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The value of training in techniques of estimating in fifth grade problem solving

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THE VALUE OF TRAINING IN TECHNIQUES OF ESTIMATING
IN FIFTH GRADE PROBLEM SOLVING

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CHAPTER I

STATEMENT OF THE PROBLEM

The purpose of this study was to determine the effect on problem solving of training pupils in the techniques of estimating answers.

This investigation was suggested by a study done by Dickey in Hackensack, New Jersey, which dealt with the value of estimating answers when working arithmetic problems and examples. In his experiment, Dickey did not train the pupils in any definite methods of estimation, but left them to their own resources in arriving at their estimated answers. The one stipulation was that they had to arrive at their estimated answers by use of mental arithmetic.

The present study differed from Dickey's in that during the first week of the practice period, the experimental groups concentrated on the methods of estimation such as rounding off numbers correctly and the techniques of making estimations for the various types of computations. It was felt that by having at hand basic methods of estimating, the pupils would be more uniform in arriving at good estimations and thus make the practice more valuable.

Although this research can be regarded as only a pilot study due to its limited samples, it is hoped that this experiment may provide a real aid to pupils in solving arithmetic problems. If the practice of including training in estimation would eliminate many of the absurd answers found in any set of problem papers, this step would make a large contribution to better performance. Any study which may lead to a new and more fertile avenue of attack on problems is justified.

The succeeding chapters of this thesis will cover the following phases of the study. Chapter II will examine a portion of the literature and research dealing with problem solving. This chapter will be more a generalized survey of the various methods used in attacking problem solving rather than a concentrated delving into any one method. The organization and the plan of the investigation will be discussed in Chapter III, and an evaluation of the data will be made in Chapter IV. The predictive conclusions reached by the investigator and the appendix which contains the problems used during the practice period of this study and the classroom test on estimation given to the experimental groups will complete this thesis.
CHAPTER II

REVIEW OF LITERATURE AND RESEARCH

Sources of difficulty in problem solving. In any study concerned with problem solving, there must be an awareness of possible sources of difficulty in solving problems.

Educators and teachers have long recognized the ability to solve problems as being the most difficult arithmetical phase for many elementary children. Newcomb went as far as to say: "Practically all pupils have more or less difficulty in solving problems." 1/

Problem solving means the solution of a quantitative situation presented in words which raises a definite question, but for which the arithmetical process to be performed is not indicated. 2/

A child may perform at a comparatively high rate of speed and accuracy in the computation of the fundamental operations where the correct arithmetical process to be used is indicated by word or symbol. Yet this same child may become


befuddled and inaccurate when his arithmetic work changes from straight arithmetical computation to the arithmetical reasoning of problem solving. A high rate of efficiency in the fundamental operations should never be regarded by the teacher as a guarantee that the child will do well in problem solving.

It has been these conflicting abilities of children in doing regular examples and solving problems that have spurred on much investigation into the sources of difficulties in solving problems and methods by which to remedy them.

Brueckner reported the chief causes of pupil difficulty in problem solving as recorded by diagnostic studies as follows:

1. Failure to comprehend the problem in whole, or in part, due to inferior reading ability, inability to visualize the situation, lack of practice in solving problems, and similar conditions;

2. Carelessness in reading resulting in the omission of essential ideas or misreading;

3. Inability to perform the computations involved, either thru forgetting of the procedure or failure to learn it;

4. Confusion of process, resulting in the random trial of any process that may come to mind;

5. Lack of knowledge of essential facts, rules, and formulas such as how many inches there are in a yard, or how to find the perimeter of a rectangle;

6. Carelessness in arranging the work and general lack of neatness;
7. Ignorance of quantitative relations due to lack of vocabulary or of understanding of principle, such as the relation between selling price, cost, profit, margin;

8. Lack of interest due to repeated failure, to difficulty of problem material, its unattractiveness, and the like;

9. General lack of mental ability.

The list was completed by Brueckner's statement that the greatest single factor responsible for lower scores by pupils in problem solving is inaccuracy in their computations.

Studies relevant to problem solving in the elementary grades have concentrated upon failure to comprehend the problem in whole, or in part, due to inferior reading ability or the inability to visualize the situation; carelessness in the reading of the problem which results in omission of essential facts; confusion of process, resulting in the random trial of any process that may come to mind; lack of interest due to difficulty of problem material or its unattractiveness, and the careless inaccuracies in the computations.

The other causes listed by Brueckner are either concerned with arithmetic above the elementary level or fall upon the classroom teacher for solution such as eliminating mistakes due to untidy and carelessly written papers. For children who lack the mental ability to solve problems, little can be done.

Comprehending the problem. In a study concerned with failure of children to comprehend the problem, Estaline Wilson suggested that such reading devices as restating the problem in the form of a story gave the problem added meaning to the child. Another proposed aid was the dramatization of the problem situations to increase the children's understanding of what the problems were about.

One must not forget the fact that the ability to read a problem does not in itself mean that the child understands the problem. Even though the child may be able to say the words and rephrase the sentences correctly in other words, he may still lack the understanding necessary to solve the problem.

In a study which analyzed certain factors which exerted an influence upon the success or failure of sixth grade pupils in solving problems, Grace A. Kramer discovered that one of the main reasons many children failed to comprehend the meaning

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of the problem was that they searched for the cue in the problem and responded to that rather than to the facts and situations presented in the problem. The children used in her study encountered much more difficulty understanding the problem when it contained a great amount of detail.

Washburne and Osborne \(^7/\) discovered that hardly any of the children in their study had any difficulty visualizing the situations in one-step problems. However, when the children encountered two-step problems, there was a sharp increase in the inability to visualize the problem.

**Reading the problem.** To combat inaccurate solutions traceable to careless reading of the problem, many teachers have relied upon some form of the problem analysis. The following three steps are usually included in this method: what is given; what do I have to find; what process should I use?

It is the opinion of teachers who employ this method in teaching problem solving that if the child answers each of the above questions, he has brought to light all the essential facts of the problem. Consequently, there should be less chance of misreading the problem.

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Through testing and interviewing, Norma M. Morandi sought to discover the value of this procedure by investigating the problem solving habits of children who had been trained to formally analyze arithmetic problems. Morandi sought to determine if those children used the formal analysis steps or some other method of solution when left to solve problems by whatever procedure they desired. Although her samplings were limited, her findings were consistent with other studies which have investigated the value of problem analysis. Morandi discovered that the pupils in her study failed to use the formal analysis method of reasoning which had been emphasized in their arithmetic course. These pupils failed to follow any definite technique of approach in solving problems. In this small group experiment, Morandi found that the group performed as well, if not better, when they were allowed to choose their own methods of reasoning than when they were required to solve their problems through the formal analysis approach method.

In a control group experiment, Washburne and Osborne discovered that the children who were left to rely upon their own resources of solving problems surpassed the pupils who

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2/ Washburne and Osborne, op. cit., pp. 219-226
spent time learning a definite method of problem solving. They found that children in the latter group were very prone in analyzing a problem correctly and solving it incorrectly, or else solving it correctly and analyzing it incorrectly.

Selecting the process. Difficulties resulting from the child's confusion in not knowing which process to use has always been a big factor in problem solving. This difficulty is always present if there is a failure to comprehend the problem due to inferior reading ability or the inability to visualize the problem situation. Even if the child is capable of comprehending and visualizing the situation, there is no guarantee that he will select the correct computational process.

West claimed that from 30 per cent to 60 per cent of the errors in problem solving were the result of lack of comprehension. In his study, he discovered that there were a multiple number of ways employed by textbooks in presenting problems. This meant that a child could not rely upon static cues in deciding upon which computational process should be used in solving the problem. He had to resort to critical thinking if he were to accurately diagnose the problem and select the correct process.

A recurrent cause of difficulty was found by Washburne and Osborne to be the pupils' inability to transfer a process they knew to a problem requiring written work and reasoning. They discovered this to be the case even when the children were able to solve similar problems which involved smaller numbers.

Many children are able to correctly visualize, comprehend and select the correct process for a problem involving small numbers, but they are unable to do so if the numbers alone are made larger. Many children will then use the first process to come to mind.

Choice of problem material. Unfamiliar vocabulary and situations have been under constant attack in recent years with the rising stature of meaningful arithmetic. Most new arithmetic texts are presenting problems which are in the realm of the pupil's world as far as situation and vocabulary are concerned.

While Washburne and Osborne agreed that unfamiliarity with the situation must be regarded as a difficulty factor in problem solving, they found that it was not as large a

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11/ Washburne and Osborne, op. cit., pp. 219-226.
12/ Brueckner, op. cit., p. 175.
13/ Washburne and Osborne, op. cit., pp. 296-304.
difficulty as was often supposed.

Kramer\(^\text{14}\) concluded that problems which were written in unfamiliar vocabulary ranked highly among those causing the greatest difficulty for children. However, she did discover that interesting problems failed to induce more successful arithmetic reasoning, and they did not raise the efficiency rate of solution.

It was the opinion of Brueckner\(^\text{15}\) that the enrichment of problems by the addition of vivid details and descriptive statements made the problems no easier or more difficult for the children to solve than those which consisted of simple concise statements. He reported that some studies had shown that due to increased reading difficulty of the longer problem created by the addition of vivid and descriptive details, there had been an increase in the frequency of errors on the part of pupils whose reading ability was below average. Brueckner recommended the conclusion reached by a number of investigators which called for the use of problems dealing with interesting familiar situations. These investigations cited by Brueckner had shown proof that such problems are easier for pupils to solve than those outside their range of experiences.

\(^\text{14}\) Kramer, _loc. cit._

\(^\text{15}\) Brueckner, _op. cit._, p. 176.
The proposed role of estimation. Even if the pupil is able to comprehend the situation presented by the problem and can select the correct process to solve it, he still must conquer the most accessible pitfall as selected by Brueckner. That is, he must correctly perform the computation.

A few investigations and textbooks have suggested the practice of estimation or approximation as an aid for pupils to use as a guide in preventing absurd answers. Approximation is used in many quantitative situations where an exact answer is not required in order to obtain usable ideas of the quantities involved.

In a problem such as "How does City A, population 81,309, compare in size with City B, population 319,845?" the procedure of approximation is usable. Spitzer believes that with problems like his illustration, where a rounded number serves the purpose, it makes for simpler and usually just as meaningful thinking.

Some people make no distinction between the two processes, approximation and estimating answers. Spitzer defines approximation as the process of rounding off the numbers in the example or problem, and using the resulting computation

16/ Ibid., p. 175.
17/ Spitzer, op. cit., p. 216.
18/ Loc. cit.
of those figures as your answer. In the process of estimation, the exact answer is eventually determined while in approximation it is not. Estimation involves first rounding off the numbers and computation of the rounded numbers, and then performing the computation using the figures given in the problem. The exact answer is then compared with the estimated answer. By using this check method, the children can judge whether or not they have made a gross error in their various computations of the exact figures.

The use of approximate answers and rounded numbers is recommended by Spitzer as a procedure which helps pupils in the mastery of problem solving. He also feels that the practice of oral solutions to problems gives the children good training in rounding numbers and in arriving at approximate answers.

Children who learn to use approximation in solving problems either orally or through the use of pencil and paper have confidence in their ability to solve problems when the exact answer is demanded.19/

Newcomb20/, in a six-week experiment with seventh and eighth grade classes, concluded that the results pointed to an advantage in estimating answers. In his study, a definite technique for estimating answers was given to the pupils along with other new instruction.

19/ Loc. cit.
20/ Newcomb, op. cit., pp. 380-386
Estimation was regarded by Barber as a means of almost entirely doing away with absurd answers. He felt that this practice could be made nearly as habitual and effective in school as it is in the case of the practical computer. Barber believed that if teachers were persistent in requiring estimation to be done, the habit would soon be formed, and the procedure would produce results out of all proportion to the time it would take.

Requiring the pupils to check their answers with the estimated answer made before the actual solution was cited by Newcomb as a valuable type of check.

In her study, Kramer found very little intelligent estimating was apparently done. She also discovered that reflective thinking and verification of their choice of operation was almost never carried out.

Wilson reported improvement from exercises which involved estimating answers and judging absurdities. One exercise asked pupils to judge whether answers were reasonable.


23/ Kramer, loc. cit.

or absurd. The absurd answers used had been actually given by pupils taking the Buckingham Scale Test.

One of the most elaborate studies regarding the value of estimating answers prior to solving arithmetic problems as carried out by Dickey.25/

There are two types of evidence on the value of estimating answers for the improvement of problem solving ability. One type is the opinion of experts; the other type, the experimental results.

All evidence of the opinion type is strongly in favor of estimating the answer before the problem is solved. The estimated answer should be compared with the computed answer.

Evidence of the experimental type is meager and not so consistently in favor of the practice of estimating answers.26/

The purpose of Dickey's study was to investigate the effect of practice in estimating answers to arithmetic problems on problem solving ability as measured by a standardized test.

His testing groups consisted of all the sixth grade students in Hackensack, New Jersey. At the beginning of his experiment, a standardized test was given to all those pupils. For the following fifty days, during the first fifteen minutes of their arithmetic period, these children were given eight problems a day to solve.


26/ Ibid., pp. 24-25.
The experimental and control groups each consisted of three hundred pupils. The control group used their entire fifteen minutes in solving the problems. The experimental group spent the first five minutes estimating the answers to the problems. The remaining ten minutes were devoted to finding the exact answers. The experimental group children not only recorded their estimated answers on the mimeographed problem sheet, but also on a separate paper which was collected at the end of the first five minutes.

Dickey regarded an estimated answer as follows: "An approximate answer arrived at without the help of objective materials such as paper and pencil, chalk and blackboard." 27/ At the completion of the fifty days, another form of the standardized test was administered. 28/ The results of the two tests were compared to measure the relative gains made by the experimental and control groups. His conclusions were as follows:

That...(estimation)...was of value can not be denied. The gains resulting from the practice period of fifty days were tremendous. It is probably safest to say that the value of estimating answers to arithmetic problems as carried out in this experiment, is equal to the value derived from the traditional practice in problem solving. 29/


28/ New Stanford Achievement Test in Arithmetic, Forms V and W.

He also found no significant superiority for either the superior group or inferior group over the other. The superior group showed an advancement of one grade, while the inferior group's gain was slightly less than one grade, which was a substantial achievement. These findings were based on selected groups of twenty-eight pupils each.

Dickey acknowledged in his conclusions that estimation might have shown to better advantage had a standard technique of obtaining estimated answers been used. As it was, the estimations done by the children in the Dickey study were arrived at either by chance or the individual child's own methods. It is safe to say that there were undoubtedly a large array of haphazard estimates given by the children. Dickey conjectured that to profit to any great extent from estimating answers, a person would have to be relatively mature in judgment.

In a study carried out by Wood,\textsuperscript{30} twenty-six seventh graders and twenty-six eighth graders, who had been taught the techniques of estimation, showed more than one and one-half years gain in problem solving ability after an extended period of practice devoted to estimating as measured by a standardized test.

These children were given three tests at the beginning of the experiment, the Iowa Every-Pupil Arithmetic Test, the New Stanford Arithmetic Test, and the author's test to determine the estimating ability of the children.

For sixteen weeks, fifty minutes a week were devoted to practice and discussion of answer approximation. The various methods used in emphasizing estimation were: lessons on rounding numbers, techniques of estimating, and discussion of the value of estimating; placing problems on the board, or having pupils read from their textbooks, and approximating answers; having pupils tell how they approximated their answer with a following discussion of the best method used and why it was; having pupils approximate answers to problems and comparing them with the actual answers; having pupils approximate answers to problems and then working the same problems for the exact answers in order to find out how many absurd answers could have been avoided if the exact answer had been compared with the approximate answer; giving the pupils a list of problems and having them classify the problems into the ones in which the exact answers were necessary and into the ones in which only the approximate answers were necessary, and encouraging pupils to use answer approximation when solving all problems. 31/
The pupils were again tested at the conclusion of the experiment to determine if such a program had had any effect on the growth of the pupils in arithmetic. General improvement was found in all three tests in problem solving, computational arithmetic, and answer approximation. The difference in the median for the seventh grade in the Iowa Every-Pupil Arithmetic Test showed a greater gain during the sixteen weeks of the experiment period than the expected gain to be made between midyear sixth grade and midyear seventh grade. In the New Stanford Arithmetic Test, there was an average gain of eleven months on the reasoning section and seven months on the computational section.

Wood admitted in his summary chapter that as no control group was used, it was difficult to evaluate the improvement shown by the groups, and thus it could not be said that the gains were entirely due to the estimation program. He did conclude that whether or not answer approximation is beneficial to developing number sense and is an aid to problem solving cannot be proved at present. However, if it has as much promise as has been credited to it by many authors, then teachers and publishers should place more emphasis on answer approximation than is being done at present.
SUMMARY

This chapter dealt with the sources of difficulty in problem solving. Brueckner's reported chief causes of difficulty in problem solving as revealed by diagnostic studies were listed, and the remainder of the chapter included a discussion of research done in hopes of remediying those causes concerned with the elementary pupil.

Under the category depicting failure to comprehend the problem due to inferior reading ability and inability to visualize the problem, brief mention was made of Estaline Wilson's suggestions for making the reading of a problem more meaningful to the child, Grace A. Kramer's reported main reasons for children failing to understand the meaning of a problem, and Washburne and Osborne's conclusion regarding the comparative difficulty in visualizing one-step and two-step problems.

The second category discussed was the possibility of overcoming errors resulting from carelessness in reading or misreading. Presented here were Norma Morandi's and Washburne and Osborne's findings dealing with the value of the formal analysis of problems.

West's, Washburne and Osborne's, and Brueckner's viewpoints on the reasons underlying the cause for confusion on the part of many children in selecting what process to use
made up the third category presented in the chapter.

Meaningful arithmetic and how it can aid problem solving difficulties as reported by Washburne and Osborne, Grace A. Kramer, and Brueckner was discussed briefly next.

The final and main category presented the findings of Spitzer, Newcomb, Barber, Kramer, Wilson, Dickey, and Wood regarding the value of estimating answers prior to solving problems as a means of eliminating absurd answers arrived at through incorrect computations. None of these studies can be regarded as definite proof that the practice of estimation is beneficial to problem solving, and there is still much room for further investigation of the value of answer approximation.
CHAPTER III

THE ORGANIZATION AND PLAN OF THE INVESTIGATION

The initial phase of this experiment was the administration of standardized tests in arithmetic reasoning and computation to all pupils involved in the investigation. After this testing, the experimental and control groups entered upon a practice period which involved the use of thirty problem worksheets. Upon the completion of those daily exercises, a second form of the standardized tests administered at the inception of the experiment, was given to all pupils. The conclusions drawn from this investigation were based on the comparative growth of the two groups as registered by the standardized test in arithmetic reasoning.

Children from the fifth grade classrooms in four schools comprised the groups which served as subjects for this study. These schools were the Center School in Norton, Massachusetts, the Plainville Elementary School in Plainville, Massachusetts, the Sturdy School in Chartley, Massachusetts, and the Barrowsville School in Barrowsville, Massachusetts. All four of these schools were under the supervision of the same superintendent.

The twenty-six fifth grade pupils in the Plainville School and the seventeen from Barrowsville were designated as
the experimental group while the thirty children in the Center School and the sixteen in the Sturdy School were to serve as the control group. At the start of the experiment, all the classes were using the text, "Modern-School Arithmetic, New Edition". During the course of the experiment, the Plainville and the Sturdy groups switched to a later publication of the same company, "Arithmetic for Young America". The regular classroom work of the Plainville School paralleled closely that of the Center School while the Barrowsville and Sturdy schools moved along uniformly at a slower pace.

The experiment began in late December when all pupils were given the Public School Publishing Company's test in Arithmetic Reasoning and Arithmetic Computation in order to establish the arithmetic achievement of the groups.


2/ John R. Clark, Monica M. Hoye, and Caroline Hatton Clark, Arithmetic for Young America, Grade 5. (New York: World Book Company, 1949)

3/ Public School Achievement Tests, (a) Arithmetic Reasoning, Form 1. (Grades 3 to 8), Jacob S. Orleans. (Bloomington, Illinois: Public School Publishing Company, 1928)

4/ Public School Achievement Tests, (b) Arithmetic Computation, Form 1. (Grades 3 to 8), Jacob S. Orleans. (Bloomington, Illinois: Public School Publishing Company, 1928)
After this testing, the members of the control group with the best scores were interviewed individually by the author to see if they tended to use estimation. This group consisted of the five children from the Center School and the four pupils from the Sturdy School who had attained the highest ratings on the standardized reasoning test. At the time of the interview, the children were presented three problems. They were asked if they could tell about how much the answer would be without doing the problem on paper. Only one pupil used estimation. One of the Center School pupils correctly explained the estimation procedure for the first example, but stated he would have to figure out the remaining two problems to arrive at any type of an answer. A few of the children attempted to computate the exact figures mentally, but they didn't recognize the possibility of rounding off the numbers. The problems used were the following:

1. If shoes sell for $9.80 a pair, how much would 19 pairs cost?

2. If 22 umbrellas cost $46.20, what would be the price of one umbrella?

3. Miami is 1480 miles from Boston. Houston is 2310 miles from Boston. How much farther is it to Houston than to Miami?
The teaching phase of the study began immediately after the children had returned to school from their Christmas vacation. Each one of the set of thirty problem worksheets consisted of five problems which were related to the work being done in the classrooms as well as being based upon the types of problems which average fifth graders are expected to be able to solve. The teachers of these children were invited to suggest certain type problems they wished to be included at this time. Other textbooks besides those in use at these schools were investigated so as to give a complete coverage of the various types of problems usable for the fifth grade. The different methods employed in the teaching phase which involved the practice sheets will be discussed in a later section of this chapter.

The practice period ran without interruption until the seventeenth of February when the schools closed for a week. On that day, the two experimental groups were given a half-hour test involving estimation alone. The first part of this test was a multiple-choice type. After each of the ten problems were five possible estimated answers. The child had to select that answer which was the best estimated answer for the problem. The second part of the test consisted of ten problems for which the children had to find the estimated answer. No figuring on paper was allowed.
Following their return to school after vacation, all the children were given the final worksheets to refresh their memories. Then the second form of the standardized tests in arithmetic reasoning and computation were administered. This ended the main segment of the experiment.

The methods of teaching in the two groups during the practice period have been set up as follows so the contrasting procedures may be noted.

**Control Group**
From the very first day, these pupils were given a problem worksheet to do each morning. The Sturdy School classroom teacher conducted these practice sessions with her own group. The investigator and the principal of the Center School were in charge during these periods at the Norton Center School.

There was no introductory discussion on methods of solving problems.

**Experimental Group**
During the first week of the practice period, the experimental pupils were introduced to the techniques of estimation. This was done in both the Plainville and the Barrowsville schools by the author. No member of either experimental group had previously used the estimation procedure when solving problems.

The first step in learning the techniques of estimation involved having
the children develop competence in rounding off correctly and rapidly the numbers which they met in their problems. Most of the children quickly recognized when to round off a number to the nearest tens and when to do so to the nearest hundreds depending upon the size of the units used in the problem.

This practice was followed by the teaching of the methods to be employed in estimating for the various computations. They were taught the following techniques for the different types of problems.

1. An airplane flew 1218 miles in six hours. How many miles an hour did it average?
(In dividing, ask yourself how many 6's there are in 12. There are two. That 12 represents the hundreds column so you have to add two zeros after the two to show that it is the hundreds column. Your estimated answer is 200 miles.)

2. How much change would you receive from $10 if you paid $6.98 for a hat and $1.98 for a pair of gloves?

(Change the $6.98 to $7 and the $1.98 to $2. Add the two together and you have spent approximately $9. Thus your estimated answer is $1.)

3. Janet's mother bought four dozen cupcakes at 48¢ a dozen. How much did she have to pay for them?
(Change the 48¢ to 50¢.
Four times 50¢ is $2. That is your estimated answer.)

4. Miss Brown told her class that their Spelling books cost 96¢ each. How much did the books cost for that class of thirty pupils?
(Change the 96¢ to $1.
Thirty times $1 is $30.)

5. Susie's mother bought six yards of ribbon at 49¢ a yard and eight yards of lace at 27¢ a yard. How much did she have to pay altogether for her purchases?
(Change the 49¢ to 50¢ and the 27¢ to 30¢. Six times 50¢ is $3, and eight times 30¢ is $2.40. Add them and your estimated answer is $5.40.)
The control group children were allowed fifteen minutes in which to solve their five problems.

6. Bill earns $9 a week. How much does he earn in a year?

(Change the $9 to $10 and the 52 weeks to 50. To multiply a number by 10, add a zero to the number. Five hundred dollars is your estimated answer.)

7. What is the area of a lot 19 ft. wide and 29 ft. long?

(Change the 19 to 20 and the 29 to 30. Two times 30 is 60 and add a zero as it is 20 and not 2 by which you are multiplying. Your estimated answer is 600 sq. ft.)

Following the one-week introductory period, the experimental pupils used ten minutes of each day's twenty-minute practice period.
to estimate the answers for the five problems on the worksheet. Instead of collecting the set of estimated answers as Dickey had done, the investigator went around the room checking the children's estimations. After all five estimations had been checked as correct, the pupil could begin finding the exact answers. At the Plainville school where there were twenty-six pupils, the classroom teacher sometimes assisted in correcting the estimated answers.

At the end of the ten minute estimation period, all the children were told to start solving the problems. If one of the problems seemed especially hard for nearly all the children, the estimated
answer was given to the class. The pupils were made conscious of the aid provided by checking their exact answers with the estimated answers to see if they had worked the problem correctly and hadn't made an outstanding error in their computation.

During the ten minute solving period, those finishing raised their hands and their papers were corrected at their desks. As the children became very familiar with the problems during the estimation period, the ten minute working period usually provided ample time for all the pupils to finish their work and have their papers corrected at their desks.

Only when persistent difficulty with a problem was experienced by many was
During the course of the experiment, the control group did only the pencil and paper work required by the daily problem worksheets.

The administration of the second form of the standardized tests in arithmetic reasoning and computation marked the end of the experiment for the control group.

The problem taken up for discussion following the collection of the papers.

The experimental group was given the test on estimation discussed previously in this chapter.

In the second form of the standardized test in arithmetic reasoning, the experimental group children were required to estimate the answers to certain problems checked by the author before trying to solve them.

Following the close of the experiment, the two experimental groups were given two sets of problem worksheets similar to those used in the practice period. The first set was given two weeks after the administration
of the second form of the standardized test. On this set, they were allowed to solve the problems as they wished. Estimation was not required. This was done to ascertain whether or not estimating the answers before solving had become a part of their practice in problem solving.

Two weeks later, the other set was given. In this case, they were required to estimate before they solved the problems. The purpose of this set was to determine if the ability to estimate had been retained, and also to see how the practice affected their problem solving ability without constant practice. This ended the experiment.
A total of eighty-nine pupils were available for this study, forty-three in the experimental group and forty-six in the control group. Following the initial administration of the standardized tests, a frequency distribution table was set up on the basis of the reasoning test scores. As these tests were scored by 7A, 7B, 6A, 6B, etc., and as the scales for the two forms were not identical, a set arbitrary value was assigned to each grade score for use in equating the groups. The equating of the groups was achieved by first disqualifying three control pupils to arrive at equal number groups, and then eliminating an equal number of cases in each group until the mean and standard deviation of the two groups compared favorably enough to term the groups as being equated.

It was necessary to eliminate six pupils from each group before the two groups were equated. Thus each group was comprised of thirty-seven pupils: Control—Center School 25, Sturdy School 12; Experimental—Plainville School 23, Barrowsville School 14.

After the administration of the second form of the reasoning test at the end of the experiment, a frequency distribution of those scores for the thirty-seven pupils in each group was plotted. The means and the standard deviations of those group scores were compared with the groups' means and standard deviations on the initial testing, and from these statistics, the conclusions drawn from this study were reached.
CHAPTER IV
CHAPTER IV

ANALYSIS OF RESULTS

Pre-experimental status. The initial status of the pupils' ability in problem solving was obtained by the administration of the Public School Achievement Test in Arithmetic Reasoning. On the basis of those test results, the control group and the experimental group were equated.

Table I shows a frequency distribution of arithmetic reasoning scores for the control group and the experimental group at the beginning of the experiment. The grade scores for the Public School Achievement Test are expressed as "A" for high level at grade and "B" for low level at grade.

The data in Table I reveal that the mean for the control group for the initial test was 15.46—high fourth grade. The standard deviation was 4.07 which made the score range for one standard deviation from 11.39 to 19.53. Twenty-eight of the thirty-seven pupils in the control group fell within this range.

The mean for the experimental group for this test was 15.32—high fourth grade. The standard deviation was 3.50 which set the range for one standard deviation from 11.82 to 18.82. Twenty-five of the thirty-seven experimental group children were included within those scores.
TABLE I

FREQUENCY DISTRIBUTION OF PRE-EXPERIMENT SCORES FOR THE CONTROL GROUP AND THE EXPERIMENTAL GROUP FROM THE PUBLIC SCHOOL ACHIEVEMENT TEST IN ARITHMETIC REASONING

<table>
<thead>
<tr>
<th>Grade Score</th>
<th>Control Group</th>
<th>Experimental Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>7A</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>7B</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>6A</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>6B</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>5A</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>5B</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>4A</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>4B</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Mean: 15.46     15.32  
S.D.: 4.07      3.50   
S.E.: .67       .58    
S.E.diff: .86    
t-Ratio .16
Using Lindquist's test of significance for difference formula for experiments which have only small samplings,

\[ \frac{M_1 - M_2}{\sqrt{\frac{N_1 \sigma_1^2 + N_2 \sigma_2^2}{N_1 N_2}}} \]

it was determined that the standard error of the difference was .86, and the critical ratio (t-ratio) was .16. The t-ratio of .16 indicated that the small difference found for the means was probably due to chance and that no real difference existed between the means for the experimental and control groups. In Lindquist's formula, "M_1" and "M_2" represented the obtained means of the two groups, "\sigma_1" and "\sigma_2" were the respective standard deviations for the two groups, and "N" indicated the number of cases in each group.

Changes during the experimental period. During the course of the experiment, the children in the experimental group were trained in the techniques of estimation and were required to put this practice into operation in the solving of thirty problem worksheets. Meanwhile the control group concentrated only upon the solving of the problems presented in the worksheets. After the completion of the thirty worksheets, the Public School Achievement Test in Arithmetic

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Reasoning, Form 2, was given to all the pupils. Table II shows a frequency distribution of the scores made by the control group and the experimental group in this post-experiment test.

The mean for the control group in the post-experiment test was 13.08—low fifth grade—with a standard deviation of 5.53. The range for one standard deviation was 12.55 to 23.61, and twenty-seven of the thirty-seven children in the group made scores entering that range.

Meanwhile the experimental group raised their mean to 20.43 which was equivalent to high fifth grade. The standard deviation for this group was 5.19 which established the score range for one standard deviation from 15.24 to 25.62. Twenty-three of the thirty-seven pupils registered scores within those bounds.

The standard error of the difference for these test results was 1.2 and the t-ratio 2 as determined by the small samplings formula. The t-ratio of 2 is significant at the 5 per cent level which means that ninety-five out of one hundred such experiments would show results favoring the practice of estimation.

When the groups are as small as those used in this study, the statistical techniques are not too dependable. However, the statistical data do serve as further evidence that
### Table II

**Frequency Distribution of Post-Experiment Scores for the Control Group and the Experimental Group from the Public School Achievement Test in Arithmetic Reasoning**

<table>
<thead>
<tr>
<th>Grade Score</th>
<th>Control Group</th>
<th>Experimental Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>7A</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>7B</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>6A</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>6B</td>
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<td>3</td>
</tr>
<tr>
<td>5A</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>5B</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>4A</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>4B</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>3A</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3B</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Mean:       | 18.08         | 20.43               |
| S.D.:       | 5.53          | 5.19                |
| S.E.:       | .91           | .85                 |
| S.E. diff:  | 1.2           |                     |
| t-Ratio:    | 2             |                     |
the experimental group showed a fairly decisive gain over the control group in this small group experiment during the thirty problem worksheet practice period. In terms of grade norms, the control group increased their mean only half a grade while the experimental group raised their mean a whole grade.

The growth on the part of both groups as a result of the concentrated practice in problem solving is shown in Table III. Here the comparative frequency distributions of the two groups in the pre-experiment test and the post-experiment test clearly indicates the upward swing brought about by improved problem solving performance.
TABLE III

COMPARATIVE FREQUENCY DISTRIBUTIONS OF PRE-EXPERIMENT TEST AND POST-EXPERIMENT TEST SCORES FOR THE CONTROL GROUP AND THE EXPERIMENTAL GROUP FROM THE PUBLIC SCHOOL ACHIEVEMENT TEST IN ARITHMETIC REASONING

<table>
<thead>
<tr>
<th>Grade</th>
<th>Control Group</th>
<th>Experimental Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test</td>
<td>Post-test</td>
</tr>
<tr>
<td>7A</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>7B</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>6A</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>6B</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>5A</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>5B</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>4A</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>4B</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>3A</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>3B</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Mean: 15.46 18.08 15.32 20.43
S.D.: 4.07 5.53 3.50 5.19
S.E.M.: .67 .91 .58 .85
The majority of the experimental group children grasped the techniques of estimation quite rapidly. The poorer students encountered some difficulty in attempting to compute mentally with rounded numbers, and they also experienced much more difficulty in selecting which process to use in order to correctly solve the problem.

One of the chief advantages credited to estimating by most textbook authors has been the elimination of absurd answers. There was a sharp decrease in the frequency of absurd answers given by the experimental group pupils in the second reasoning test as compared to the first test results. Using just the types of problems with which they had come in contact with during the experiment, and not considering any of the wild guesses made on higher grade problems in the latter part of the achievement test, the results were as follows: the experimental group had a count of 121 absurd answers on the first test--Plainville sixty-nine, Barrowsville fifty-two--while in the second test such absurdities numbered sixty-seven--Plainville twenty-nine, Barrowsville thirty-eight. Meanwhile the control group accumulated 126 absurd answers on the first test--Norton ninety-seven, Sturdy twenty-nine. On the second test, 118 such answers were given with seventy-nine being charged against Norton and thirty-nine to the Sturdy group. Judging by these results, it would appear that concentrated practice including
the practice of estimation in solving problems is more beneficial in tending to eliminate absurd answers than is an identical length period of only concentrated practice in solving the problems.

One of the dangers in estimation observed in this study was that frequently a child estimated absurdly when he selected an incorrect process in his attempt to solve a problem. Such an estimated answer was misleading to the child for when his real answer approximated the absurd estimated answer, he mistakenly believed his solution was correct. In cases where the absurd answer was the result of a computational error, the correctly performed estimated answer was responsible for improved performance. The answers given in the first reasoning test by the two highest-ranking members of the Plainville experimental group illustrate this point.

The problem was: "How many $14 coats can you buy for $378?" 2/

The answers given by these two top pupils were 2700 and 4292. The child who gave the first answer made a correct choice of computation, but incorrectly added two zeros to her answer. One might conjecture that her reason for this mistake resulted from confusion in dividing money by money. As this error was made before the introduction of the techniques of

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2/ Public School Achievement Tests (c) Arithmetic Reasoning, Form 1. (Grades 2 to 8). Jacob S. Orleans. (Bloomington, Illinois: Public School Publishing Company, 1928.)
estimation, it is impossible to theorize whether or not she would have correctly estimated the answer and thus have realized the absurdness of her given answer.

The answer of 4292 given by the other pupil clearly indicated that she misunderstood the problem and multiplied the two numbers. It would seem safe to say that if she had estimated first, she would have rounded the numbers and multiplied. Then when her answer of 4292 compared favorably with her estimated answer, disregarding her omission of the dollar sign as she did, she would have mistakenly believed her answer was correct.

The difficulty cited above was certainly the most apparent pitfall of estimating. As mentioned previously, the basic techniques of estimating such as rounding off numbers, multiplying by tens, and approximating quotients were readily understood by most of the children. At the beginning of the experiment, mistakes resulting from the incorrect choice of process were common. As the children obtained more experience in solving problems, they became more adept at selecting the correct process, and both experimental groups--especially the Plainville group--were surprisingly quick in arriving at their estimated and correct answers.

One of the main contributions of estimation to problem solving as recognized in this investigation was that the
practice of estimating called for a more careful reading of the problem and eliminated many errors caused by misreading the problem. The control group children were more prone to quickly read a problem, jot down the figures immediately, and then follow through with their computation. In contrast, the experimental children worked with the problems much more carefully to determine which technique of estimation they had to use for that particular problem. Then they had to read the problem again in order to determine which process they had to use with their transfigured numbers. Finally, the actual solving of the problem required a third reading.

The above conclusion that estimation required a more careful reading of the problem and a better chance of correct interpretation was borne out by the two post-experimental tests given the experimental groups. The first test was given two weeks after the completion of the experiment and called for the children to solve five problems. They were given optional choice with regards to estimating. Three of the twenty-three Plainville pupils made use of their estimation practice. Two of these pupils had perfect papers while the third child had four out of five correct. The scores for the remainder of the group were well below their standard of work on the same type of papers during the course of the experiment. In this later test, none of the fourteen Barrowsville pupils estimated before
solving their problems. Their scores also were below the average they had maintained during the experiment.

The second test of five problems was given two weeks later--four weeks after the close of the experiment. This test required estimation before solving. There was some evidence of a slight decrease in estimation proficiency on the part of the poorer pupils as compared to their ability during the latter part of the experiment. However, the good and average pupils had retained their estimating ability and achieved more satisfactory scores than they had on the test where they had not estimated. The comparative scores made in these two tests are shown in Table IV.

The Barrowsville group was sharply divided by this second test. Six of the children faired very poorly in this test in both estimating and solving. Six other children did exceptionally well, two of them scoring five out of five, and the other four having four out of five correct. The other two pupils performed at the mediocre level which was consistent with their experiment performance. Considering that only two pupils from this group had been up to grade level at the beginning of the experiment, it was very pleasing to find six of them performing so well a month after the completion of the experiment.
TABLE IV

FREQUENCY DISTRIBUTION OF PERCENTAGE SCORES OF EXPERIMENTAL GROUPS FROM THE TWO POST-EXPERIMENT PROBLEM WORKSHEETS

<table>
<thead>
<tr>
<th>Score</th>
<th>Plainville</th>
<th></th>
<th>Barrowsville</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimation</td>
<td>Optional</td>
<td>Required</td>
<td>Estimation</td>
</tr>
<tr>
<td>100</td>
<td>2</td>
<td>5</td>
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<td>2</td>
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<tr>
<td>80</td>
<td>3</td>
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<td></td>
<td>4</td>
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<tr>
<td>60</td>
<td>10</td>
<td>4</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>40</td>
<td>5</td>
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<td></td>
<td>4</td>
</tr>
<tr>
<td>20</td>
<td>3</td>
<td>1</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>


All four of the teachers of the pupils used in this experiment expressed their pleasure at their pupils' improved post-experiment performances in problem solving. They praised the confidence with which the children attacked problems and were pleased to report that the old dread of problems had almost entirely disappeared, and that the results were more satisfying.

**Individual group changes.** From Table V, it will be noted that the mean of each experimental group was raised a full grade. The Plainville fifth grade increased their achievement scores from low fifth to low sixth while the Barrowsville fifth grade progressed from a high fourth grade mean to a high fifth grade mean.

There was a range of low fourth to high sixth in the Plainville group for the pre-experiment test. The range in the post-experiment test was high fourth to low seventh. Twelve of the twenty-three pupils were at or above grade level on the first test, while twenty of the twenty-three reached that level in the second test. Their advancement in arithmetic reasoning was paralleled by a comparative gain in computational work during this period. Though no table has been provided which shows the results for the computation test, the mean for the group in the initial computation test was high fourth as contrasted to a mean equivalent to high fifth in the final test.
<table>
<thead>
<tr>
<th>Grade Score</th>
<th>Plainville Pre-test</th>
<th>Plainville Post-test</th>
<th>Barrowsville Pre-test</th>
<th>Barrowsville Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>7A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6A</td>
<td>1</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6B</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5A</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>5</td>
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<td>5B</td>
<td>4</td>
<td>3</td>
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</tr>
<tr>
<td>4A</td>
<td>7</td>
<td>2</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>4B</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>3A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mean:       17.17    20.13    14.57    17.57
S.D.:       3.03      4.23      3.35      5.41
S.E.M.:     .51       .71       .56       .90
Whereas the standard deviation for the reasoning tests increased from only 3.03 to 4.23, that for the computation tests advanced from 4.41 to 6.53. The percentage of pupils attaining grade level scores progressed from 39 per cent to 83 per cent.

The range of scores for the reasoning test in the Barrowsville group varied from high third to low sixth in the initial test to low fourth to high seventh in the final test. During this same period, the range of scores in the computation tests remained constant at high third to low fifth, and the mean was raised only half a grade--from low fourth to high fourth. In the final reasoning test, there were seven additional pupils to attain grade level scores for a total of nine children, while in the final computation test there was only an increase of two for a total of four.

From Table VI, it will be noted that one of the control groups--the Norton Center School fifth grade--also raised their mean a full grade for the reasoning test. The remaining group used in the experiment--the Chartley Sturdy School fifth grade--did not raise their mean which remained static at a low fifth grade level for both tests.

The Center School increased their mean from high fourth to high fifth with little resulting change in the standard deviation. The range for the initial test was from low third to high sixth while for the final test, it ranged from high
TABLE VI

FREQUENCY DISTRIBUTION OF THE PRE-EXPERIMENT TEST AND POST-EXPERIMENT TEST SCORES FOR THE CONTROL GROUPS FROM THE PUBLIC SCHOOL ACHIEVEMENT TEST IN ARITHMETIC REASONING

<table>
<thead>
<tr>
<th>Grade Score</th>
<th>Norton Center</th>
<th></th>
<th>Chartley Sturdy</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test</td>
<td>Post-test</td>
<td>Pre-test</td>
<td>Post-test</td>
</tr>
<tr>
<td>7A</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>7B</td>
<td>2</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>6A</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6B</td>
<td>5</td>
<td>6</td>
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<td>2</td>
</tr>
<tr>
<td>5A</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>5B</td>
<td>6</td>
<td>6</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>4A</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4B</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3A</td>
<td>2</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3B</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mean: 15.50 17.50 16.83 16.58
S.D.: 4.38 4.95 3.60 5.39
S.E.M.: .73 .83 .60 .90
third to high seventh. The percentage of pupils achieving grade level was enlarged from 46 per cent, eleven out of twenty-five, to 69 per cent, seventeen out of twenty-five, which was a substantial gain. The comparative figures for the computation test showed only a half grade gain in the mean--from high fourth to low fifth. The number of pupils achieving grade level scores was increased from twelve to sixteen.

In analyzing the test results for the other control group--the Sturdy group--it is impossible to determine the factor which would explain their failure as a group to have shown improvement. Of the twelve members in the group, five showed improvement, six registered a lower score on the second test than they had on the initial reasoning test, and the remaining pupil made an identical score on both tests. The five showing improved performance raised their scores from a full grade to a grade and a half. This latter gain was achieved by three pupils. Meanwhile, two pupils made scores a grade and a half below their first test scores, two were a grade below, and the other two children were a half grade below their original scores. In the case of one of the pupils scoring a grade and a half lower, the reason for his failure could be attributed to a changeable attitude. During the administration of the first test, he worked out the problems conscientiously. In the final test, he refused to attempt a solution for most of
the problems. He performed in the same erratic manner throughout the experimental period.

The Sturdy group showed an increase of a half grade in their mean for the computation tests—from low fourth to high fourth. Their standard deviation was extremely high in both cases—3.52 for the first and 3.30 for the second. There was only a small increase in the number of pupils attaining grade level scores. Two pupils achieved that mark in the first test, while four of them were successful in doing so in the final computation test. The range for this group in the computation tests was also more static than the other groups. For the first test, the scores ranged from low third to high fifth while in the final test, the range was from low third to low fifth.

The frequency distributions of the pre-experiment test and the post-experiment test grade scores for the individual groups composing the control and experimental groups are given in Tables V and VI.

Individual pupil changes. There were many gratifying and surprising individual gains uncovered by this experiment. Tables VII and VIII show the comparative scores made by the individual pupils on the two forms of the test in arithmetic reasoning. In Table VII, which represents this data on the
TABLE VII

COMPARATIVE GRADE SCORES ATTAINED BY MEMBERS OF CONTROL GROUP IN PRE-EXPERIMENT AND POST-EXPERIMENT REASONING TESTS

<table>
<thead>
<tr>
<th>Grade Score</th>
<th>Norton Center Pre-test</th>
<th>Norton Center Post-test</th>
<th>Chartley Sturdy Pre-test</th>
<th>Chartley Sturdy Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>7A</td>
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<td>N-6, N-7, N-21</td>
<td>S-1</td>
<td>S-5, S-9</td>
</tr>
<tr>
<td>7B</td>
<td>N-1, N-5</td>
<td>N-2, N-12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6A</td>
<td>N-3</td>
<td>N-9, N-10, N-11, N-22</td>
<td>S-9</td>
<td>S-2, S-3</td>
</tr>
<tr>
<td>6B</td>
<td>N-4, N-5, N-6, N-7</td>
<td>N-15, N-16, N-18, N-19</td>
<td>S-4</td>
<td>S-7, S-8</td>
</tr>
<tr>
<td>5A</td>
<td>N-8</td>
<td>N-9, N-14</td>
<td>S-5, S-6</td>
<td>S-11, S-12</td>
</tr>
<tr>
<td>5B</td>
<td>N-11</td>
<td>N-20</td>
<td>S-7, S-8</td>
<td></td>
</tr>
<tr>
<td>4A</td>
<td>N-12, N-13, N-8</td>
<td>N-9, N-10, N-13, N-22</td>
<td>S-9</td>
<td>S-2, S-3</td>
</tr>
<tr>
<td>4B</td>
<td>N-14, N-15, N-13, N-22</td>
<td>N-17, N-23, N-25</td>
<td>S-10, S-11</td>
<td>S-4, S-10</td>
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<td>3A</td>
<td>N-16, N-17</td>
<td>N-20, N-21</td>
<td>S-11, S-12</td>
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<tr>
<td>3B</td>
<td>N-18, N-19</td>
<td>N-22, N-23, N-24</td>
<td>S-12</td>
<td>S-6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N-25</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
control group, the letter "N" denotes pupils from the Norton Center School, while the letter "S" indicates pupils from the Sturdy School. Thus in the table, N-1 represents the Norton pupil who attained the highest score in the first reasoning test. In the pre-experiment test, this pupil made a grade score of low sixth, while in the post-experiment test his grade score was raised to low seventh. By using this table, one can readily discern the individual changes in arithmetic reasoning ability which occurred during the course of the experiment.

Two control cases worthy of mention were S-9 and N-4. The pupil shown as S-9 had always been regarded as a poor arithmetic student. Her initial test score of high fourth grade was considered an honest appraisal of her arithmetic reasoning ability. Through conscientious effort, she was able to make a grade score of low sixth grade in her final test.

Pupil N-4, a boy, had always been recognized as a capable arithmetic student. However, he was uniformly regarded as being inferior to the top tier in his class. His final test score of high seventh grade earned for him the honor of highest rank in his class, and it tied the best score made by any pupil connected with this study.

The individual performances of the experimental group members are shown in Table VIII. The letter "P" represents
## TABLE VIII

**COMPARATIVE GRADE SCORES ATTAINED BY MEMBERS OF EXPERIMENTAL GROUP IN PRE-EXPERIMENT AND POST-EXPERIMENT REASONING TESTS**

<table>
<thead>
<tr>
<th>Grade Score</th>
<th>Plainville Pre-test</th>
<th>Plainville Post-test</th>
<th>Barrowsville Pre-test</th>
<th>Barrowsville Post-test</th>
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<tbody>
<tr>
<td>7A</td>
<td></td>
<td></td>
<td></td>
<td>B-2</td>
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<tr>
<td>7B</td>
<td>P-1,P-2,P-3</td>
<td>P-4,P-5</td>
<td></td>
<td>B-1</td>
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<tr>
<td>6A</td>
<td>P-1</td>
<td>P-9,P-12,P-13</td>
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<td>B-4</td>
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<tr>
<td>6B</td>
<td>P-2</td>
<td>P-11,P-19,P-20</td>
<td>B-1</td>
<td>B-3,B-5,B-6</td>
</tr>
<tr>
<td>5A</td>
<td>P-3,P-4, P-7,P-8,P-17</td>
<td>P-5,P-6,P-23</td>
<td>B-2</td>
<td>B-11,B-13</td>
</tr>
<tr>
<td>5B</td>
<td>P-9,P-10, P-11,P-12</td>
<td>P-6,P-14,P-15</td>
<td></td>
<td>B-12</td>
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<tr>
<td>4A</td>
<td>P-13,P-14, P-15,P-16</td>
<td>P-10,P-21</td>
<td>B-3,B-4, B-7,B-8, B-9</td>
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<tr>
<td>4B</td>
<td>P-20,P-21, P-22</td>
<td></td>
<td></td>
<td>B-10,B-11, B-12</td>
</tr>
<tr>
<td>3A</td>
<td>P-22,P-23</td>
<td></td>
<td></td>
<td>B-13,B-14</td>
</tr>
<tr>
<td>3B</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
pupils from the Plainville School while the initial "B" stands for the Barrowsville pupils.

Student P-9 showed surprising improvement. He had always been in the bottom third of his class. His initial score of low fifth grade was a surprise in itself. During the experiment, it was apparent to both his classroom teacher and the investigator that he was doing his utmost to do well. His final test score of high sixth grade, which was the highest boy's score in his group, gave him much needed confidence.

The degree to which a Barrowsville pupil--B-2--had been held back by being in a relatively slow group was revealed by his results in the arithmetic reasoning tests. There he raised his score from a high fifth grade level to high seventh grade. Meanwhile his computation grade score remained constant at low fifth grade level. The new types of examples used in the experiment had presented him a challenge to which he had responded. His final arithmetic reasoning score matched the highest score made by any pupil in this experiment.

Most gratifying to the investigator was the large increase in percentage of pupils attaining grade level scores in the final test as compared to the initial test. Regardless of the conclusions reached relative to the value of training in the techniques of estimation, these results were evidence that the experiment had accomplished better performance in solving problems for most of the children concerned.
CHAPTER V
CHAPTER V

SUMMARY AND CONCLUSIONS

Summary of the procedure. The purpose of this study was to evaluate the effect of training in the techniques of estimation upon fifth grade problem solving. The training was based upon developing the ability to round off numbers, multiply by tens, approximate quotients, and other methods of estimation. After determining the initial problem solving ability of the pupils concerned through the administration of the Public School Achievement Test in Arithmetic Reasoning, Form 1, the control group and the experimental group were equated. The control pupils were given daily problem worksheets for thirty days. Each day's period consisted of twenty minutes. The experimental group, after being trained in the techniques of estimation, were required to estimate the answers to the problems on the daily worksheets before solving them. Upon the completion of the worksheets, the pupils were re-tested and comparative scores were thus obtained for analysis. Two worksheets were presented to the experimental group children at later dates. The first, given two weeks after the close of the experimental period, did not require the children to estimate before solving the problems. The second worksheet, given one month after the completion of the experiment, required estimation before solution.
Summary of the results. The experimental group, which had been trained in the techniques of estimation with regards to approximating an answer before solving the problem, showed more improvement in problem solving ability than the control group, which had spent the entire period merely solving problems, as measured by a standardized test in arithmetic reasoning. The mean of the experimental group progressed from 15.32—high fourth grade—to 20.43—high fifth grade. The control group raised their mean from 15.46—high fourth grade—to 18.08—low fifth grade. The t-ratio of 2 as determined by the small samplings formula is significant at the 5 per cent level which indicates that ninety-five out of one hundred such experiments would disclose results favoring the practice of estimation.

Conclusions. Previous to the introduction of the techniques of estimation, knowledge of effective methods of estimating were unknown, and the technique was not used at all in regular classroom work.

With the exception of a few below average students, the children in the experimental groups became suitable proficient in the ability to correctly round off numbers and estimate properly during the course of the investigation.

The pupils in the experimental groups appeared to realize the value of comparing their estimated answers with
their real answers as a guide in detecting gross computational mistakes. They employed this method faithfully throughout the investigation. However, this practice did not become a habitual part of their arithmetic performance, and for the most part, it ceased to function after the completion of the experiment.

Concentration on problem solving, regardless of the method employed, results in improved performance and is well worth the time.

**Limitations of the study.** Only a small number of pupils participated in the study.

The pupils were only equated on the basis of performance in one test.

The limited choice of problems usable during the study made problem selection difficult because many mid-year fifth grade arithmetic problems are not suitable for estimation.

**Implications of the study.** Estimation involves a more careful scrutiny of the problem and should result in clearer comprehension and fewer errors due to careless reading.

The practice of estimation should eliminate absurd answers traceable to incorrect computations if children are conscious of the value of the approximated answer. It will not, however, detect absurd answers which are the result of an incorrect choice of computational operation.
As many life situations demand the ability to mentally approximate a computation, training in the techniques of estimation should prove valuable for children in social experiences.

The practice of estimation as concerned with problem solving would be more valuable for the higher grades where the problems deal with larger numbers which are not suitable for exact mental computation.

Estimation is worthy of further investigation. If the results of this study are substantiated by future large-scaled investigations, teachers should devote more time to the teaching of the techniques of estimation, and the children should be trained in those methods until they become habitual in all their arithmetic work.
BIBLIOGRAPHY


DAILY PROBLEM WORKSHEET

1. Jack earns $11 a month. How much does he earn in a year?

2. How many 49¢ dolls can a welfare home buy with $20?

3. In the morning while the sun was out, the temperature was 53 degrees. At night it went down to 29 degrees. How many degrees did the temperature drop?

4. How much would 21 pairs of shoes cost at $9.50 a pair?

5. When Lucy was sick her temperature rose 2.8 degrees above the normal temperature of 98.6 degrees. What was her temperature while she was sick?
1. Robert has saved $15 toward a bicycle. The bicycle he wants costs $24.95. How much more money does he need?

2. Ruthie is going to Chicago by train, a distance of 817 miles. If the train travels 43 miles an hour, how many hours will it take Ruthie to get to Chicago?

3. Rose paid 93¢ for some grapes and some plums. The grapes cost 39¢. How much did the plums cost?

4. Miss Brown told the class that their Spelling books cost 96¢ each. How much did the books cost for that class of 30 pupils?

5. Susie's mother bought six yards of ribbon at 49¢ a yard and eight yards of lace at 27¢ a yard. How much did she have to pay for her purchases?
1. How much change would you receive from $10.00 if you paid $6.98 for a hat and $1.98 for an umbrella?

2. Janet's mother bought four dozen cupcakes at 48¢ a dozen. How much did she have to pay for them?

3. An airplane flew 1218 miles in six hours. How many miles an hour did it average?

4. A farmer had 946 sheep and sold all but 249 of them. How many sheep did he sell?

5. Twenty-one boys went to a summer youth camp. The total cost of their trip was $483. If the boys shared the expenses equally, how much did each boy have to pay?
1. A pet canary cost $16.75 and the cage cost $3.98. How much did the canary and the cage cost together?

2. John has 59 baby chicks and Bert has 121. How many more baby chicks does Bert have than John?

3. How much would 17 bananas cost at 9¢ each?

4. A truck when empty weighs 2754 pounds. When it has a full load of coal it weighs 5710 pounds. How much does the coal weigh?

5. Jack's brother bought 14 gallons of gasoline at 22¢ a gallon. How much did he have to pay for it?
DAILY PROBLEM WORKSHEET

1. Mr. James owned 48 pigeons. He bought 31 more and his son gave him 17 of his. How many pigeons did Mr. James then have?

2. Eleanor had 51 matchbook covers. She gave 18 of them to her sister. How many did she have left?

3. On a business trip, Mr. Ross traveled 2580 miles in six days. How many miles a day did he average?

4. Mary's marks in Arithmetic for a week were 80, 90, 60, 100, and 80. What was her average mark for the week?

5. Nancy bought eight notebooks at 19¢ each. How much did she have to pay for them?
DAILY PROBLEM WORKSHEET

1. What is the area of a room nineteen feet long and eleven feet wide?

2. If it is 1590 miles to Miami and 2820 miles to Reno, how much nearer is Miami than Reno?

3. How many cars would be needed to transport 484 cattle if each car held 22 cattle?

4. A dress which Mary liked was priced at $29.69. It was marked down to $17.98 during a sale. How much did Mary save by waiting until the sale to buy the dress?

5. How much change would Laura receive from $4 after buying eight dish towels at 39¢ each?
DAILY PROBLEM WORKSHEET

1. Janet had five dollars. She spent $2.10 in one store and $1.98 in another store. How much money did she have left?

2. Seven boys went on a camping trip. The total cost of the trip was $185.50. If the boys shared the cost equally, how much would each boy have to pay?

3. Nine boys shared a jar of marbles among themselves. Each boy received 29 marbles and there were six left over. How many marbles had there been in the jar?

4. On Sunday the Ruths drove 208 miles. They traveled 297 more on Monday and 252 more on Tuesday. How many miles did they travel in the three days?

5. After Jed had read 49 pages in an adventure story, he was ½ through the book. How many pages were there in the book?
Making Comparisons

<table>
<thead>
<tr>
<th>Building</th>
<th>Location</th>
<th>Height in Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empire State</td>
<td>New York</td>
<td>1065</td>
</tr>
<tr>
<td>Eiffel Tower</td>
<td>Paris</td>
<td>984</td>
</tr>
<tr>
<td>Board of Trade</td>
<td>Chicago</td>
<td>609</td>
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<tr>
<td>Penobscot Building</td>
<td>Detroit</td>
<td>557</td>
</tr>
<tr>
<td>City Hall</td>
<td>Philadelphia</td>
<td>548</td>
</tr>
<tr>
<td>Cologne Cathedral</td>
<td>Germany</td>
<td>524</td>
</tr>
<tr>
<td>Pyramid of Cheops</td>
<td>Egypt</td>
<td>461</td>
</tr>
<tr>
<td>St. Patrick's Cathedral</td>
<td>New York</td>
<td>328</td>
</tr>
<tr>
<td>Westminster Tower</td>
<td>London</td>
<td>310</td>
</tr>
</tbody>
</table>

1. How much higher is the Egyptian pyramid than Westminster Tower?

2. How much higher is the Eiffel Tower than the Pyramid of Cheops and Westminster Tower combined?

3. If the Cologne Cathedral were placed on top of St. Patrick’s Cathedral, by how much would they lack reaching the top of the Empire State Building?

4. How much greater would be the combined heights of the Pyramid of Cheops and Westminster Tower than the height of Chicago’s Board of Trade Building?

5. How much greater would be the combined heights of the Penobscot Building and Philadelphia’s City Hall than the height of the Empire State Building?
DAILY PROBLEM WORKSHEET

1. Jerry earns $20 a week helping out on his uncle's farm. How much money does he earn in a year?

2. What is the area of a room nine feet long and nineteen feet wide?

3. In the Johnson School there are 529 pupils. On a stormy day last week there were 447 present. How many were absent?

4. How much would a banquet committee have to pay for 48 quarts of ice cream at $3.25 a gallon?

5. Mr. Davis drove his car 597 miles in three days. What was the average distance he traveled each day?
**DAILY PROBLEM WORKSHEET**

1. There were 254 people at a dinner for a basketball coach. Each person paid $1.85 for his ticket. How much money was taken in by the sale of tickets?

2. What is the area of a pony stable which is nineteen feet wide and twenty-one feet long?

3. It took an airplane eleven hours to travel the 2513 miles between Ireland and New York. What was its average rate of speed an hour?

4. If Ruthie banked $36.00 during the year, what was the average amount she banked each week?

5. Farmer Jones paid $384 for twelve goats. How much would he have had to pay if he had bought only seven goats?
1. Mr. Johnson bought a radio for $121. He paid $58 cash and the rest in nine equal payments. What was the amount of each remaining payment?

2. Mr. Clark owned 59 chickens. He bought 41 baby chicks from one dealer and 39 from another one. How many chickens did he then own?

3. Jane had 153 stamps in her collection. She gave her cousin 39 so that she could start a collection. How many stamps did that leave Jane?

4. In an arithmetic test, Bill had 80, Ruth 100, Charlie 60, Jane 100, Carl 50, and Steve 90. What was their average mark?

5. A carpenter was paid $1590 for building a garage. He paid out $232.50 for materials and $480 for his helper's pay. How much did he actually make on the job?
1. Five boys shared a box of cookies among themselves. Each boy received nine cookies and there were three left over. How many cookies had been in the jar?

2. John's spelling marks for the week were 40, 60, 70, 90, and 90. What was his average mark?

3. After Marie had read 39 pages in a story, she was 1/5 through the book. How many pages were there in the book?

4. Bill earns $9 a month. How much does he earn in a year?

5. How many 24¢ lead soldiers can Bob buy for $3?
DAILY PROBLEM WORKSHEET

1. If Nome, Alaska is 3,314 miles north of Chicago, and Valparaiso, Chile is 5,268 miles south of Chicago, how far is it from Nome to Valparaiso?

2. How many square feet are there in a hallway eleven feet wide and thirty-nine feet long?

3. Bill earned $492 last year. What was his average monthly earnings?

4. A train that was due at 3:29 was 53 minutes late. At what time did the train arrive?

5. After Farmer Chase gave away 59 baby chicks, he had 92 left. How many had he had altogether?
1. Which would you rather have 1/ three quarters, two dimes, three nickels, and four pennies or 2/ a half dollar, four dimes, two nickels, and ten pennies?

2. If you went to the store to buy eleven dish towels at 38¢ each, how much would you have to pay for them?

3. At one grocery store, you would have to pay nine cents each for a dozen bananas. At another store, you could buy a dozen for 98¢. How much would you save by going to the second store?

4. A dozen small fancy cakes cost $1.29. How much would you have to pay for 1/3 of a dozen?

5. You have invited six friends to a party. There will be four glasses of tonic in each bottle. How many bottles of tonic must you have so that each one of you can have three glasses?
DAILY PROBLEM WORKSHEET

1. If Charlie earns $3 a week, how much will he earn in a year?

2. What is the area of a lot nine feet by twenty-nine feet?

3. Spelling books cost 97¢ each. How much would a school have to pay for books for a class of 42 pupils?

4. Mrs. Jones had $14.75 when she went shopping. When she returned home she had $5.90. How much had she spent?

5. How much would Fred have to pay for eleven party favors if they cost 23¢ each?
1. Julie's arithmetic marks were 74, 88, 92, 78, and 98. What was her average mark?

2. If Carl earns $4 a month, how much does he earn in a year?

3. It is 3,514 miles from Chicago to Nome, Alaska, and it is 5,268 miles from Chicago to Valparaiso, Chile. How much farther is it to Valparaiso than to Nome?

4. If it takes two men four days to paint a house, how long would it take four men to paint the same house?

5. The number 867 is how much larger than 498?
1. Mr. Hewitt weighs 173 pounds. His son, John, weighs 84 pounds less than his father. How much does John weigh?

2. After Miss Church had corrected 19 history papers, she was done. How many history papers did she have to correct?

3. It is 5,297 miles from New York City to Buenos Aires. It is 4,820 miles distant from New York City to Rio de Janeiro, Brazil. How much farther south is Buenos Aires than Rio de Janeiro?

4. If Jane bought six yards of lace at 69¢ a yard and twelve yards of cloth at 98¢ a yard, how much would she have to pay for her purchases?

5. The number 374 is how much smaller then the number 742?
1. Mr. Carroll pays $50 a month rent. How much rent does he pay in a year?

2. How much would four grapefruit cost if they sell for $1.68 a dozen?

3. Carl went to a clothing store and bought a topcoat for $54.98, a pair of shoes for $8.50, and a tie for $1.98. If he gave the clerk four ten-dollar bills and two five-dollar bills, how much change would he receive?

4. What is the area of a room eleven feet by nineteen feet?

5. Janet wants to buy a dress which costs $7.98. She has only $5.19. How much more money must she have before she can buy the dress?
DAILY PROBLEM WORKSHEET

1. Mr. Jenks owes the grocer $19.35, the plumber $15.50, the laundryman $4.60, the tailor $69.00, and the garageman $41.00. He has $249.00 in his checking account. How much will he have left after he pays his bills?

2. A fire engine cost $14,690 and a chemical fire-fighting wagon cost $2985. How much would the town of Lawndale have to pay for the two trucks?

3. Bill, Bob, and Jim had $5.94 to split up among them. How much did each boy receive?

4. Tommy wants a skating outfit. The skates cost $8.98, the hockey stick $1.49, a woolen sweater $9.95, a cap $.89, and a windbreaker $14.90. How much will the whole outfit cost?

5. The Mann Orchestra plays at dances six nights a week all year round. How many evenings do they play in a year?
DAILY PROBLEM WORKSHEET

1. Seven classes were to share equally 448 pieces of drawing paper. How many would each class receive?

2. If Jerry earns $276 a year, what is his average monthly earnings?

3. Bobby wants a toboggan which costs $23.40. How much must he save every week for a year, so that he can buy the toboggan at this time next year?

4. On a trip of 927 miles, Mr. Allen drove 458 miles the first day and 393 miles the second day. How many more miles did he have to go?

5. After John had earned $5.75 a week for six weeks, he bought a jacket for $18.75. How much money did he have left?
1. Mrs. Clyde had $80.20 when she went shopping. She spent $30.98 at the stores. How much money did she have left?

2. If a geography book sells for $1.50, what would be the cost of 53 books?

3. Nine boys on a baseball team decided to buy new uniforms. The cost for the nine uniforms was $73.80. How much did each boy pay for his uniform?

4. A bushel of shelled corn weighs 52 pounds. How many bushels of corn are there in 4784 pounds of corn?

5. Mrs. Harvey had 9 1/2 yards of linen and she bought 4 1/2 yards more. How much linen did she then have?
DAILY PROBLEM WORKSHEET

1. If Rob earns $7.80 a week, how much will he earn in a year?

2. Jack's mother had $25 when she went shopping. When she came home she had $7.10. How much money had she spent?

3. Nine boys had to buy sleeping bags for themselves for a camping trip. If sleeping bags sell for $9.90 each, how much will the nine of them cost?

4. In an assembly room there are 32 rows of seats with 18 seats in each row. How many seats are there in the assembly hall?

5. Roberta spends 15¢ for trolley fare and 32¢ for lunch every school day. Last month she went to school 21 days. How much did it cost her for trolley fares and lunches last month?
DAILY PROBLEM WORKSHEET

1. Doris wanted to buy her mother a bottle of perfume which sold for $1.82. She had 78¢ in her bank and her father gave her 64¢. How much more money did Doris need before she could buy the perfume?

2. At one store Bob would have to pay 19¢ each for a dozen bayberry candles. At the second store, he could buy them at a price of three for 50¢. How much would he save by buying the candles at the second store?

3. Nine boys went to a sportsmen's store to buy some fishing tackle. Each boy bought a new pole, new reel, and some fancy flies for a total cost of $18.90. How much did the boys spend altogether?

4. There were 95 cookies to be served at a party. If each of the twenty-nine people there ate three cookies, how many would be left?

5. How much would a store owner have to pay for six coats if they sold at $154.80 a dozen?
1. Mr. Lucy was going on a business trip of 1680 miles. The first day he drove 352 miles, the second day 429 miles, the third day 395 miles, and the fourth day 374 miles. How far would he have to drive the fifth day to complete his trip?

2. Jack's arithmetic marks were 64, 88, 84, 76, and 98. What was his average mark?

3. Billy receives an allowance of $2.50 a month. How much does he receive in a year?

4. After Bud had shoveled the snow from 19 feet of sidewalk, he was 1/2 done. How long was the sidewalk from which he had to shovel the snow?

5. Johnstown is 1880 miles directly west of Burgundy. Dorsett is 720 miles directly east of Burgundy. How far is it from Johnstown to Dorsett?
DAILY PROBLEM WORKSHEET

1. After an oil company had drilled 89 feet, they were $1/3$ the way down. How far did they wish to drill?

2. If each one of a set of a dozen books cost 98¢, how much did the whole set cost?

3. Mr. Smith asked a bank clerk to give him six smaller bills for his fifty-dollar bill. Give a combination of six bills the clerk might have given him.

4. If six trays cost $3.78, how much would you have to pay for two of them?

5. What is the area of a lot 97 feet by 47 feet?
DAILY PROBLEM WORKSHEET

1. How much would Mrs. Pierce have to pay for six geraniums at 69¢ each and two boxes of pansies at 39¢ a box?

2. Bill hit a baseball 291 feet. Jack hit his baseball 1/3 of the distance that Bill's traveled. How far did Jack's baseball go?

3. Jimmy gets 25¢ a week allowance. How much does he receive in a year?

4. Clifford had $3. He gave his brother 95¢ and his sister 45¢. How much money did he have left?

5. How many feet are there in 252 inches?
1. At one store Mary would have to pay 11¢ each for a dozen dish towels. At a second store, she could buy them at a price of three for 25¢. How much would she save by buying them at the second store?

2. Five boys on a basketball team decided to buy new uniforms. The cost for the five uniforms was $39.40. How much did each boy have to pay for his uniform?

3. Billy's brother weighs 153 pounds. Billy weighs 68 pounds less than his brother. How much does Billy weigh?

4. The flag pole in the schoolyard is 72 feet high. How many yards high is it?

5. Mrs. Nolan had 15 3/8 yards of cloth. After she finished making a chair cover, she had 7 3/4 yards left. How much cloth did she use in making the chair cover?
1. There were 173 sandwiches to be served at a large picnic. If each one of the 49 people at the picnic ate three sandwiches, how many would be left?

2. How much would Rose have to pay for six aprons if they sold for $27.60 a dozen?

3. Mrs. Webster spent $2.51 for laundry one week, $1.56 the second week, $2.07 the third week, $1.98 the fourth week, and $1.43 the fifth week. What was her average laundry bill for those five weeks?

4. Jerry's father bought a phonograph player for $49.80. He paid for it in six equal payments. How much was each payment?

5. Mr. Ryder works six days a week and receives a weekly salary of $59.70. If he works the same number of hours a day, how much does he earn in a day?
1. After Mr. Johnson had varnished 21 square feet of his living room floor, he was 1/3 done. How many square feet does his living room floor contain?

2. At one store Jess would have to pay 11¢ each for a dozen notebooks. At another store, he could buy them at a price of four for 39¢. How much would he save by buying them at the second store?

3. In an assembly room there are 32 rows of seats with 18 seats in each row. If 1/3 of these chairs are occupied, how many empty ones are there?

4. Betty had $9 when she went shopping. She spent $3.10 in one store and $4.98 in another store. How much money did she have left?

5. Ruth, Anne, and Dora had $8.94 to divide among themselves. How much money did each girl receive?
1. An airplane flew 2436 miles in twelve hours. How many miles an hour did it average?

2. How much would eight grapefruit cost if they sold for $1.68 a dozen?

3. Shakerville is 990 miles from Magden. Portis is 1210 miles beyond Shakerville. How far is it coming from Magden to Portis?

4. If Scotstown is 3150 miles from Cedarham, and Blue Bonnet is 1940 miles from Cedarham, how much nearer to Cedarham is Blue Bonnet than Scotstown?

5. Badgerton is 620 miles directly north of Pineburg. Matchey is 590 miles directly south of Pineburg. How far is it from Badgerton to Matchey?
EXPERIMENTAL GROUP ESTIMATION TEST

Make a circle around the correct estimated answer. Do not find the exact answer. Do not use pencil and paper to do any figuring.

1. How much change would you receive from $20.00 if you bought a pair of shoes for $8.98 and a sweater for $2.98?

   $8  $9  $10  $11  $12

2. An airplane flew 2512 miles in eight hours. How many miles an hour did it average?

   200  3000  400  300  250

3. Jack has saved $17.20 toward a radio-phonograph. The one he wants to buy costs $39.90. How much more money does he need?

   $56  $30  $20  $21  $23

4. Marie's mother bought seven yards of ribbon at 59¢ a yard and eight yards of lace at 37¢ a yard. How much did she pay for her purchases?

   $1.00  $4.20  $3.20  $7.40  $8.50

5. Mr. Clark owned 59 pigeons. He bought 61 more and his son gave him 19 more for his birthday present. How many pigeons did Mr. Clark then have?

   110  140  80  100  130

6. How much change would you receive from $5.00 after buying six rolls of film at 39¢ a roll?

   $2.40  $1.60  $7.40  $4.60  $2.60
7. How many 49¢ toy cars could you buy with $7.00?

28 350 14 21 7

8. How much would you have to pay for two pictures if they are priced at six for $37.80?

$18 $240 $9 $12 $50

9. How much would a banquet committee have to pay for 44 quarts of ice cream at $2.90 a gallon?

$60 $50 $25 $120 $150

10. After Bill had read 59 pages in a book, he was \( \frac{1}{4} \) through the book. How many pages were there in the book?

180 15 240 12 200

On the blanks write the estimated answer for each one of the following problems. Do not do any figuring on paper. Do not find the exact answers.

___ 1. Geography books cost $1.98 each. How much would a school have to pay for books for a class of 26 pupils?

___ 2. What is the area of a playroom which is nine feet wide and nineteen feet long?

___ 3. Alden earns $9 a week. How much does he earn in a year?

___ 4. Mary Louise bought eight handkerchiefs at 69¢ each. How much did she have to pay for them?
5. Billy's arithmetic marks were 82, 78, 94, 88, and 68. What was his average mark?

6. How many cars would be needed to transport 682 cattle if each car holds 22 cattle?

7. Philip earns $21 a month. How much does he earn in a year?

8. If Dowville is 890 miles directly north of Kingsbury, and Hawley is 1320 miles directly south of Kingsbury, how far is it from Dowville to Hawley?

9. Nine boys shared a jar of hard candy among themselves. If each boy received 38 pieces of candy and there were seven pieces left, how many pieces of candy had there been in the jar?

10. How many feet are there in 492 inches?