20 problems; on the next school day (Day 2), he would assign 4 of the remaining 12 problems; on the fourth school day (Day 4), he would assign 3 of the remaining 8 problems; and so on. The teachers were told that on the day a topic was introduced they should give their distributed classes the full range of problems assigned to the massed classes. This could be done by assigning every other problem or every third problem, depending on the length of the massed assignment. After the first assignment on a given topic the teachers were free to make any choice they wished as to how the remaining problems should be distributed, as long as they adhered to the distribution chart in determining the number of problems to assign.

The Assignment Calendar

In order to minimize the difficulties involved in keeping track of the homework assignments that were distributed in assignments after the initial assignment, monthly assignment calendars were provided to each teacher for his use during the experiment. Each day of the calendar was divided into two sections. The instructors were asked to write the assignment for their massed class in one section and the corresponding assignments for their distributed classes in the other section. Figure 2 shows a calendar with a week of hypothetical assignments.

As the experiment progressed, on a given night the

Number of Problems Assigned to M Class / Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	1	1	1	1	2	2	2	3	3	4	4	4	5	5	6	6	6	7	7	8	8	8	9	9	10	10	10	11	11	12
2		1	1	1	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	4	4	4	4	4	5	5	5	5	5	6
4			1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	3	3	3	3	3	3	3	4	4	4	4
7				1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	3	3	3	3	3	3	3	4	4	4	4
12						1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	3
19							1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1
29									1		1	2	2	1		1	2	2	3			1	1	2	1	2	1	1	2	

Figure 1.--Distribution Chart To Be Used in Assigning Homework Practice

Assignment Calendar

Month of __________

	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
Massed	p. 139:1-9	p. 141:1-12	p. 143:all even probs.	p. 145:1-30	p. 146:1-20
Distrib-uted	p. 139:1,5,9	p. 139:2 p. 141:1,3,6,9	p. 141:4,12 p.143:2,8,14,20,26,32 38,44,48	p. 139:7 p. 143:6,12,18,24 p. 145:1,3,6,9,12, 15,18,21,24, 27,29,30	p. 141:5 p. 145:5,7,11, 17,23,28 p. 146:even probs. 4-18
Massed					
Distrib-uted	p. 143:30,36, 42 p. 146:2,7, 15,20	p. 139:3 p. 145:2,8,13,26	p. 141:11 p. 146:1,9,17	p. 143:4,16,38	p. 145:4,10, 19,25
Massed					
Distrib-uted	p. 146:3,11,19	p. 139:8	p. 141:2	p. 143:6,20	p. 145:16,20,22
Massed					
Distrib-uted	p. 146:5,13			p. 139:4	p. 141:7

Figure 2.

homework for a distributed class could come from four or five different sets of exercises, with the bulk of the problems coming from the exercise set corresponding to the topic just taught. Teachers were instructed that if they felt that a given assignment was excessively long, they could partition it and include some of the problems in a succeeding assignment that did not include as many exercises.

Experimental Materials

The experimental phase of the study involved the treating and testing of Chapter 10, Percent, and Chapter 11, Real Numbers, from the textbook Holt School Mathematics, Grade 8 by Nichols, et al. Although the work with percents deals with real numbers, examination of the material in Chapters 10 and 11 revealed that the concepts developed in the two chapters did not overlap. In order to prevent contamination of the massed treatment, the teachers were instructed not to review concepts from Chapter 10 with their massed classes during the treatment of Chapter 11.

Instruments

The General Ability Test

The Short Form Test of Academic Aptitude, Level 4 was administered to all eighth grade students during October, 1974 as part of the regular testing program of the Putnam City Schools. This is a 38 minute, 16 page test that provides three scores: language, nonlanguage, total. The total scores on the test were used to categorize students in the sample in three ability groups: high, middle, and low.

The Achievement Tests

1. Percent I was a thirty-minute, 20-item chapter test that covered concepts and skills developed in the chapter on percents.

2. Percent II was a 12-item retention test that covered concepts and skills developed in the chapter on percent.

3. Real Numbers I was a forty-minute, 25-item chapter test that covered concepts and skills developed in the chapter on real numbers.

4. Real Numbers II was a 13-item delayed retention test that covered concepts and skills developed in the chapter on real numbers.

Percent II and Real Numbers II were combined to make one thirty-minute examination.

The Subtests

1. Percent I (R) was a 12-item subtest of Percent I that was constructed to be parallel to Percent II.

2. Real Numbers I (R) was a 13-item subtest of Real Numbers I that was constructed to be parallel to Real Numbers II.

Development of the Achievement Tests

The two chapter tests, Percent I and Real Numbers I, and the delayed retention tests, Percent II and Real Numbers II, were designed and constructed by the researcher. Since the major variable to be investigated was the effect on students' performance of two types of homework assignments, the examinations sampled only the types of problems to which a student would be exposed by doing the homework exercises from the textbook.

A preliminary version of each chapter test was administered to classes not involved in the experiment to determine item discrimination, item difficulty, and the length of the examination. This information was used to construct a second version that was submitted to a panel of mathematics educators for critical examination. The panel for Percent I consisted of three members of the Department of Mathematics of Southwestern Oklahoma State University all of whom had teaching experience at the junior high school level and were experienced in test construction. The panel for Real Numbers I consisted of the Mathematics Supervisor for the Oklahoma City Public Schools, an Oklahoma City junior high school mathematics teacher, and a mathematics education professor at Central State University of Oklahoma. The reactions of these panelists were used to construct the final versions of the chapter tests which were administered to each experimental class.

The purpose for using the panel was to help judge the content validity of each chapter test. The panel members were asked to refer to the textbook and classify each test item according to a checklist divided into content objectives by level-of-behavior categories. They were then asked to refer to each content objective and to rate the set of test items that they had identified as measuring that particular objective. A rating scale ranging from "represents objective very well" to "represents not at all" was provided. The resulting summary matrix was used as the basis for the final revision of the chapter test. Sample checklists and rating forms are included in Appendix D.

By referring to the two summary matrices, twelve test items from Percent I and thirteen items from Real Numbers I were selected that covered all of the content areas. Twenty-five items written parallel to the items selected from the two chapter tests made up the retention tests. All four tests are included in Appendix B.

Instrument Reliability

The Kuder-Richardson Formula 20 was used to determine the internal consistency of each of the achievement tests and subtests. Table 6 gives these data. An item analysis for each test is included in Appendix C.

TABLE 6

ACHIEVEMENT TEST INFORMATION

Test	Number of Items	N	KR20
Percent I	20	348	0.88
Percent I (R)	12	348	0.81
Real Numbers I	25	340	0.84
Real Numbers I (R)	13	340	0.76
Percent II	12	306	0.74
Real Numbers II	13	306	0.61

Procedures

Pre-Experimental Phase

In May, 1974 the mathematics department chairpersons of three Putnam City, Oklahoma junior high schools were contacted and the purposes of the research project were explained. Each of these chairpersons agreed to assist the researcher in carrying out the purposes of the research. The names of seven teachers were suggested who met the requirements of teaching at least two classes of eighth grade mathematics that would be using the same textbook during the 1974-1975 school year. The seven teachers were contacted and each agreed to participate in the experiment. However, because of the involvement of the researcher and the teachers in writing objectives during the Fall, 1974 semester as part of the Oklahoma Accountability Plan, it was decided to conduct the experimental phase of the study during the Spring, 1975 semester.

During the last week of January, 1975 the teachers were visited at their respective schools and the plan of the experiment was explained. One of the purposes of the visit was to check to make sure that each teacher had followed the sequence of chapters in the textbook and determine which chapters would be most appropriate to treat during the experimental phase of the study.

Letters were sent to the teachers during the second week of February, 1975 thanking them for agreeing to cooperate and informing them that the study would begin the first week of March and that the experimental material would be Chapters 10 and 11. An abstract of the research proposal, along with assignment charts and calendars, was included with the letter. The teachers were also reminded that they should not inform their students that they would be participating in an experiment.

During the third week of February, the researcher met with the teachers to discuss the experimental procedures. At these meetings ways of answering students' questions about the experiment were discussed, the use of the Distribution Chart and Assignment Calendar were illustrated, methods for checking homework and supplementing the textbook exercises were discussed, and the testing procedure was explained. The sequence of events during the experiment and methods of using post experiment material were also discussed in these meetings.

Following the February meetings, a letter that included a summary of the items discussed at the meetings was sent to each teacher. On the first Saturday in March each teacher was contacted by telephone in order to answer any questions they had before the experiment began on the following Monday. During these conversations, it was suggested that each teacher fill out his assignment calendar daily rather than weekly or several days in advance. In this way, if a class was cancelled, only one day's assignment would be affected.

During October, 1974, the general ability test was administered to all eighth grade students as a part of the regular testing program of the schools. Scores obtained for students in the sample were used to partition each class into three subclasses: high ability, middle ability, and low ability. The high-ability subclass consisted of students whose IQ scores were in the upper third (greater than or equal to 107) of the total distribution of IQ's. The middle-ability subclass consisted of students whose IQ scores were in the middle third of the total distribution of IQ's. The low-ability subclass consisted of students whose IQ scores were in the lower third (less than or equal to 97) of the total distribution of IQ's. The number of students in each subclass is indicated in Table 7.

To determine if the stratification had indeed produced comparable treatment groups, the mean IQ scores were computed for each subclass, and the Wilcoxon Match-Pairs Signed-Ranks

TABLE 7

FREQUENCY DISTRIBUTION OF SUBJECTS BY CLASS AND ABILITY LEVEL

	Distributed Practice			Massed Practice		
Teacher	High	Middle	Low	High	Middle	Low
1	10	16	4	13	6	8
2(a)	8	7	9	8	11	8
2(b)	6	13	6	9	5	10
3(a)	5	7	13	6	6	12
3(b)	7	8	12	8	14	4
4	8	12	2	9	5	5
5	5	8	10	10	9	11

test was used to compare the treatment groups within ability levels. Tables 8, 9, and 10 give the mean IQ scores for the subclasses, and Table 11 includes the data required to apply the statistical test. Whenever the number of students in a subclass was less than 4, the matched pair to which it belonged was excluded from the analysis.

If T is the smaller absolute value of the sums of the like signed ranks, then for N = 6, a T = 0 is significant at the .05 level for a two-tailed test. For N = 7, a $T \leq 2$ is significant. Table 11 indicates that at each ability level, the treatment groups did not differ significantly.

TABLE 8

MEANS AND RANKED DIFFERENCE SCORES FOR LOW-ABILITY SUBCLASSES ON IQ TEST

Teacher	Distributed (D)		Massed (M)			Signed-Rank
	N	$\bar{X}$	N	$\bar{X}$	D-M	of D-M
1	4	94.5	8	91.63	2.87	$^+6$
2	9	92.33	8	91.25	1.08	$^+3$
3	6	91.67	10	93.8	$^-2.13$	$^-4$
4	13	92.62	12	92.17	0.45	$^+2$
5	12	92.58	4	84.25	8.33	$^+7$
6	2		5	94.2		
7	10	92.0	11	92.27	$^-0.27$	$^-1$

Experimental Phase

The experimental phase of the study began the first week of March with the treatment of Chapter 10. Contact with the teachers was maintained throughout the experimental phase by telephone and by visits to the schools. During the school visits problems were discussed and assignment calendars were inspected.

Meetings were scheduled with the teachers during the course of the experiment to distribute and pick up the achievement tests. The tests were scored by the teachers and returned to the students for in-class discussion. After the discussion period, all tests were collected and rescored by the researcher.

TABLE 9

MEANS AND RANKED DIFFERENCE SCORES FOR MIDDLE-ABILITY SUBCLASSES ON IQ TEST

Teacher	Distributed (D)		Massed (M)		D-M	Signed-Rank of D-M
	N	$\bar{X}$	N	$\bar{X}$		
1	16	103.88	6	101.17	2.71	$^{+}7$
2	7	101.29	11	101.73	$^{-}0.44$	$^{-}4$
3	13	102.23	5	102.4	$^{-}0.17$	$^{-}2$
4	7	103	6	102.67	$^{-}0.33$	$^{-}3$
5	8	104.63	14	102.21	2.42	$^{+}6$
6	12	102.42	5	103.80	$^{-}1.38$	$^{-}5$
7	8	101.63	9	101.67	$^{-}0.04$	$^{-}1$

TABLE 10

MEANS AND RANKED DIFFERENCE SCORES FOR HIGH-ABILITY SUBCLASSES ON IQ TEST

Teacher	Distributed (D)		Massed (M)		D-M	Signed-Rank of D-M
	N	$\bar{X}$	N	$\bar{X}$		
1	10	115.5	13	113.08	2.42	$^{+}4$
2	8	115.5	8	114	1.5	$^{+}2$
3	6	117.33	9	116.44	0.89	$^{+}1$
4	5	114	6	110.5	3.5	$^{+}6$
5	7	117.14	8	115.5	1.64	$^{+}3$
6	8	119.88	9	114.67	5.21	$^{+}7$
7	5	112.8	10	115.9	$^{-}3.1$	$^{-}5$

TABLE 11

SIGNED-RANKS TEST ON MEAN IQ DIFFERENCE BETWEEN GROUPS D AND M BY ABILITY LEVEL

Ability Subclass	Smaller Sum of Like Signed Ranks	N	P less than
Low	5	6	.30
Middle	13	7	.90
High	5	7	.20

The delayed retention test was given without prior review during the first week of school in August, 1975. This test was given as part of an inventory test that covered the content of eighth grade mathematics and was machine scored by the researcher. Those students who attended summer school during the summer were excluded from the sample. The achievement tests and the retention tests, with their accompanying sets of directions, are included in Appendix B.

Post-Experimental Phase

Since the major variable affecting students' performance on the retention tests was to be the type of homework practice given during the teaching of Chapters 10 and 11, the teachers were asked to provide similar classroom experiences for massed and distributed classes during the teaching of Chapters 12 and 13. After completing Chapter 11, the teachers were asked to select one assignment procedure and to use it in both of their classes. To check whether the treatments were administered as planned, each teacher's assignment calendars were collected at the end of school in May, 1975.

CHAPTER IV

ANALYSIS OF DATA

The analysis of data is presented in four sections. The first section contains the results of the performance of each ability group on the initial learning tests. The second section contains the results of the two retention tests. The third section provides data analysis designed to determine the differential effects of distributed and massed treatments across ability levels. The fourth section attempts to determine from the obtained data trends of the scores of students who took all four tests--Percent I(R), Percent II, Real Numbers I(R), and Real Numbers II.

In the analysis, the data was organized by teacher, treatment, and ability. Thus the class was used as the experimental unit. Since the sample size was relatively small ($N \leq 7$) a non-parametric test appeared to be best suited for the data. The Wilcoxan Matched-Pairs Signed-Ranks Test was used to test the following null hypotheses:

Ho 1. At each ability level, there is no significant difference in the initial learning of students receiving distributed practice and students receiving massed practice.

Ho 2. At each ability level, there is no significant difference in the retention of learning between students receiving distributed practice and students receiving massed practice.

A 0.05 level of significance was required for each test.

The data was also analyzed as though the student were the experimental unit. In this case, the t-test was used to test the null hypothesis. A 0.05 level of significance was also required when this test was used.

Performance of Ability Groups on Initial Learning Tests

This section contains the analysis of data obtained from initial learning tests Percent I and Real Numbers I. For each test, the scoring procedure was to give one point for each correct answer. The maximum possible scores were 20 for Percent I and 25 for Real Numbers I. Tables 12 and 13 give the frequency distributions of scores on the two tests by ability level.

On Percent I, the scores for the low-ability students were skewed toward the low end of the scale and the scores for the high-ability students were skewed toward the high end of the scale. The median score of 8.94 for the low-ability students indicated that at least one half of the students answered fewer than 45 percent of the items correctly. The median score of 14.2 for the high-ability students indicated that at least one half of the students answered more than 71 percent of the items correctly. The median score of

12.06 for the middle-ability students corresponded to 60 percent of the items on Percent I.

On Real Numbers I, the median score of 12.75 for the low-ability students indicated that one half of these students answered at least 51 percent of the items correctly. This result indicated that as a group the low-ability students did better on Real Numbers I than they did on Percent I. The median scores of 15.75 and 18.79 for the middle-ability and high-ability groups corresponded to 63 and 75 percent of the items, respectively.

TABLE 12

FREQUENCY DISTRIBUTION OF SCORES ON PERCENT I BY ABILITY LEVEL

Range of Scores	Low	Middle	High
18-20	1	7	25
15-17	13	33	28
12-14	19	27	20
9-11	27	21	21
6-8	25	21	9
3-5	16	12	7
0-2	12	4	0
TOTAL	113	125	110
Highest	20	20	20
Median	8.94	12.06	14.2
Lowest	0	1	4

TABLE 13

FREQUENCY DISTRIBUTION OF SCORES ON REAL NUMBERS I
BY ABILITY LEVEL

Range of Scores	Low	Middle	High
23-25	1	5	5
20-22	3	18	33
17-19	15	31	28
14-16	29	32	15
11-13	20	14	12
8-10	22	14	7
5-7	13	7	5
2-4	3	2	3
0-1	1	2	0
TOTAL	107	125	108
Highest	23	24	25
Median	12.75	15.75	18.79
Lowest	1	0	3

Low-Ability Group

The means and ranked difference scores on Percent I and Real Numbers I are given in Tables 14 and 15, respectively. The means ranged from 4.88 to 12.42 on Percent I and from 8.0 to 15.64 on Real Numbers I. The low subclass means on both tests came from classes taught by Teacher 2. Similarly, the high subclass means on both tests came from classes taught by Teacher 3. Table 7 in Chapter 3 showed that the classes taught by Teacher 2 had approximately 33 percent low-ability students while the classes taught by Teacher 3 had approximately 40 percent low-ability students.

TABLE 14

MEANS AND RANKED DIFFERENCE SCORES FOR LOW-ABILITY SUBCLASSES ON PERCENT I

Teacher	Distributed (D)		Massed (M)		D-M=d_L	Signed-Rank of d_L
	N	$\bar{X}$	N	$\bar{X}$		
1	4	9.25	8	9.13	0.12	1
2(a)	9	7.22	8	4.88	2.34	6
2(b)	6	5.33	10	6.8	-0.47	-4
3(a)	12	11.25	12	11.67	-0.42	-2.5
3(b)	12	12.42	4	12.0	0.42	2.5
4	*		5	8.4		
5	10	7.1	11	8.27	-1.17	-5

*N Less than 4

TABLE 15

MEANS AND RANKED DIFFERENCE SCORES FOR LOW-ABILITY SUBCLASSES ON REAL NUMBERS I

Teacher	Distributed (D)		Massed (M)		D-M=d_L	Signed-Rank of d_L
	N	$\bar{X}$	N	$\bar{X}$		
1	4	14.5	8	12.63	1.87	4
2(a)	9	11.0	8	9.5	1.5	3
2(b)	6	8.83	8	8.0	0.83	1
3(a)	10	13.0	12	15.0	-2.0	-5
3(b)	11	15.64	4	14.25	1.39	2
4	*		4	12.75		
5	10	13.0	11	10.64	2.36	6

*N Less than 4

In applying the Wilcoxan Matched-Pairs Signed-Ranks Test, difference scores and their ranks were computed only when each member of a matched-pair contained four or more students with scores. Therefore, scores on both Percent I and Real Numbers I for the low-ability students of Teacher 4 were excluded from the analysis. These scores were included, however, when the scores were grouped by treatment and the t-test was applied (Table 16).

For the low-ability subclasses on Percent I, T=9.5, (T represents the smaller absolute value of the sums of the like-signed ranks). For N=6, T=9.5 has an associated probability p of 0.83. For the low-ability subclasses on Real Numbers I, T=5 and N=6 so p=0.25. Therefore Ho 1 was not rejected for the low-ability students.

Table 16 shows that for the low-ability students, the mean scores of the distributed practice group on both Percent I and Real Numbers I were higher than the mean scores for the massed practice group. However, neither of the differences between groups was significant at the 0.05 level.

TABLE 16

t-TEST COMPARING THE EFFECTS OF MASSED AND DISTRIBUTED PRACTICE ON THE PERFORMANCE OF LOW-ABILITY STUDENTS ON PERCENT I AND REAL NUMBERS I

Test	Distributed Practice			Massed Practice			
	N	$\bar{X}$	S	N	$\bar{X}$	S	t
Percent I	55	9.22	4.77	58	8.60	4.41	0.70
Real Numbers I	52	12.90	4.38	55	11.75	4.59	1.32

Middle-Ability Group

Means and ranked difference scores for the middle-ability subclasses are contained in Tables 17 and 18. Means on Percent I ranged from 5.29 to 16.00 and on Real Numbers I the means ranged from 9.57 to 17.75. The lowest means for both tests came from the same subclass, namely the distributed practice subclass of Teacher 2(a). The highest means for both tests came from the same subclass, namely the distributed practice subclass of Teacher 3(b).

For the middle-ability subclasses, T=8 for Percent I (N=7, p=0.31) and T=12 for Real Numbers I (N=7, p-0.73). Therefore Ho 1 was not rejected for the middle-ability students.

TABLE 17

MEANS AND RANKED DIFFERENCE SCORES FOR MIDDLE-ABILITY SUBCLASSES ON PERCENT I

Teacher	Distributed (D)		Massed (M)		D-M=d_M	Signed-Rank of d_M
	N	$\bar{X}$	N	$\bar{X}$		
1	16	10.94	6	10.33	0.61	2
2(a)	7	5.29	11	9.73	-4.44	-7
2(b)	13	9.54	5	9.6	-0.06	-1
3(a)	6	12.67	6	15.17	-2.50	-5
3(b)	8	16.0	14	12.93	3.07	6
4	11	12.73	5	13.8	-1.07	-3
5	8	10.0	9	11.44	-1.44	-4

TABLE 18

MEANS AND RANKED DIFFERENCE SCORES FOR MIDDLE-ABILITY SUBCLASSES ON REAL NUMBERS I

Teacher	Distributed (D)		Massed (M)		$D-M=d_M$	Signed-Rank of d_M
	N	$\overline{X}$	N	$\overline{X}$		
1	16	17.13	6	16.0	1.13	2
2(a)	7	9.57	11	13.18	-3.61	-6
2(b)	12	16.0	5	11.0	5.0	7
3(a)	7	15.7	5	18.8	-3.1	-5
3(b)	8	17.75	13	14.69	3.06	4
4	12	15.58	5	16.4	-0.82	-1
5	8	15.75	9	14.33	1.42	3

Table 19 shows that, for the middle-ability students, the massed practice group did slightly better on Percent I than the distributed practice group, but on Real Numbers I the distributed practice group did better than the massed practice group. However, the differences were not significant at the 0.05 level.

High-Ability Group

Tables 20 and 21 contain the means and ranked difference for the high-ability subclasses. Means for Percent I ranged from 9.5 to 19.0 and means for Real Numbers I ranged from 12.88 to 20.6. The lowest mean score on Percent I was for the massed subclass of Teacher 2(b). The lowest mean score on Real Numbers I was for the massed subclass of

Teacher 2(a). For each test the highest mean score was for the distributed subclass of Teacher 3(a).

For both Percent I and Real Numbers I T=3 and N=7 so p=0.06. Therefore Ho 1 was not rejected.

TABLE 19

t-TEST COMPARING THE EFFECTS OF MASSED AND DISTRIBUTED PRACTICE ON THE PERFORMANCE OF MIDDLE-ABILITY STUDENTS ON PERCENT I AND REAL NUMBERS I

Test	Distributed Practice			Massed Practice			t
	N	$\bar{X}$	S	N	$\bar{X}$	S	
Percent I	69	11.00	4.71	56	11.80	4.44	-0.98
Real Numbers I	70	15.40	5.00	54	14.67	5.00	0.77

TABLE 20

MEANS AND RANKED DIFFERENCE SCORES FOR HIGH-ABILITY SUBCLASSES ON PERCENT I

Teacher	Distributed (D)		Massed (M)		$D-M=d_H$	Signed-Rank of d_H
	N	$\bar{X}$	N	$\bar{X}$		
1	10	13.1	13	12.46	0.64	1
2(a)	8	11.88	8	10.63	1.25	4
2(b)	6	13.83	8	9.5	4.33	7
3(a)	5	19.0	5	15.8	3.2	6
3(b)	7	13.71	8	14.88	-1.17	-3
4	8	16.5	9	13.67	2.83	5
5	5	15.0	10	13.9	1.1	2

TABLE 21

MEANS AND RANKED DIFFERENCE SCORES FOR HIGH-ABILITY SUBCLASSES ON REAL NUMBERS I

Teacher	Distributed (D) N	Distributed (D) $\bar{X}$	Massed (M) N	Massed (M) $\bar{X}$	D-M=d_H	Signed Rank of d_H
1	9	17.0	13	17.31	-0.31	-1
2(a)	7	14.0	8	12.88	1.12	3
2(b)	6	14.5	9	12.89	1.61	4
3(a)	5	20.6	6	18.17	2.43	5
3(b)	6	18.0	8	19.0	-1.0	-2
4	8	18.63	9	16.0	2.63	6
5	5	19.8	10	15.5	4.3	7

Table 22 shows that, on the average, the distributed practice group did better than the massed practice group on both Percent I and Real Numbers I. As was the case with the low- and middle-ability students, the differences were not significant when the t-test was applied.

TABLE 22

t-TEST COMPARING THE EFFECTS OF MASSED AND DISTRIBUTED PRACTICE ON THE PERFORMANCE OF HIGH-ABILITY STUDENTS ON PERCENT I AND REAL NUMBERS I

Test	Distributed Practice N	Distributed Practice $\bar{X}$	Distributed Practice S	Massed Practice N	Massed Practice $\bar{X}$	Massed Practice S	t
Percent I	49	14.22	4.29	61	12.84	4.40	1.64
Real Numbers I	46	17.33	4.79	63	16.10	5.34	1.27

Performance of Ability Groups on Retention Tests

The analysis of data obtained from the retention tests Percent II and Real Numbers II is contained in this section. The scoring scheme, for each test, was to give one point for each correct answer. The maximum possible scores on the two retention tests were 12 for Percent II and 13 for Real Numbers II. Tables 23 and 24 contain frequency distributions of scores for the two tests by ability level.

The tables show that the median score for the high-, middle-, and low-ability groups were in the corresponding rank order, and at each ability level, the median score on Percent II was higher than the median score on Real Numbers II. On Percent II, the scores for the low-ability group were skewed toward the low end of the scale, but the scores for the other two ability groups were more uniformly distributed. On Real Numbers II, the scores at the middle-, and low-ability levels were generally low. However, the scores of the high-ability group were more evenly spread across the range of scores. The medians on Real Numbers II for the high-, middle-, and low-ability groups, respectively, correspond to 38, 32, and 23 percent of the items answered correctly.

Low-Ability Group

The performance of the low-ability students on the two retention tests is given in Tables 25 and 26. For Percent II, $T=5$ ($N=6$, $p=0.25$). For Real Numbers II, $T=6$ ($N=6$, $p=0.35$).

Therefore Ho 2 was not rejected for the low-ability students.

TABLE 23

FREQUENCY DISTRIBUTION OF SCORES ON
PERCENT II BY ABILITY LEVEL

Score	High	Middle	Low
12	2	1	1
11	3	3	1
10	11	3	0
9	6	9	2
8	15	14	0
7	15	10	5
6	15	12	7
5	10	19	9
4	10	11	21
3	4	16	12
2	7	6	18
1	1	5	14
0	1	2	5
TOTAL	100	111	95
Median	6.63	5.32	3.38

TABLE 24

FREQUENCY DISTRIBUTION OF SCORES ON
REAL NUMBERS II BY ABILITY LEVEL

Score	High	Middle	Low
13	0	0	1
12	1	0	0
11	2	0	0
10	1	2	0
9	5	2	1
8	6	2	2
7	12	5	2
6	12	15	9
5	17	24	12
4	15	17	9
3	14	16	22
2	13	13	25
1	0	11	8
0	1	4	4
TOTAL	100	111	95
Median	4.91	4.18	2.98

TABLE 25

MEANS AND RANKED DIFFERENCE SCORES FOR LOW-ABILITY SUBCLASSES ON PERCENT II

Teacher	Distributed (D)		Massed (M)		$D-M=d_L$	Signed-Rank of d_L
	N	$\bar{X}$	N	$\bar{X}$		
1	4	3.25	6	3.83	-0.58	-2
2(a)	9	3.00	7	3.71	-0.71	-4
2(b)	5	3.60	10	2.60	1.00	5
3(a)	11	2.91	9	3.56	-0.65	-3
3(b)	10	3.60	4	5.50	-1.90	-6
4	*		*			
5	9	3.78	10	4.10	-0.32	-1

*N less than 4

On Percent II, all but one pair of subclasses showed a difference in favor of massed practice. However, the small sample size and large value of the signed-rank associated with this pair of subclasses, probably accounts for the non-significant T-value.

TABLE 26

MEANS AND RANKED DIFFERENCE SCORES FOR LOW-ABILITY SUBCLASSES ON REAL NUMBERS II

Teacher	Distributed (D)		Massed (M)		D-M=d_L	Signed-Rank of d_L
	N	$\bar{X}$	N	$\bar{X}$		
1	4	4.75	6	4.17	0.58	5
2(a)	9	2.56	7	2.75	-0.19	-2
2(b)	5	2.20	10	2.40	-0.20	-3
3(a)	11	4.27	9	4.11	0.16	1
3(b)	10	2.60	4	6.00	-3.40	-6
4	*		*			
5	9	3.11	10	3.40	-0.29	-4

*N less than 4

Table 27 shows that, for the low-ability students, the massed practice group did better on the average on both retention tests than did the distributed practice group. The differences, however, were not significant.

TABLE 27

t-TEST COMPARING THE EFFECTS OF MASSED AND DISTRIBUTED PRACTICE ON THE PERFORMANCE OF LOW-ABILITY STUDENTS ON PERCENT II AND REAL NUMBERS II

Test	Distributed Practice			Massed Practice			t
	N	$\bar{X}$	S	N	$\bar{X}$	S	
Percent II	48	3.33	2.22	47	3.68	2.46	-0.73
Real Numbers II	48	3.31	1.76	47	3.57	2.46	-0.59

Middle-Ability Group

Tables 28 and 29 indicate the performances of the middle-ability students on Percent II and Real Numbers II. On Percent II, T=6 (N=6, p=0.35), and on Real Numbers II, T=7 (N=6, p=0.47). Therefore, Ho 2 was not rejected for the middle-ability students.

Table 30 shows that, for the middle-ability students, the massed practice group did better on the average on both Percent II and Real Numbers II than did the distributed practice group. However, the differences between the groups on each test were not significant.

TABLE 28

MEANS AND RANKED DIFFERENCE SCORES FOR MIDDLE-ABILITY SUBCLASSES ON PERCENT II

Teacher	Distributed (D)		Massed (M)		$D-M=d_M$	Signed-Rank of d_M
	N	$\bar{X}$	N	$\bar{X}$		
1	14	5.21	5	4.20	1.01	4
2(a)	6	3.50	11	4.45	-0.95	-3
2(b)	9	6.11	*			
3(a)	6	5.00	5	7.80	-2.80	-6
3(b)	7	6.14	13	5.92	0.22	2
4	10	5.10	5	7.80	-2.70	-5
5	8	6.00	9	6.11	-0.11	-1

*N less than 4

TABLE 29

MEANS AND RANKED DIFFERENCE SCORES FOR MIDDLE-ABILITY SUBCLASSES ON REAL NUMBERS II

Teacher	Distributed (D)		Massed (M)		$D-M=d_M$	Signed-Rank of d_M
	N	$\bar{X}$	N	$\bar{X}$		
1	14	5.79	5	4.60	1.19	4
2(a)	6	3.17	11	3.55	-0.38	-1
2(b)	9	3.78	*			
3(a)	6	3.50	5	6.40	-2.90	-6
3(b)	7	5.14	13	4.08	1.06	3
4	10	2.80	5	4.60	-1.80	-5
5	8	2.88	9	3.78	-0.90	-2

*N less than 4

TABLE 30

t-TEST COMPARING THE EFFECTS OF MASSED AND DISTRIBUTED PRACTICE ON THE PERFORMANCE OF MIDDLE-ABILITY STUDENTS ON PERCENT II AND REAL NUMBERS II

Test	Distributed Practice			Massed Practice			t
	N	$\bar{X}$	S	N	$\bar{X}$	S	
Percent II	60	5.35	2.41	51	5.76	2.94	-0.79
Real Numbers II	60	4.03	2.21	51	4.12	2.12	-0.22

High-Ability Group

Tables 31 and 32 contain the means and ranked difference scores for the high-ability subclasses on Percent II and Real Numbers II. On Percent II, T=7 (N=6, p=0.16), and on

Real Numbers II T=3 (N=7, p=0.06). Thus Ho 2 was not rejected for the high-ability students.

TABLE 31

MEANS AND RANKED DIFFERENCE SCORES FOR HIGH-ABILITY SUBCLASSES ON PERCENT II

Teacher	Distributed (D)		Massed (M)		D-M=d_H	Signed-Rank of d_H
	N	$\bar{X}$	N	$\bar{X}$		
1	10	5.80	11	6.00	-0.20	-2
2(a)	7	5.43	8	5.50	-0.07	-1
2(b)	6	5.83	7	6.86	-1.03	-4
3(a)	4	8.00	4	5.50	2.50	6
3(b)	7	8.29	8	6.50	1.79	5
4	7	7.57	8	7.00	0.57	3
5	5	7.00	8	7.00	0.00	*

*Drop from analysis since d_H=0

TABLE 32

MEANS AND RANKED DIFFERENCE SCORES FOR HIGH-ABILITY SUBCLASSES ON REAL NUMBERS II

Teacher	Distributed (D)		Massed (M)		D-M=d_H	Signed-Rank of d_H
	N	$\bar{X}$	N	$\bar{X}$		
1	10	6.20	11	5.64	0.56	3
2(a)	7	4.00	8	3.25	0.75	4
2(b)	6	5.50	7	5.57	-0.07	-1
3(a)	4	5.25	4	4.25	1.00	5
3(b)	7	5.00	8	5.50	-0.50	-2
4	7	6.43	8	3.75	2.68	7
5	5	6.00	8	4.75	1.25	6

Table 33 shows that on both Percent II and Real Numbers II the mean scores for the distributed practice group were higher than the mean scores for the massed practice group. However, using the t-test, the differences between the treatment groups were not significant at the 0.05 level.

TABLE 33

t-TEST COMPARING THE EFFECTS OF MASSED AND DISTRIBUTED PRACTICE ON THE PERFORMANCE OF HIGH-ABILITY STUDENTS ON PERCENT II AND REAL NUMBERS II

Test	Distributed Practice			Massed Practice			
	N	$\overline{X}$	S	N	$\overline{X}$	S	t
Percent II	46	6.72	3.02	54	6.37	2.26	0.65
Real Numbers II	46	5.52	2.52	54	4.74	2.18	1.63

Effects of Distrubuted Practice Across Ability Groups

In order to determine whether distributed practice had different effects across ability levels, the differences d_i, i=L, M, H, for each pair of subclasses were compared. Since d_i measured the superiority of distributed practice over massed practice at the i-th ability level (see, for example, Table 14), the sign of $(d_i - d_j)$, $i \neq j$, indicated the difference in the effect distributed practice for each pair of subclasses at the i-th and j-th ability levels. For example, for Teacher 1 (See Tables 17 and 20):

$$\begin{aligned} d_H - d_M &= 0.64 - 0.61 \\ &= 0.03 \\ &> 0 \end{aligned}$$

Therefore, distributed practice had a more positive effect on Teacher 1's high-ability students than it did on his middle-ability students.

The differences on the initial learning tests for the three combinations of ability levels are shown in Table 34. Similar data for the retention tests is presented in Table 35. In Table 34, under Percent I and the column headed "$d_H - d_M$", 0.03 is the difference calculated for Teacher 1 in the preceding example.

TABLE 34

COMPARISONS OF SUPERIORITY OF DISTRIBUTED OVER MASSED PRACTICE AT THREE ABILITY LEVELS ON PERCENT I AND REAL NUMBERS I

Teacher	Percent I			Real Numbers I		
	d_H-d_M	d_M-d_L	d_H-d_L	d_H-d_M	d_M-d_L	d_H-d_L
1	0.03	0.49	0.52	-1.44	-0.74	-2.18
2(a)	5.69	-6.78	-1.09	4.73	-5.11	-0.38
2(b)	4.39	0.41	4.80	-3.39	4.17	0.78
3(a)	5.72	-2.08	3.62	5.53	-1.10	4.43
3(b)	-4.24	2.65	-1.59	-4.06	1.67	-2.39
4	3.90	*	*	3.45	*	*
5	2.54	-0.27	2.27	2.88	-0.94	1.94

*N less than 4

TABLE 35

COMPARISON OF SUPERIORITY OF DISTRIBUTED OVER MASSED PRACTICE AT THREE ABILITY LEVELS ON PERCENT II AND REAL NUMBERS II

Teacher	Percent II			Real Numbers II		
	d_H-d_M	d_M-d_L	d_H-d_L	d_H-d_M	d_M-d_L	d_H-d_L
1	-1.21	1.59	0.38	-0.63	0.61	-0.02
2(a)	0.88	-0.24	0.64	1.13	-0.19	0.94
2(b)			-2.03			0.13
3(a)	5.30	-2.15	3.15	3.90	-3.06	0.84
3(b)	1.57	2.12	3.69	-1.56	4.46	2.90
4	3.27			4.48		
5	0.11	0.21	0.32	2.15	-0.61	1.54

Note: A blank space means that a subclass had fewer than 4 members

Each column of differences $d_i - d_j$, $i \neq j$, in Tables 34 and 35 was tested using the sign test. Table 36 summarizes the results of the sign test for Percent I and Real Numbers I. Table 37 summarizes the results of the sign test for Percent II and Real Numbers II. As the values of p in the two tables show, there was no evidence of a significant difference, across ability levels, in the relative effectiveness of distributed practice versus massed practice.

TABLE 36

SIGN TEST COMPARING THE EFFECTS OF DISTRIBUTED PRACTICE ACROSS ABILITY LEVELS ON PERCENT I AND REAL NUMBERS I

Difference	Percent I			Real Numbers I		
	X	N	P	X	N	P
d_H-d_M	1	7	0.12	3	7	1.00
d_M-d_L	3	6	1.00	2	6	0.69
d_H-d_L	2	6	0.69	3	6	1.00

Note: X=number of fewer signs; N=number of signs, p=the two-tailed probability that the number of fewer signs is X or less assuming that $p(+)=p(-)=\frac{1}{2}$.

TABLE 37

SIGN TEST COMPARING THE EFFECTS OF DISTRIBUTED PRACTICE ACROSS ABILITY LEVELS ON PERCENT II AND REAL NUMBERS II

Difference	Percent II			Real Numbers II		
	X	N	P	X	N	P
d_H-d_M	1	6	0.22	2	7	0.45
d_M-d_L	2	5	1.00	2	5	1.00
d_H-d_L	1	6	0.22	1	6	0.22

Note: X=number of fewer signs, N=number of signs, p=the two-tailed probability that the number of fewer signs is X or less assuming that $p(+)=p(-)=\frac{1}{2}$.

Changes in Scores Between Initial Learning Tests and Retention Tests

This section contains the analysis of data used to determine the relationship among treatments, performance on initial learning tests, and performance on retention tests. Scores of those students who took both of the initial learning tests and both of the retention tests were analyzed. Graphs were constructed to compare the mean scores on the retention tests to the mean scores on the corresponding initial learning tests at each ability level. At each ability level, students were identified as having done better, the same, or worse on each retention test in comparison with the corresponding initial learning test. This information was summarized in contingency tables to determine trends in performance between the initial learning tests and the retention tests.

Changes in Means Between Initial Learning and Retention Tests

To compare retention with initial learning, subtests of the initial learning tests were used. These subtests, Percent I(R) and Real Numbers I(R), contained items on the initial learning tests that were written to be parallel to the items on the retention tests, Percent II and Real Numbers II, respectively. Use of these subtests, rather than the full initial learning tests, provided a more direct measure of changes in performance.

Table 38 shows the means and standard deviations for Percent I(R), Percent II, Real Numbers I(R), and Real Numbers II, categorized by treatment and ability level. The means shown in Table 38 were used to construct the graphs shown in Figures 3 and 4. Figure 3 shows a graph of the means for Percent I(R) and Percent II; Figure 4 shows a graph of the means for Real Numbers I(R) and Real Numbers II. Both graphs indicate a decrease in performance on each of the retention tests in comparison with the corresponding initial learning test.

Figure 3 shows that, for the low-ability students, the decrease in performance between Percent I(R) and Percent II was about the same for the massed and distributed practice groups. For the high-ability students the decrease in performance between Percent I(R) and Percent II was greater for the distributed practice group than it was for the massed practice group. Figure 3 also shows that for the middle-ability students the mean on Percent I(R) was higher for the distributed practice group, but on Percent II the mean for the massed practice group was higher.

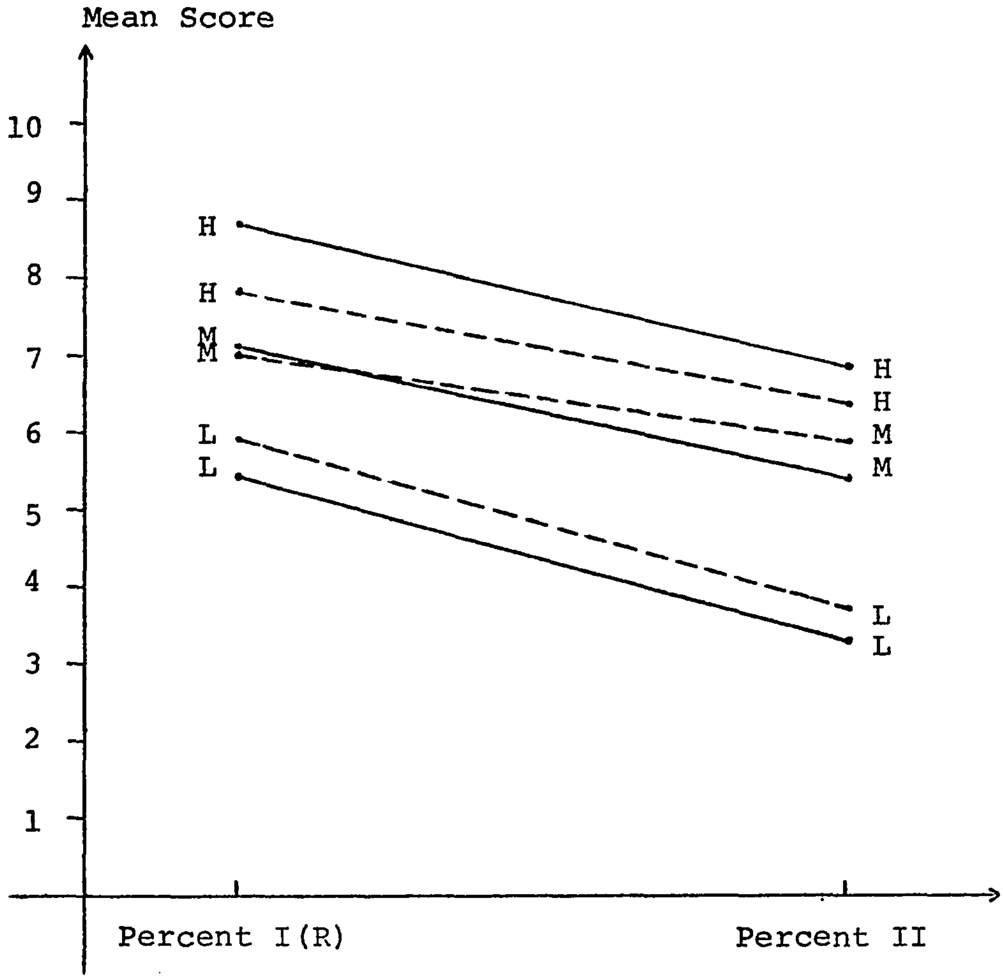
Figure 4 shows that the decrease in the performance of the high-ability students between Real Numbers I(R) and Real Numbers II was slightly steeper for the massed practice group than for the distributed practice group. For the middle-ability and low-ability groups, the means were higher for the distributed practice groups than for the massed practice groups on Real Numbers I(R). However, on Real Numbers II, the means of the massed practice groups were higher than the means for the distributed practice groups at the middle- and low-ability levels.

Figures 3 and 4 show that in comparing student performance on retention tests to performance on initial learning tests, there was greater difference between ability levels than between treatment groups at any one ability level.

TABLE 38

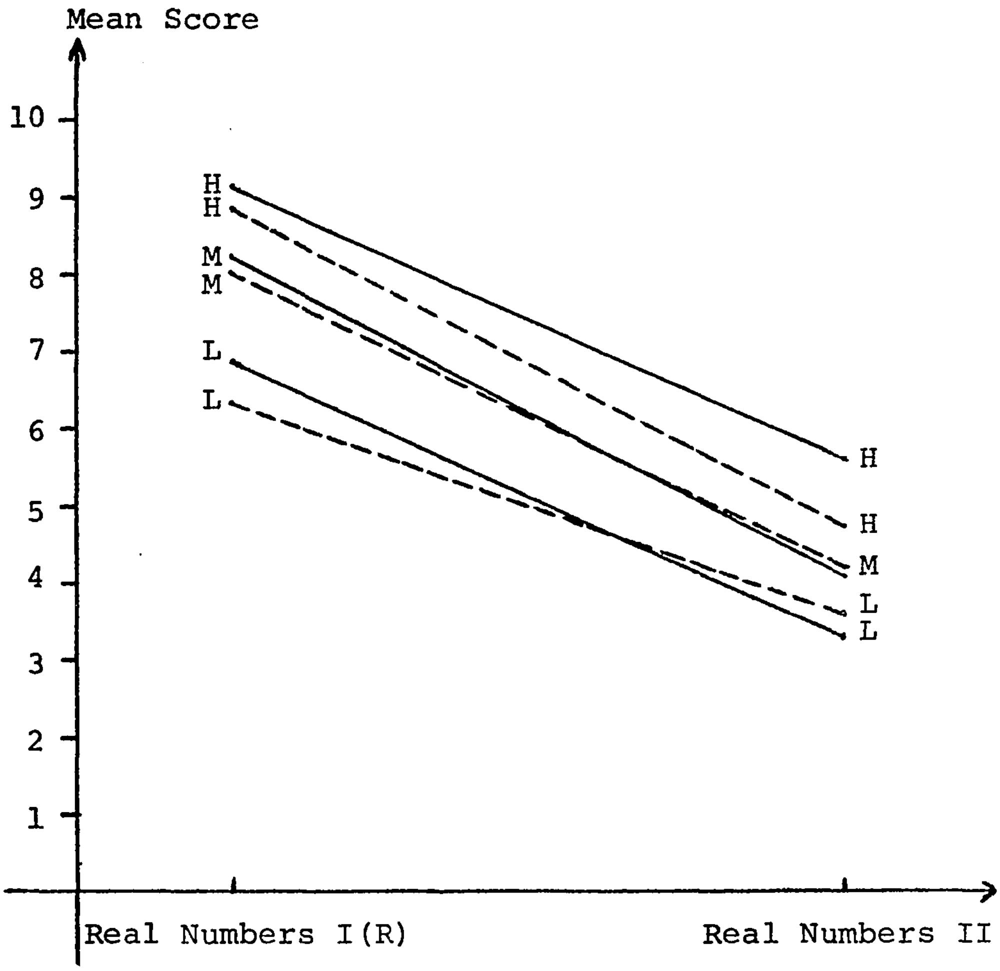
MEANS AND STANDARD DEVIATIONS FOR ALL TESTS BY TREATMENT AND ABILITY LEVEL

Ability Level	N	Distributed Practice Percent I(R)	Distributed Practice Percent II	Distributed Practice Real No. I(R)	Distributed Practice Real No. II	N	Massed Practice Percent I(R)	Massed Practice Percent II	Massed Practice Real No. I(R)	Massed Practice Real No. II
High	43	8.67	6.84	9.12	5.58	52	7.79	6.37	8.87	4.73
		(2.48)	(2.29)	(2.84)	(2.56)		(2.70)	(2.28)	(3.07)	(2.22)
Middle	58	7.10	5.40	8.21	4.09	50	7.04	5.86	8.00	4.16
		(2.90)	(2.43)	(3.16)	(2.21)		(2.67)	(2.89)	(2.71)	(2.15)
Low	45	5.42	3.31	6.84	3.29	45	5.89	3.71	6.31	3.62
		(3.03)	(2.16)	(2.79)	(1.77)		(2.50)	(2.50)	(2.80)	(2.50)
TOTAL	146	7.02	5.21	8.06	4.28	147	6.96	5.34	7.79	4.19
		(3.08	(2.84)	(3.08)	(2.36)		(2.73)	(2.81)	(3.04)	(2.31)



Note: i———i represents the i-th ability distributed practice group and i-----i represents the i-th ability massed practice group (i=H, M, L).

Figure 3. Plot of Mean Scores on Percent I(R) and Percent II by Treatment and Ability Level.



Note: i———i represents the i-th ability distributed practice group and i-----i represents the i-th ability massed practice group (i=H, M, L).

Figure 4. Plot of Means Scores on Real Numbers I(R) and Real Numbers II by Treatment and Ability Level.

Movement of Students' Scores

To determine how the treatments affected the movement of students' scores, the performance of each student was identified as better, the same, or worse on each retention test in comparison to the corresponding initial learning test. Table 39 shows the number of students at each ability level and treatment group who did better, the same, or worse on Percent II in comparison to Percent I(R). Table 40 contains the same data for Real Numbers II compared to Real Numbers I(R).

Chi-square tests at each ability level, between treatment and movement, showed no significant association. Tables 39 and 40 show that at each ability level on both the percent tests and the real numbers tests, students were more likely to do worse than to do better or stay the same.

TABLE 39

CONTINGENCY TABLE FOR THE NUMBER OF STUDENTS AT EACH ABILITY LEVEL WHO DID BETTER, THE SAME, OR WORSE ON PERCENT II COMPARED TO PERCENT I(R)

Level	Distributed Practice			Massed Practice			x^2
	Better	Same	Worse	Better	Same	Worse	
High	7	5	31	12	8	32	1.24
Middle	12	14	32	16	8	26	2.25
Low	8	5	32	8	4	33	0.13

Note: For 2df, x^2=3.22 has associated probability of 0.20; x^2=4.60 has associated probability of 0.10.

TABLE 40

CONTINGENCY TABLE FOR THE NUMBER OF STUDENTS AT EACH ABILITY LEVEL WHO DID BETTER, THE SAME, OR WORSE ON REAL NUMBERS II COMPARED TO REAL NUMBERS I(R)

Level	Distributed Practice			Massed Practice			X^2
	Better	Same	Worse	Better	Same	Worse	
High	3	5	35	4	5	43	0.26
Middle	5	3	50	2	1	47	1.82
Low	5	1	39	6	2	37	0.48

Note: For 2df, X^2=3.22 has associated probability of 0.20; X^2=4.60 has associated probability of 0.10.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of the study was to compare the effects of massed practice and distributed practice on the initial learning and the retention of students in eighth grade mathematics. Fourteen classes, taught by five teachers, were paired so that one class in a pair received massed practice and the other class received distributed practice. Practice on a particular topic was consolidated in one or more consecutive assignments for the massed (M) group, but the distributed practice group (D) was given the <u>same</u> problems spaced over several assignments with intervals of rest between assignments.

Each teacher was given a chart and assignment calendar to use in distributing the assignments and recording the homework problems he gave to each class. Teachers were free to choose the number and type of problems to be assigned.

Instructional material used in the experiment was contained in two chapters from the textbook <u>Holt School Mathematics</u>, Grade 8 by Nichols, et al. One of the chapters was on percents and the other was on real numbers.

Each class was subdivided into subclasses on the basis of ability level: high, middle, and low. Initial learning tests and retention tests were used to test the null hypotheses:

Ho 1. At each ability level, there is no significant difference between the initial learning of students receiving distributed practice and students receiving massed practice.

Ho 2. At each ability level, there is no significant difference in the retention of learning between students receiving distributed practice and students receiving massed practice.

In addition, the following questions were studied:

1. Does distributed practice have different effects on students at three different levels of ability?
2. What is the relationship among treatment, performance on the initial learning tests, and performance on the retention tests?

Results

Scores on the initial learning tests, Percent I and Real Numbers I, indicate that, at each ability level, there was no significant difference between the means of the subclasses receiving distributed practice and the means of the corresponding subclasses receiving massed practice. However, on Percent I, the mean score of the distributed practice group was higher than the mean score for the massed practice group at the low-ability and the high-ability levels. At the middle-ability level, the mean score for the massed group was higher than the mean score of the distributed group. On Real Numbers I, the mean score of the distributed practice group was higher than the mean score of the massed practice group at all three ability levels.

On the retention tests, Percent II and Real Numbers II, there was no significant difference, at each ability level, between the means of the subclasses receiving distributed practice and the means of the subclasses receiving massed practice. At the high-ability level, the mean of the distributed practice group was higher than the mean of the massed practice group on both Percent II and Real Numbers II. However, at the other two ability levels, the massed practice group performed better than the distributed practice groups on both retention tests.

The relative superiority of distributed practice over massed practice did not differ significantly across the three ability levels.

By comparing the performance of ability-treatment subgroups on Percent I(R) and Percent II, it was determined that each subgroup scored lower on the retention test than it did on the initial learning test. At each ability level the distributed practice groups scored higher on Percent I(R) than the corresponding massed practice groups. On the retention test, the distributed practice students performed better than the massed practice students at both the high-ability and the low-ability levels. For the middle-ability subgroups, those who had massed practice performed better on Percent II than those who had distributed practice.

For the real numbers topics, all ability-treatment subgroups scored lower on the retention test than on the initial learning test. At the high-ability level, the distributed practice students scored higher than the massed practice students on both the initial learning test and the retention test. However, at the other two ability levels, the trend was reversed. The distributed practice subgroups performed better on the initial learning test, but the massed practice subgroups performed better on the retention tests.

At each ability level, there was no significant association between the treatment a student received and whether he did better, the same, or worse on a retention test than on an initial learning test.

Discussion

Data obtained from the scores on the initial learning test indicated no significant difference, at each ability level, between the distributed practice groups and the massed practice groups. Therefore, null hypothesis Ho 1 was not rejected for any ability level. Similarly, there were no significant differences between treatment groups in performance on the retention test. Thus null hypothesis Ho 2 was not rejected at any ability level.

Many of the results found in this study were similar to those reported by other researchers. Reynolds and Glaser (1964) and Laing (1970) found that distributed practice facilitated learning. Camp (1973) reported inconsistent results, indicating that distributed practice facilitated the learning of one topic while massed practice produced better learning of another topic. In the present study, the results of both initial learning tests, with the exception of the performance of the middle-ability students on Percent I, supported the conclusions of Laing, and Reynolds and Glaser.

Reynolds and Glaser (1964), Laing (1970), Urwiller (1971), and Camp (1973) reported results that indicated that groups receiving distributed practice retained more than groups receiving massed practice. The results of the retention tests in the present study do not support their observations. At each ability level, except the high-ability level, students receiving massed practice performed better on the retention tests than students receiving distributed practice. This result contradicts Madsen's (1963) conjecture that low-ability students, in particular, profit from distributed practice because they require a long period of time for consolidating their learning. In this study, there was no evidence of a significant difference across ability levels in the relative effectiveness of distributed practice.

One possible explanation for the non-significant differences between treatment groups on the retention tests may be related to the length of time between initial learning tests and retention tests. The initial learning tests were administered in May just prior to the end of the school year and the retention tests were given during the first week of the following school year. This time lapse of three months may have been sufficiently long, compared to the relatively short initial learning period, that the general ability of the student was the most significant factor in the amount of forgetting that occurred. If this conjecture is indeed true, the treatment may have had relatively little effect on retention test performance.

Another possible reason for the non-significant differences between treatment groups may be that the distributed assignments required students to go back in the textbook to pages where they had previously worked problems. Thus, they may have received clues to problem solutions from the location of the problem in the textbook. In so doing, the students lost one of the advantages of the distributed practice procedure, that is, having to discriminate between problem solving techniques. In future studies on massed versus distributed practice it would be advantageous for the investigator to write the homework problems on hand-out sheets for the students and avoid the use of the textbook for assignments.

Recommendations for Further Research

One of the difficulties encountered in arriving at definite conclusions from research on related topics lies in the fact that the research designs and experimental procedures differ from study to study. Comparison of the studies of Laing (1970) and Camp (1973) with the present study reveals that this difficulty has been overcome to some measure. All of these studies showed no significant differences between the performance of students who had massed practice and those who had distributed practice. The basic difference in the three studies is found in the functions used to determine the length of the rest interval between distributed assignments and the functions used to determine the number of problems to assign in each distributed assignment. By further small modifications in the two functions, additional contributions can be made to a body of comparable research on the effects of distributed practice upon learning and retention.

Another difference found between the studies of Laing and Camp and this study is the length of time between the initial learning test and the retention test. In the studies of both Laing and Camp, an interval of about three weeks was used. In this study the interval was about three months. In all these studies the length of the initial learning period was approximately the same. Further research is needed to determine the effects of distributed practice over relatively long periods of time. A longitudinal study needs to be done in which distributed practice on all topics in a full year of work is given to on experimental group and massed practice is given to another group on the same work. Retention tests could then be given at various intervals such as at the end of the second and third years. This type of study could also help determine whether or not the effectiveness of distributed practice depends upon the type of topic being taught. For example, does distributed practice have a different effect on a skill-oriented topic than it does on a non-skill-oriented topic?

Another question that could be investigated in a longitudinal study is whether distributed practice is more effective with one instructional technique than it is with another. For example, is the lecture technique and distributed practice more effective than a "laboratory" approach together with massed practice?

The results of studies done to date indicate that the effects of distributed practice in complex learning-retention situations are still unclear. There are trends and hints but conclusions are tentative and no consistent, significant results have been found. Further study of the relative merits of massed and distributed practice is needed before definite conclusions can be reached.

BIBLIOGRAPHY

Ahrens, Carsten. "What Students Think About Homework," National Education Association Journal. 46:373-374, September, 1957.

Ash, P. "The Relative Effects of Massed Versus Spaced Film Presentation," Journal of Educational Psychology. 41: 19-30, January, 1950.

Austin, Dean A. "Effect of Distributed and Massed Practice Upon the Learning of a Velocity Task," The Research Quarterly. 46:23-30, March, 1975.

Ausubel, David P. "Early Versus Delayed Review in Meaningful Learning," Psychology in Schools. 3:195-198, 1966.

Ausubel, D. P. Educational Psychology: A Cognitive View. New York: Holt, Rinehart, and Winston, Inc., 1968.

Ausubel, D. P. The Psychology of Meaningful Verbal Learning. New York: Grune and Stratton, 1963.

Bayless, B. S. J. "Analysis of the Relationships of Different Amounts of Repetition Within a Program for Automated Teaching," Dissertation Abstracts. 23:4619, June, 1963.

Baumeister, A. and Berry, F. M. "Distribution of Practice and Specificity of Learning in Normals and Retardates," American Journal of Mental Deficiency. 72:227-231, September, 1971.

Brogden, W. J. "Animal Studies of Learning," in S. S. Stevens (Ed.), Handbook of Experimental Psychology. New York: John Wiley and Sons, 1951.

Bruno, F. J. "Stimulus Change as a Factor in Massed and Distributed Practice," Dissertation Abstracts. 29:2647(B).

Bumstead, A. P. "Distribution of Effort in Memorizing," American Journal of Psychology. 77:669-670, December, 1964.

Butler, Charles H. and Wren, F. Lynwood. The Teaching of Secondary Mathematics. New York: McGraw-Hill Book Company, 1965.

Cain, L. F. and Wiley, R. "The Effect of Spaced Learning on the Curve of Retention," Journal of Experimental Psychology. 25:209-214, 1939.

Camp, J. S. "The Effects of Distributed Practice Upon Learning and Retention in Introductory Algebra," Unpublished Ph.D. Dissertation, Columbia University, New York, New York, 1973.

Cierpilowski, Gerald. "Effects of Repetition, Total Time of Review, and Student Retention Level on the Relearning and Delayed Retention of Facts," Dissertation Abstracts. 32:201-A, July, 1971.

Cochran, D. "The Effect of Practice Schedules and Perceptual Variables on Learning from a Filmed Demonstration," Dissertation Abstracts, 27:109-A, July, 1966.

Cook, T. W. "Massed and Distributed Practice in Puzzle Solving," The Psychological Review. 41:330-355, 1934.

Davis, R. A. "Remembering and Forgetting Arithmetic Abilities," Journal of Educational Psychology. 38:216-222, April, 1947.

Dodes, Irving. "Planned Instruction," The Learning of Mathematics: Its Theory and Practice. Twenty-first Yearbook of the National Council of Teachers of Mathematics. Washington, D.C., NCTM, 303-334, 1953.

Dore', Leon and Hilgard, Ernest. "Spaced Practice as a Test of Snoddy's Two Processes in Mental Growth," Journal of Experimental Psychology. 23:359-374, 1938.

Easley, H. "The Curve of Forgetting and the Distribution of Practice," Journal of Educational Psychology, 28:474-478, 1937.

Ebbinghaus, Hermann. Memory: A Contribution to Experimental Psychology. New York: Teachers College, Columbia University, 1913.

Ellis, Henry. "Distribution of Practice and Meaningfulness in Verbal Learning," Psychological Reports. 6:319-325, June, 1960.

Ferguson, George A. Statistical Analysis in Psychology and Education. Second Edition. New York: McGraw-Hill Book Company, 1966.

Fishman, E. J., Keller, L., and Atkinson, R. C. "Massed Versus Distributed Practice in Computerized Spelling Drills," Journal of Educational Psychology, 59:290-296, 1968.

Gagne', R. M., Mayor, J. R., Garstens, H. L., and Paradise, N. E. "Factors in Acquiring Knowledge of a Mathematical Task," Psychological Monographs, 7:1-21, 1962.

Garrett, Henry. "Variability in Learning Under Massed and Spaced Practice," Journal of Experimental Psychology. 26:547-567, June, 1940.

Gordon, Kate. "Class Results with Spaced and Unspaced Memorizing," Journal of Experimental Psychology. 8:337-343, 1925.

Griff, Ernest R. "The Comparative Effectiveness of One-Level and Three-Level Assignments in Plane Geometry," Mathematics Teacher, 50:214-216, March, 1957.

Hilgard, Ernest and Bower, Gordon. Theories of Learning, Third Edition. New York: Appleton-Century-Crofts, Inc., 1966.

Hillman, T. "The Spiral Technique in Homework Assignments," The Mathematics Teacher. 55:251, March, 1967.

"Homework," The Nation's Schools. 61:51, March, 1958.

Hovland, C. I. "Experimental Studies in Rote Learning Theory: III. Distribution of Practice with Varying Speeds of Syllable Presentations," Journal of Experimental Psychology, 23:172-190, 1938.

Hovland, C. I. "Experimental Studies in Rote Learning Theory: VI. Comparison of Retention Following Learning to the Same Criterion by Massed and Distributed Practice." Journal of Experimental Psychology. 26:568-587, June, 1940.

Hovland, C. I. "Human Learning and Retention" in S. S. Stevens (Ed.), Handbook of Experimental Psychology. New York: John Wiley and Sons, 1951, 613-689.

Ingle, R. B., Remstad, R. C., Gephant, W. J., and Lampsa, L. V. "Massed Versus Spaced Practice: A Clasroom Investigation," Educational Leadership. 27:261-264, December, 1969.

Johnson, D. and Rising, G. Guidelines for Teaching Mathematics. Belmont, California: Wodsworth Publishing Company, 1967.

Kintz, B. L. "Short-Term Retention and Long-Term Retention as a Function of Practice," The Journal of Psychology. 59:309-314, 1965.

Knight, F. B. "The Superiority of Distributed Practice in Drill in Arithmetic," Journal of Educational Research. 15:157-165, March, 1927.

Krumboltz, John. "Meaningful Learning and Retention: Practice and Reinforcement Variables," Review of Educational Research. 31:535-546, December, 1961.

Laing, Robert. "Relative Effects of Massed and Distributed Scheduling of Topics on Homework Assignments of Eighth Grade Mathematics Students," Unpublished Dissertation, The Ohio State University, Columbus, Ohio, 1970.

Laing, R. A. and Peterson, J. C. "Assignments: Yesterday, Today, and Tomorrow--Today," The Mathematics Teacher. 66:508-518, 1973.

Lankford, Frances. "Implications of the Psychology of Learning for the Teaching of Mathematics," Twenty-fourth Yearbook of the National Council of Teachers of Mathematics. Washington, D.C.: NCTM, 405-430, 1959.

Madsen, Millard C. "Distribution of Practice and Level of Intelligence," Psychological Reports. 13:39-42, August, 1963.

Miller, Beverly W. "A Study of Distributed Versus Massed Practice in Human Anatomy and Physiology Instruction in a Collegiate Program for Student Nurses," Dissertation Abstracts. 28:1347-A, October, 1967.

Minnick, Barbara. "Can Spaced Review Help Students Learn Brief Forms?" Journal of Business Education. 44:146-148, January, 1969.

Mordock, John. "Distribution of Practice in Paired-Associate Learning," American Journal of Mental Deficiency. 73:399-404, November, 1968.

Mulry, June Grant. "We Need Research on Homework," National Education Journal. 50:49, April, 1961.

Nichols, E., et al. Holt School Mathematics, Grade 8. New York: Holt, Rinehart and Winston, Inc., 1974.

Oseas, L. and Underwood, B. "Studies of Distributed Practice: V. Learning and Retention of Concepts," Journal of Experimental Psychology. 43:143-148, February, 1952.

Peterson, H. A., Ellis, M., Toohill, H. and Kloss, P. "Some Measurements of the Effects of Reviews," Journal of Educational Psychology. 26:65-72, 1935.

Reed, H. B. "Distributed Practice in Arithmetic," Journal of Educational Psychology. 15:248-250, 1924.

Reynolds, J. and Glaser, R. "Effects of Repetition and Spaced Review Upon Retention of a Complex Learning Task," Journal of Educational Psychology. 55:297-308, 1964.

Rieth, Herbert et al. "Influence of Distributed Practice and Daily Testing on Weekly Spelling Tests," Journal of Educational Research. 68: 73-77, October, 1974.

Robinson, E. S. "The Relative Efficiencies of Distributed and Concentrated Study in Memorizing," Journal of Experimental Psychology. 4: 327-343, 1921.

Scanlon, J. A. "The Relative Effectiveness of Supplementary Instruction with Blocked Versus Spaced Review," Dissertation Abstracts. 28:1352-A, October, 1967.

Schunert, J. "The Association of Math Achievement with Certain Factors Resident in the Teacher, in the Pupil, and in the School," Journal of Experimental Education. 19:219-238, 1951.

Siegel, Sidney. Nonparametric Statistics for the Behavioral Sciences. New York: McGraw-Hill Book Company, Inc., 1956.

Slamecka, N. J. "Studies of Retention of Connected Discourse," American Journal of Psychology. 72: 409-416, September, 1959.

Slamecka, N. J. and Ceraso, J. "Retroactive and Proactive Inhibition of Verbal Learning," Psychological Bulletin. 57:449-475, 1960.

Spright, Julian B. "Day and Night Intervals and the Distribution of Practice," Journal of Experimental Psychology. 11:397-398, 1928.

Stroud, J. B. "The Role of Practice in Learning," The Psychology of Learning. Forty-first Yearbook of the National Society for the Study of Education, Part II. Chicago University, Chicago Press, 1942, 353-376.

Taso, J. C. "Studies in Spaced and Massed Learning: II. Meaningfulness of Material and Distribution of Practice," Quarterly Journal of Experimental Psychology. 1:79-84, 1948.

Ten Brinke, Dirk Pieter. "Homework: An Experimental Evaluation of the Effect on Achievement in Mathematics in Grades Seven and Eight," Dissertation Abstracts, 27:4176-A, 1967.

Thorndike, E. L. The Psychology of Algebra. New York: The MacMillan Company, 1923.

Tsai, L. S. "The Relation of Retention to the Distribution of Relearning," Journal of Experimental Psychology. 10:30-39, 1927.

Underwood, B. "Ten Years of Massed Practice on Distributed Practice," Psychological Review. 68: 229-247, July, 1961.

Urwiller, Stanley. "A Comparative Study of Achievement, Retention, and Attitude Toward Mathematics Between Students Using Spiral Homework Assignments and Students Using Traditional Homework Assignments in Second Year Algebra," Unpublished Ed.D. Dissertation, The University of Nebraska, Lincoln, Nebraska, 1971.

Waechter, R. F. "A Comparison of Achievement and Retention by Junior College Students in an Earth Science Course After Learning Under Massed and Spaced Conditions," Dissertation Abstracts. 27: 3642-A, May, 1967.

Welborn, E. and English, H. "Logical Learning and Retention: A General Review of Experiments with Meaningful Verbal Materials," Psychological Bulletin. 34:1-20, 1937.

APPENDIX A

CORRESPONDENCE WITH TEACHERS AND INFORMATION FOR THEIR USE IN IMPLEMENTING THE OBJECTIVES OF THE EXPERIMENT

917 Schulze
Norman, Oklahoma 73069

February 12, 1975

I am writing to thank you for meeting with me when I visited your school several days ago and for agreeing to cooperate with me by participating in the study we discussed. My doctoral committee at the University of Oklahoma has approved the plans we have made and has given me permission to proceed with the experiment.

I have enclosed an abstract of the proposed study and assignment charts and calendars to be used with the experimental classes. After visiting with each teacher who will participate in the study, it appears the experimental phase of the study should begin with Chapter 10 and 11. The experiment should begin the first week of March. I will schedule an appointment with you and your colleagues during the last week of February to discuss details of the experiment and to distribute other materials for the study.

Let me encourage you not to tell your students that they will be participating in an experiment since such knowledge has been shown to affect student achievement. When I meet with you later in the month, we will discuss some ways to answer students' questions about the assignment procedures.

Please fill out the enclosed form and mail it back to me in the stamped, self-addressed envelope enclosed. If you have any immediate questions, you can reach me at 329-1910 (home) or at 521-3361 (office).

Sincerely,

Joseph R. Weaver

JBW:eg

ABSTRACT OF RESEARCH PROPOSAL

Submitted by

Joseph R. Weaver
Mathematics Specialist
State Department of Education
Oklahoma City, Oklahoma 73105

Title: The Effects of Distributed Practice Upon Learning and Retention In Eighth Grade Mathematics

Objective: The objective of the study is to develop a procedure for distributing students' assignments and to investigate the following question for several topics in mathematics:

> Is there a significant difference in the learning and retention of a topic between students whose practice is distributed over several assignments and students whose practice is massed in one or more consecutive assignments?

Procedure: The sample for the study will consist of 20 eighth grade mathematics classes that are using the same textbook. Teachers of the classes in the sample will teach one class in which the practice is massed in one or more consecutive assignments and one class in which the practice is distributed over several assignments. The classes will be randomly assigned to treatment groups.

Ten teachers from the junior high schools of Putnam City will be selected to participate in the experiment. The selection will be made with the assistance of the chairpersons of the mathematics departments and the administrators of the schools.

The experimental phase of the study will involve the treating and testing of concepts and skills developed in two chapters of the textbook. Each of the two classes taught by a particular teacher will receive the same treatment except for the manner in which practice exercises are assigned. A distribution chart will be provided for the teachers to use in making assignments. By using the chart the teacher can assign the same problems to both the "massed class" and the "distributed class." The experiment will cover approximately a two month period that will best fit the fall semester schedules of the participating teachers.

Instruments used will include a general ability test administered to all participating classes in order to stratify each class into three ability levels: high, middle, and low. Initial learning tests and retention tests designed by the investigator will be administered to each participating class. The retention test will be administered approximately three weeks after completing the second experimental chapter.

Number of Problems Assigned To M Class / Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	1	1	1	1	2	2	2	3	3	4	4	4	5	5	6	6	6	7	7	8	8	8	9	9	10	10	10	11	11	12
2		1	1	1	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	4	4	4	4	4	5	5	5	5	5	6
			1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	3	3	3	3	3	3	3	4	4	4	4
7				1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	3	3	3	3	3	3	3	4	4	4	4
12						1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	3
19							1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1
29									1		1	2	2	1		1	2	2	3			1	1	2	1	2	1	1	2	

Distribution Chart

ASSIGNMENT CALENDAR

MONTH OF ____________________ TEACHER ____________________

CHAPTER ____________________ CLASS ____________________

	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
MASSED					
DISTRIB-UTED					
MASSED					
DISTRIB-UTED					
MASSED					
DISTRIB-UTED					
MASSED					
DISTRIB-UTED					

NAME: ____________________

HOME ADDRESS: ____________________

____

HOME PHONES: ____________________

SCHOOL PHONE: ____________________

TIME OF PLANNING PERIOD: ____________________

For each of your eighth grade classes using the text, Holt School Mathematics by Nichols, et. al., please indicate the period that it meets, time and the number of students in the class.

PERIOD	TIME	NUMBER OF STUDENTS

917 Schulze
Norman, Oklahoma 73069

February 26, 1975

Enclosed are some additional materials for your use during the experimental phase of the study. The work with Chapter 10 should begin Monday, March 3. I will contact you Saturday, March 1, by telephone to answer any final questions before the experiment begins.

Thank you again for your cooperation.

Sincerely,

Joseph R. Weaver

pl

Enclosures

Suggestions to follow during experimental phase of study

1. Experimental Conditions

   In order to accomplish the purposes of this study it will be necessary for both massed and distributed classes to have similar classroom experiences. Both classes should receive the same assignments--the only difference should be in the way the assignments are distributed. Students should not be told that they are participating in an experiment. If students should ask about the new assignment procedure simply tell them that you like various ways of making assignments. You may have some other plausible explanation.

2. Use of Tuning Up Exercises

   The Tuning Up pages may be used at the beginning of the experimental work to provide more exercises to the distributed class. The students will not be tested on the concepts and skills contained in these exercises. However, they should be assigned to the massed class at some time during the experimental phase of the study.

3. Testing

   The chapter and delayed retention tests will be researcher-assigned instruments. Each test will be tried out in classes not participating in the study to help determine item difficulty, length of test, etc. In addition a panel of educators will examine the tests to help judge their validity.

   After you have administered and scored each test for your use, I will pick them up for analysis. For each test, absentees will be required to take the test at a later date.

4. Assignment Calendars and Distribution Charts

   I have enclosed assignment calendars for your use. I would suggest that you fill them in daily rather than weekly. When you have selected the exercises to be assigned to the massed class, write those in the appropriate slot on the calendar and then distribute them on the calendar according to the distribution chart. For your convenience I have enclosed an extended distribution chart.

A copy of the table that defines the distribution function is also enclosed for your use. Please keep the assignment calendars, so that I can document the research procedure.

5. Checking Homework

Homework should be checked daily in both M and D classes. It is important that the problems assigned are actually being done. You may choose whatever method works best for you to insure that the assignments are done.

6. Supplementing The Textbook

At times you may wish to supplement the practice problems in the textbook. It is permissible for you to do this provided you give the same exercises to both M and D classes. This applies to dittoed or verbally assigned problems not found in the textbook.

7. Chapter Reviews

If problems are assigned from the chapter reviews on the chapter tests in the textbook as a means of preparing students for the chapter test, both M and D classes should receive the same concentrated assignment. It should not be in the form of distributed practice for the D classes.

8. Work Following Chapters Ten and Eleven

Since the delayed retention test will not be administered until four or five weeks after the completion of chapter eleven, there are several precautions that must be taken.

(1) After administering the chapter test for chapter 11 you may adopt any assignment procedure that you desire for your M and D classes. However, the experiences of these two groups should be as similar as possible so whatever procedure you elect to use, use it in both classes.

(2) Do not intentionally review topics developed in chapter 10 and 11 unless they are necessary for the development of topics in the succeeding chapters.

(3) Do not inform your students that they will be taking a retention test on chapters 10 and 11. This test will be given without prior notice about the middle of May.

(4) Since some of the teachers involved in the experiment have not followed the sequence of chapters in the

textbook, I would like for you to discuss with me what topics will be covered after chapter 11. All classes should have similar experiences before the retention test is administered.

ASSIGNMENT CALENDAR

MONTH OF __________

	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
Massed	p. 139:1-9	p. 141:1-12	p. 143:all even probs.	p. 145:1-30	p. 146:1-20
Distrib-	p. 139:1,5,9	p. 139:2 p. 141:1,3,6,9	p. 141:4,12 p.143:2,8,14,20,26,32 38,44,48	p. 139:7 p. 143:6,12,18,24 p. 145:1,3,6,9,12, 15,18,21,24, 27,29,30	p. 141:5 p. 145:5,7,11, 17,23,28 p. 146:even probs. 4-18
Massed					
Distrib- uted	p. 143:30,36, 42 p. 146:2,7, 15,20	p. 139:3 p. 145:2,8,13, 26	p. 141:11 p. 146:1,9,17	p. 143:4,16,38	p. 145:4,10, 19,25
Massed					
Distrib- uted	p. 146:3,11,19	p. 139:8	p. 141:2	p. 143:6,20	p. 145:16,20,22
Massed					
Distrib- uted	p. 146:5,13			p. 139:4	p. 141:7

APPENDIX B

LEARNING TESTS, RETENTION TESTS, AND INSTRUCTIONS

Appendix B contains the initial learning tests, retention tests, and the directions for administering the tests. Percent I(R), the subtest of Percent I, and Real Numbers I(R), the subtest of Real Numbers I, have been identified by placing an asterik before each item that was used on these two subtests.

The retention test was given as part of a mathematics inventory test including 12 items on percent, 13 items on real numbers, and 15 items covering other content in eighth grade mathematics.

INSTRUCTIONS FOR ADMINISTERING CHAPTER 10 TEST

The materials in the envelopes are the tests on Chapter 10 to be administered to the massed and distributed classes. The tests should be given immediately after the distributed class has completed all assignments on Chapter 10. Both massed and distributed classes should be given one day of review previous to taking the test.

The test has been administered to one of the classes not participating in the experiment, then revised and given to a panel of mathematics educators to check content validity.

Directions for Administering the Test: Please have the students do all work on the test sheet and write answers in the spaces provided. They may use the back if it is needed. Make sure that each student writes his name on his paper.

Directions for Grading and Processing the Tests: If you wish to use the test scores for your grading purposes, score them as you wish and record the scores. Please place the tests back in the envelopes they are now in. I will pick them up after I return from Denver. Be sure not to mix the papers of the massed and distributed classes.

Name________________________ Score_________

Percent

Answers

1) Write the simplest fractional numeral for 56%. 1.____________

* 2) Express 7% as a decimal. 2.____________

* 3) Change .02 to a percent. 3.____________

4) Change 16.3% to a decimal. 4.____________

* 5) Write the simplest fractional numeral for 16 2/3%. 5.____________

Change the following to percents: 6.____________

* 6) $\frac{5}{6}$ 7) $\frac{3}{12}$ 7.____________

8.____________

Compute:

9.____________

* 8) 18% of 200 *9) 120% of 75

10) What percent of 30 is 6? 10.____________

*11) 40 is what percent of 16? 11.____________

*12) 30% of what number is 27? 12.____________

13) 192 is 240% of what number? 13.____________

*14) Change .5% to a decimal. 14.____________

15.____________

Solve the following problems:

*15) Hank Moore borrowed $2,000 at 10% interest for 2 years. How much interest did he pay? 16.____________

17.____________

*16) At a sale, fishing reels regularly priced at $12 were reduced to $8. What percent was the price reduced? 18.____________

19.____________

17) Lori bought a pair of shoes at a 20%-off sale. The marked price of the shoes was $20. How much did Lori pay for the shoes? 20.____________

*18) On March 1, Bob was able to bench press 200 pounds. On April 1, he could bench press 260 pounds. What percent increase did he make?

19) There are 18 people in the cast of a play. If 66 2/3% of them are girls, how many boys are in the cast?

20) During a basketball game, a team made 48% of their field goal attempts. If they made 36 field goals, how many did they attempt?

Instructions for Administering Chapter 11 Test

The materials in the envelopes are the tests on Chapter 11 to be administered to the massed and distributed classes. The tests should be given immediately after the distributed class has completed all assignments on Chapter 11. Both massed and distributed classes should be given one day of review previous to taking the test.

The test has been administered to one of the classes not participating in the experiment, then revised and given to a panel of mathematics educators to check content validity. A second revision was made based upon the responses of the panel.

Directions for Administering [illegible] Please have the students do all work on the [illegible]th answers in the spaces provided. They [illegible]t is needed. Make sure that each st[illegible]n his paper.

Directions for Gradir[illegible]s: If you wish to use the test scor[illegible]s, score them as you wish and reco[illegible]e the tests back in the envelope[illegible] pick them up after you are finishe[illegible] do not mix the papers of the mas[illegible]es.

REAL NUMBERS

Name________________________ Score__________

Work each problem and write the answer in the space provided.

Compute

1) 9^2 *2) $(-.4)^2$ 3) $\frac{25}{36}$ *4) $-\sqrt{.49}$ *5) $\left(\frac{2}{7}\right)^2$

Write fractional numerals in simplest form for each of these decimals.

* 6) 0.8 *7) $0.6\overline{363}$ 8) $2.\overline{55}$

*10) Which of the following is the best approximation for $\sqrt{17}$?

a) 3.9 b) 4.1 c) 5.1 d) 4.2

*11) Find $\sqrt{729}$

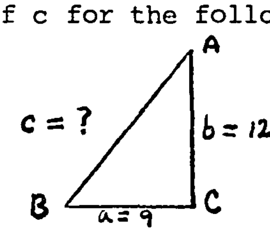
Write decimals for each of the following:

*12) $\frac{5}{6}$ 13) $\frac{3}{8}$ *14) $\frac{11}{9}$

State whether the following numbers are rational or irrational.

*15) 144 16) 50 17) 12 18) 0.123456789101112...

*19) Find the value of c for the following right triangle:



20) A 20 foot ladder is leaning against a wall. If the foot of the ladder is 12 feet from the base of the wall, how high up the wall does the ladder reach?

21) Find a rational number between $\frac{2}{7}$ and $\frac{3}{7}$.

*22) Which of the following is not a real number?

0.110111011110..., $\sqrt{-16}$, $3.28\overline{28}$

23) Find an approximation for $\sqrt{13}$ correct to the nearest tenth.

1.______
2.______
3.______
4.______
5.______
6.______
7.______
8.______
9.______
10.______
11.______
12.______
13.______
14.______
15.______
16.______
17.______
18.______
19.______
20.______
21.______
22.______
23.______

Instructions for Administering Chapter 11 Test

The materials in the envelopes are the tests on Chapter 11 to be administered to the massed and distributed classes. The tests should be given immediately after the distributed class has completed all assignments on Chapter 11. Both massed and distributed classes should be given one day of review previous to taking the test.

The test has been administered to one of the classes not participating in the experiment, then revised and given to a panel of mathematics educators to check content validity. A second revision was made based upon the responses of the panel.

Directions for Administering the Test: Please have the students do all work on the test sheet and with answers in the spaces provided. They may use the back if it is needed. Make sure that each student writes his name on his paper.

Directions for Grading and Processing the Tests: If you wish to use the test scores for your grading purposes, score them as you wish and record the scores. Please place the tests back in the envelopes they are now in. I will pick them up after you are finished with them. Be sure you do not mix the papers of the massed and distributed classes.

REAL NUMBERS

Name______________________________ Score____________

Work each problem and write the answer in the space provided.

Compute

1) 9^2 *2) $(-.4)^2$ 3) $\frac{25}{36}$ *4) $-\sqrt{.49}$ *5) $\left(\frac{2}{7}\right)^2$

Write fractional numerals in simplest form for each of these decimals.

* 6) 0.8 *7) $0.63\overline{63}$ 8) $2.\overline{55}$

*10) Which of the following is the best approximation for $\sqrt{17}$?

a) 3.9 b) 4.1 c) 5.1 d) 4.2

*11) Find $\sqrt{729}$

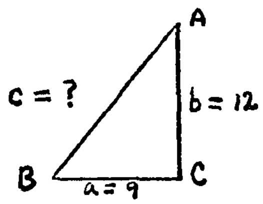
Write decimals for each of the following:

*12) $\frac{5}{6}$ 13) $\frac{3}{8}$ *14) $\frac{11}{9}$

State whether the following numbers are rational or irrational.

*15) 144 16) 50 17) 12 18) 0.123456789101112...

*19) Find the value of c for the following right triangle:



20) A 20 foot ladder is leaning against a wall. If the foot of the ladder is 12 feet from the base of the wall, how high up the wall does the ladder reach?

21) Find a rational number between $\frac{2}{7}$ and $\frac{3}{7}$.

*22) Which of the following is not a real number?

0.110111011110..., $\sqrt{-16}$, $3.28\overline{28}$

23) Find an approximation for $\sqrt{13}$ correct to the nearest tenth.

1.______________
2.______________
3.______________
4.______________
5.______________
6.______________
7.______________
8.______________
9.______________
10.______________
11.______________
12.______________
13.______________
14.______________
15.______________
16.______________
17.______________
18.______________
19.______________
20.______________
21.______________
22.______________
23.______________

*24) True or False?

There are more than 1,000,000 real numbers between 0.05 and 0.06.

24.______________

25.______________

25) True or False?

$-\sqrt{7}$ is not a real number.

MATHEMATICS INVENTORY TEST

Description:

This is a 45 minute multiple choice test of your ability to work with mathematical concepts and skills that were studied in the eighth grade or in earlier grades. Data obtained from this test will be used by your teacher to determine your strengths and weaknesses in basic mathematics. This information will enable them to better fit the ninth grade mathematics program to your individual needs.

Directions:

Please print your name (first and last), math class period, and the name of your teacher on the answer sheet. If you attended summer school in 1975 please put the letters (ss) above your name. For each item on the test select one of the four possible answers and mark the appropriate slot on the answer sheet. Do not mark more than one answer for each item. If you think that none of the possible answers for a particular item are correct, mark the answer slot (e).

All scratch work should be done on the test booklet.

Do not open the test booklet until you are told to do so.

1. Express 4% as a decimal.

   a) 0.4

   b) 0.04

   c) 0.004

   d) 4.0

2. Express 0.325 as a percent.

   a) 3.25%

   b) 0.325%

   c) 32.5%

   d) 325%

3. The simplest fractional numeral for $83\frac{1}{3}\%$ is

   a) $\frac{4}{5}$

   b) $\frac{5}{8}$

   c) $\frac{4}{9}$

   d) $\frac{5}{6}$

4. Express $\frac{3}{8}$ as a percent

   a) 40%

   b) 30%

   c) 52.5%

   d) 37.5%

5. Find 13% of 300.

   a) 39

   b) 390

   c) 3.9

   d) 0.39

6. Find 115% of 80.

   a) 55

   b) 550

   c) 92

   d) 9.2

7. 48 is what percent of 16.

   a) 30%

   b) $33\frac{1}{2}\%$

   c) 130%

   d) 300%

8. 70% of what number is 91?

   a) 130

   b) 63.7

   c) 13

   d) 0.769

9. Find 0.6% of 400.

a) 240

b) 24

c) 2.4

d) 0.24

10. If Jim borrowed $3000 at 9% interest for 3 years, how many dollars in interest did he pay?

a) $270

b) $27

c) $81

d) $810

11. If sport coats were marked down from $48 to $36, what percent was the price reduced?

a) 75%

b) 25%

c) 33%

d) 20%

12. When Jane was 11 years old she weighed 40 kg. When she was 13 years old she weighed 50 kg. What percent did her weight increase?

a) 30%

d) 25%

b) 20%

c) 2.5%

13. $-\sqrt{0.64}$

a) 0.8

b) -0.8

c) -0.08

d) -0.32

14. $(\frac{3}{5})^2 =$

a) $\frac{6}{10}$

b) $\frac{9}{25}$

c) $\frac{-6}{10}$

d) $\frac{-9}{25}$

15. Write a fractional numeral in simplest form for $0.54\overline{54}$

a) $\frac{6}{11}$

b) $\frac{27}{50}$

c) $\frac{3}{5}$

d) $\frac{5}{9}$

16. Write a fractional numeral in simplest form for 0.125.

a) $\frac{5}{4}$

b) $\frac{25}{2}$

c) $\frac{1}{8}$

d) $\frac{125}{999}$

17. Which of the following is the best approximation for $\sqrt{23}$?

a) 4.9

b) 4.8

c) 4.2

d) 5.1

18. $\sqrt{1681} =$

a) 49

b) 409

c) 39

d) 41

19. Express $\frac{1}{6}$ as a decimal.

a) 0.17

b) 0.167

c) $0.16\overline{6}$

d) .66

20. Which of the following is <u>not</u> an irrational number?

a) $\sqrt{60}$

b) 0.001000100001...

c) $\sqrt{8}$

d) $\sqrt{196}$

21. How many rational numbers are there between 0.003 and 0.004?

a) None

b) Exactly one

c) Less than 1,000,000

d) More than 1,000,000

22. Which of the following is <u>not</u> a real number?

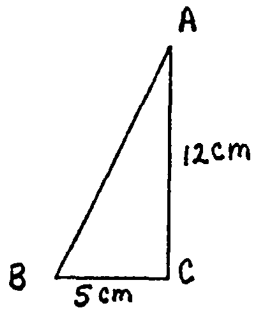
a) $\sqrt{^-25}$

b) $4.32\overline{32}$

c) $\sqrt{13}$

d) 1.23456789101112...

23. Find the length of the hypotenuse of the right triangle shown.



a) 11 cm

b) 14 cm

c) 20 cm

d) 13 cm

24. Express $\frac{5}{9}$ as a decimal.

a) 0.5

b) 0.54

c) $0.5\overline{5}$

d) 0.56

25. $(^-0.3)^2 =$

a) 0.9

b) $^-0.09$

c) 0.09

d) $^-0.9$

26. Which statement is true?

a) $^-3 < {}^-4$

b) $|^+7| > |^-7|$

c) $^+4 < {}^-8$

d) $|^-5| = |^+5|$

27. If $n \cdot {}^-5 = {}^-5$, then n = ?

a) $^-1$

b) $^+5$

c) $^-5$

d) $^+1$

28. If $n + {}^+5 = {}^+5$, then n = ?

a) 0

b) $^+5$

c) $^-5$

d) $^-1$

29. $\angle A$ and $\angle B$ are supplementary angles. $m\angle A = 65°$. What is $m\angle B$?

a) 25°

b) 180°

c) 115°

d) 90°

30. Solve: $x + 18 = 7$

a) 11

b) $^-11$

c) 0

d) $^-9$

31. Solve: $8x = 72$

a) 64

b) 80

c) 9

d) $\frac{1}{9}$

32. Solve: $\frac{x}{3} = {}^-6$

a) $^-2$

b) $^+2$

c) 18

d) $^-\frac{1}{2}$

33. Which is the equation for the following sentence? A number decreased by 8 is 40.

a) $x - 8 = 40$

b) $8 - x = 40$

c) $40 + x = 8$

d) $8 + x = 40$

34. Replacement set: $\{0, 1, 2, \ldots, 10\}$. Find the solution set for $x + 3 < 8$.

a) $\{5\}$

b) $\{0, 1, 2, 3, 4\}$

c) $\{0, 1, 2, 3, 4, 5\}$

d) $\{0, 1, 2\}$

35. Bob drove from 10:00 a.m. to 3:00 p.m. at a rate of 50 miles per hour. How many miles did he drive?

a) 350 miles

b) 300 miles

c) 500 miles

d) 250 miles

36. $6\frac{3}{8} - 2\frac{5}{6} = ?$

a) $4\frac{1}{4}$

b) $3\frac{1}{3}$

c) $3\frac{1}{8}$

d) $3\frac{13}{24}$

37. ${}^{+}12 - {}^{-}7 = ?$

a) ${}^{+}5$

b) ${}^{+}19$

c) ${}^{-}5$

d) ${}^{-}19$

38. $\frac{1}{4} \div \frac{2}{5} = ?$

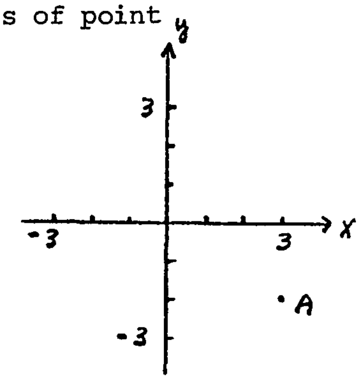
a) $\frac{1}{10}$

b) $\frac{1}{3}$

c) $\frac{3}{20}$

d) $\frac{5}{8}$

39. The coordinates of point A are:



a) $({}^{-}2, 3)$

b) $(2, {}^{-}3)$

c) $(3, {}^{-}2)$

d) $(3, 2)$

40. The GCF of 24 and 40 is?

a) 960

b) 8

c) 4

d) 120

APPENDIX C

ITEM ANALYSIS OF LEARNING AND RETENTION TESTS

ITEM ANALYSIS FOR PERCENT I (N = 348)

Item	Number Missed	Number Correct	Number Omitted	% Correct	% Missed
1	92	246	10	73	27
. 2	28	319	1	92	8
. 3	16	331	1	95	5
4	50	294	4	85	15
. 5	246	67	35	21	79
. 6	156	171	21	52	48
7	96	228	24	70	30
. 8	86	237	25	73	27
. 9	89	228	31	72	28
10	137	194	17	59	41
. 11	201	121	26	38	62
. 12	139	174	35	56	44
13	157	136	55	46	54
. 14	55	284	9	84	16
. 15	99	211	38	68	32
. 16	204	109	35	35	65
17	136	168	44	55	45
. 18	148	149	51	50	50
19	148	108	92	42	58
20	154	109	85	41	59

ITEM ANALYSIS FOR REAL NUMBERS I (N = 340)

Item	Number Missed	Number Correct	Number Omitted	% Correct	% Missed
1	8	329	3	98	2
2	155	178	7	53	47
3	35	287	18	89	11
4	192	137	11	42	58
5	67	256	17	79	21
6	92	225	23	71	29
7	165	127	48	43	57
8	201	84	55	29	71
9	111	197	32	64	36
10	113	218	9	6	34
11	103	194	43	65	35
12	108	206	26	66	34
13	102	208	30	67	33
14	106	205	29	66	34
15	23	303	14	93	7
16	105	223	12	68	32
17	123	204	13	62	38
18	76	249	15	77	23
19	95	208	37	69	31
20	211	73	56	26	74
21	106	156	78	60	40
22	135	194	11	59	41
23	155	120	65	44	56
24	139	198	3	59	41
25	119	217	4	65	35

ITEM ANALYSIS FOR PERCENT II (N = 306)

Item	Number Missed	Number Correct	Number Omitted	% Missed	% Correct
1	176	130	0	58	42
2	166	140	0	54	46
3	243	60	3	80	20
4	170	129	7	57	43
5	129	171	6	43	57
6	130	168	8	44	56
7	215	87	4	71	29
8	158	140	8	53	47
9	208	94	4	69	31
10	179	121	6	60	40
11	206	94	6	69	31
12	271	31	4	90	10

ITEM ANALYSIS FOR REAL NUMBERS II (N = 306)

Item	Number Missed	Number Correct	Number Omitted	% Missed	% Correct
1	219	82	5	73	27
2	214	86	6	71	29
3	278	18	10	94	6
4	197	99	10	67	33
5	205	92	9	69	31
6	215	84	7	72	28
7	239	55	12	81	19
8	257	44	5	85	15
9	196	102	8	66	34
10	163	140	3	54	46
11	247	46	13	84	16
12	155	140	11	53	47
13	269	29	8	90	10

APPENDIX D

INSTRUMENTS USED TO HELP JUDGE THE CONTENT VALIDITY OF THE LEARNING TESTS

Test; Chapter 10 Percents

Content Validity

1. Purpose

The enclosed test is designed to measure a student's ability to work with percents as developed by doing the homework exercises from Chapter 10 of the textbook Holt School Mathematics, Grade 8 by Nichols and others. The test will be used to determine the differences between two groups whose homework practice is either distributed or massed. To help judge the validity of the test, would you please, by referring to the textbook, classify each item according to the accompanying checklist. The following describe the types of items to be included under each of the three column headings of the checklist:

a. Level A--skill-type items that are relatively simple.

b. Level B--skill-type items that are more difficult than Level A items.

c. Level C--items which require the student to perform at a high level of understanding by interpreting and/or by applying his knowledge of percent concepts to solve problems.

2. Checklist

By referring to the textbook, classify each item on the test by its NUMBER in one of the cells of the checklist on the basis of the ability it is measuring. In some cases an item can be assigned to more than one cell if it is testing more than one concept. In those cases, classify the item by placing its number in each of the cells to which it belongs. However, each item should be uniquely assigned to one column.

3. Rating Form

Please fill out the Rating Form on the last page of the test booklet.

4. Comments

After you have completed the checklist and rating form, please refer to the test and comment on individual items. Based upon an item's place in the checklist, how well does it measure the ability being tested, is it mathematically correct, and is the vocabulary appropriate? If you feel that an item needs revision, please make the revision next to the item on the test.

CHECKLIST

Skills \ Level	A	B	C
Write fractional numeral for percents			
Write decimals for percents			
Write percents for fractional numerals			
Write percents for decimals			
Find a percent of a number			
Find the base when given rate and percentage			
Find what percent a number is of another number			
Apply percents in problems about interest			
Apply percents in problems about discount			
Apply percents in problems about rate of change			

RATING FORM

1. For each of the skills on the checklist, examine the test items that you have identified as measuring that particular ability. Indicate how well you feel these items, as a group, measure that ability by circling one of the numbers: 0, 1, 2, 3, 4 where

   4 means "represents very well"
   3 means "represents well"
   2 means "represents fairly well"
   1 means "represents not well"
   0 means "represents not at all"

   Please comment on your responses if you so desire.

Write fractional numerals for percents	0	1	2	3	4
Write decimals for percents	0	1	2	3	4
Write percents for fractional numerals	0	1	2	3	4
Write percents for decimals	0	1	2	3	4
Find a percent of a number	0	1	2	3	4
Find the base given the rate and percentage	0	1	2	3	4
Find what percent a number is of another	0	1	2	3	4
Apply percents in problems about interest	0	1	2	3	4
Apply percents in problems about discount	0	1	2	3	4
Apply percents in problems about rate of change	0	1	2	3	4

2. For each column heading on the checklist, examine the items which you have identified as falling into that classification. Indicate how well you feel the group of items reflects the types of homework problems in the textbook by indicating whether this test includes too few, just right, or too many of this type of item. Circle your response.

Level A	Too Few	Just Right	Too Many
Level B	Too Few	Just Right	Too Many
Level C	Too Few	Just Right	Too Many

Test: Chapter 11 Real Numbers

Content Validity

1. Purpose

The enclosed test is designed to measure a student's ability to work with percents as developed by doing the homework exercises from Chapter 11 of the textbook Holt School Mathematics, Grade 8 by Nichols and others. The test will be used to determine the differences between two groups whose homework practice is either distributed or massed. To help judge the validity of the test, would you please, by referring to the textbook, classify each item according to the accompanying checklist. The following describe the types of items to be included under each of the three column headings of the checklist:

a. Level A--skill-type items that are relatively simple.

b. Level B--skill-type items that are more difficult than Level A items.

c. Level C--items which require the student to perform at a high level of understanding by interpreting and/or by applying his knowledge of real number concepts to solve problems.

2. Checklist

By referring to the textbook, classify each item on the test by its NUMBER in one of the cells of the checklist on the basis of the ability it is measuring. In some cases an item can be assigned to more than one cell if it is testing more than one concept. In those cases, classify the item by placing its number in each of the cells to which it belongs. However, each item should be uniquely assigned to one column.

3. Rating Form

Please fill out the Rating Form on the last page of the test booklet.

4. Comments

After you have completed the checklist and rating form, please refer to the test and comment on individual items. Based upon an item's place in the checklist, how well does it measure the ability being tested, is it mathematically correct, and is the vocabulary appropriate? If you feel that an item needs revision, please make the revision next to the item on the test.

CHECKLIST

Skills \ Level	A	B	C
Find square of rational numbers			
Recognize and use Pythagorean Relationship			
Find square roots of perfect squares			
Write terminating or repeating decimals for rational numbers			
Write fractional numerals for terminating or repeating decimals			
Identify irrational numbers			
Identify real numbers			
Find square roots of whole numbers to nearest tenth			

RATING FORM

1. For each of the skills on the checklist, examine the test items that you have identified as measuring that particular ability. Indicate how well you feel these items, as a group, measure that ability by circling one of the numbers: 0, 1, 2, 3, 4 where

4 means "respresents very well"
3 means "represents well"
2 means "represents fairly well"
1 means "represents not well"
0 means "represents not at all"

Please comment on your responses if you so desire.

Find square of rational numbers	0	1	2	3	4
Recognize and use Pythagorean Relationship	0	1	2	3	4
Find square roots of perfect squares	0	1	2	3	4
Write terminating or repeating decimals for rational numbers	0	1	2	3	4
Write fractional numerals for terminating or repeating decimals	0	1	2	3	4
Identify irrational numbers	0	1	2	3	4
Identify real numbers	0	1	2	3	4
Find square roots of whole numbers to nearest tenth.	0	1	2	3	4

2. For each column heading on the checklist, examine the items which you have identified as falling into that classification. Indicate how well you feel the group of items reflects the types of homework problems in the textbook by indicating whether this test includes too few, just right, or too many of this type of item. Circle your response.

Level A	Too Few	Just Right	Too Many
Level B	Too Few	Just Right	Too Many
Level C	Too Few	Just Right	Too Many