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How extraneous number in problems affects the ability of sixth-grade pupils to solve such problems

Gallagher, Rosella M.
Boston University

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Boston University
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Thesis

HOW EXTRANEOUS NUMBER IN PROBLEMS AFFECTS THE ABILITY
OF SIXTH-GRADE PUPILS TO SOLVE SUCH PROBLEMS

Submitted by

Rosella Marie Gallagher
(B.S. in Ed., State Teachers College at Salem, Mass., 1940)

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First Reader: Dr. J. Fred Weaver  
Associate Professor of Education

Second Reader: Dr. Mark Murfin  
Associate Professor of Education
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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I. STATEMENT OF THE PROBLEM.</strong></td>
<td>1</td>
</tr>
<tr>
<td>Justification</td>
<td>1</td>
</tr>
<tr>
<td>Scope</td>
<td>2</td>
</tr>
<tr>
<td>Organization</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>II. REVIEW OF THE LITERATURE AND RESEARCH IN PROBLEM SOLVING</strong></th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>4</td>
</tr>
<tr>
<td>Methods of Solving Problems</td>
<td>4</td>
</tr>
<tr>
<td>Factors of Intelligence, Reading Comprehension, Vocabulary, and Computational Skill</td>
<td>9</td>
</tr>
<tr>
<td>The Effect of Extraneous Number in Problems Upon the Pupil's Ability to Solve Problems</td>
<td>17</td>
</tr>
<tr>
<td>Summary of Literature and Research in Problem Solving</td>
<td>21</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>III. PLAN AND PROCEDURE OF THE INVESTIGATION.</strong></th>
<th>23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organization of the tests</td>
<td>23</td>
</tr>
<tr>
<td>Administration of the tests</td>
<td>24</td>
</tr>
<tr>
<td>Scoring of the tests</td>
<td>24</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>IV. STATISTICAL ANALYSIS AND INTERPRETATION</strong></th>
<th>26</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis of test items</td>
<td>39</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>V. SUMMARY AND CONCLUSIONS</strong></th>
<th>41</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summary of the investigation</td>
<td>41</td>
</tr>
<tr>
<td>Conclusions</td>
<td>44</td>
</tr>
<tr>
<td>Limitations of the study</td>
<td>44</td>
</tr>
<tr>
<td>Suggestions for further study</td>
<td>45</td>
</tr>
<tr>
<td>CHAPTER</td>
<td>Page</td>
</tr>
<tr>
<td>----------</td>
<td>------</td>
</tr>
<tr>
<td>APPENDIX</td>
<td>46</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>54</td>
</tr>
</tbody>
</table>
LIST OF TABLES

Table                                      Page
I. Distribution of Intelligence Quotients for Sixty-one Sixth-Grade Pupils............................. 27
II. Distribution of Process and Computation Scores on Test I.......................................................... 29
III. Distribution of Process and Computation Scores on Test II......................................................... 31
IV. Distribution of Differences: Process Scores - Computation Scores................................................. 33
V. Distribution of Differences: Test I Scores - Test II Scores.............................................................. 35
VI. Summary of t-Tests of Significance.................................................. 37
VII. Distribution of Frequency of Errors Caused by Extraneous Number................................................ 40
CHAPTER I
STATEMENT OF THE PROBLEM

The purpose of this study is to discover, through testing, the extent to which the presence of extraneous number in problems affects the ability of pupils to solve such problems in Grade VI.

In this study the term problem refers to "...a quantitative situation described in words in which a definite question is raised, but for which the arithmetical operation is not indicated." 1

Extraneous number is any quantity expressed in the problem but which is not needed by the pupil in arriving at the solution of the problem. For example, the following problem can be found on page 10 of a well-known arithmetic series: "Pilots can fly 85 hours a month. In a recent year they were paid $4.60 an hour for day flying. How much did a pilot receive for flying 7 hours?" The number 85 is extraneous since it is not necessary to know this fact in order to answer the question posed in the problem.

Justification.-- It is generally recognized that in real-life situations problems do not come neatly packaged with just the right


numbers given which are necessary to solve the problem. Sanford says, "Many 'real life' problems contain information that is not needed." Problems which are of this kind challenge the pupil's ability, as well as his skill and ingenuity.

In several recent textbook series which this writer has investigated it has been discovered that there is a tendency to include among the problems some which contain extraneous number.

Little is known about the extent to which the presence of extraneous number in problems affects the ability of pupils to solve such problems, since hardly any studies have been made on this subject.

Scope.-- Sixty-one sixth-grade students in the town of Arlington, Massachusetts were used in this investigation. These were made up of two different classes in two different schools. Henceforth the classes will be referred to as Group A and Group B. Two tests containing 20 problems each were constructed. Test I contained problems of a general nature which dealt with whole number manipulations through the four fundamental processes, but contained no extraneous numbers. Test II contained problems similar to those in Test I, but extraneous number was injected in 15 of the 20 problems. Both groups, A and B, were tested with both Tests, I and II.

Organization.-- The remaining chapters include the detailed procedure of administering the two testing instruments, Test I and Test II; the presentation and interpretation of the test results; and the

summary and conclusions including suggestions for further study.
CHAPTER II
REVIEW OF THE LITERATURE AND RESEARCH
IN PROBLEM SOLVING

Introduction.-- Most children have experienced difficulty occasionally with problem solving in arithmetic. Johnson states that it is one of the greatest challenges in teaching elementary school arithmetic. There are numerous reasons why problem-solving situations cause much difficulty or failure among children. Many educators have made studies of the factors which influence a child's ability to solve problems. Some of the aspects of problem solving which will be considered in this review are: (1) methods of solving problems; (2) factors of intelligence, reading comprehension, vocabulary, and computational skill; and (3) the effect of extraneous number in problems upon the pupil's ability to solve problems.

1. Methods of Solving Problems

Among the methods which have been developed to aid pupils in the solution of problems, the four which follow are often taught:

1. Formal analysis method
2. Analogies method

3. Graphic method

4. Individual method.

In the formal analysis method the pupil follows a set pattern of steps, such as:

1. Read the problem.
2. What is given?
3. What am I asked?
4. What process must I use?
5. Solve the problem.

In the analogies method the pupils are trained to see similarities between problems. By noting the likenesses in situations, they would then apply similar methods of solution to such problems.

In the graphic method the pupil analyzes factors in the problem which depend upon other factors, and so on, until all the pertinent facts for the problem's solution have been revealed.

In the individual method the pupil is left to his own good judgment in choosing whatever process he feels can best reveal the answer the problem has asked.

In a study made in Grades 4 and 7 to determine which of three procedures in problem solving were most recommended, Hanna found, after studying textbooks, courses of study, and professional literature, that the formal analysis method or similar methods were most frequently suggested. He also studied the effectiveness of three methods of

problem solving, using 1,000 children from the fourth and seventh grades. These children were given careful drill for six weeks on problems with two or more steps. At the initial and final testing, identical standardized forms were used which included the New Stone Reading Test in Arithmetic and the Stanford Achievement Test in Arithmetic Reasoning. At first he considered the "dependencies method," which is sometimes referred to as the "graphic method." The second method, which he called the "conventional formula method," is sometimes termed the "formal analysis method," and the third method was termed the "individual method," in which the children used any procedure they wished. The results of Hanna's experiment showed that pupils who used the dependencies method or the individual method were superior in speed and accuracy to those who used the conventional formula method. In a study of the findings from the fourth grade, it was revealed that the dependencies method was superior over others for those with inferior ability, while there was no evidence of the superiority of any of the methods for pupils with high reasoning ability.

Clark and Vincent tested 80 children in the seventh and eighth grades at the Lincoln School, Teachers College, and found that, on the basis of results on the Stone Reasoning Test in Arithmetic and the Stanford Achievement Test, the dependencies method was superior to the conventional method.

Washburne and Osborne made a study using children in the sixth and seventh grades. The investigators matched these children on: ability to solve problems, and in arithmetic fundamentals, I.Q., C.A., and the judgment of the teacher. After a six weeks' study they concluded that formal analysis is less effective than the individual method with help given wherever needed. For those of inferior ability, problem analysis was found to be of some value.

Morandi carried on an experiment with 38 pupils from two sixth grades to investigate whether children who have been trained in the formal analysis method use this or some other procedure in problem solving. One group was thoroughly trained in analyzing problems. The second group was given an unusual amount of intensive drill in the analysis method, in addition to extra problem-solving practice. Morandi used an adaptation of the Spache Test of Abilities in Arithmetic Reasoning. The problem test consisted of 13 problems based on the fundamental processes, and were to be solved by the analysis method. The correct response out of a choice of four was encircled in Steps 1 to 4. Computation was done in Step 5. The steps were:


1. What does the problem tell you?
2. What must you find?
3. What must you do?
4. Guess the answer closest to the right answer.
5. Do the problem.\(^6\)

Group I was given the analysis test in two parts. Two weeks later they were interviewed and given an oral test (which excluded steps 1-4) to see how they would solve these problems when not told to follow a set pattern.

Group II was tested orally using the 13 problems without the analysis steps. The children then were interviewed. Two weeks later the same test was administered again. No specified technique was suggested for solving the problems, but it was felt these pupils might be influenced by the work they had done in formal analysis procedure.

Morandi concluded that the pupils in the study failed to follow the formal analysis procedure and used no definite techniques of attack in solving problems. However, only a limited number of pupils were used in this study and no attempt was made to control the practice effect.

In an experiment involving 1200 children of the fourth-grade level in Detroit, Theile equated three groups on the Stanford Achievement Test results. Each was taught a different method of problem solving for the next 15 weeks. One group was taught by the association method

\(^6\) Morandi, op. cit., p. 20.

whereby they learned to associate each problem with a model. The second group was taught the analysis method. The third group learned the vocabulary method whereby an important word was omitted from the statement of the problem and the pupils chose the correct missing word from a given set of words.

The gains on the Stanford Achievement Test revealed that the association method was statistically superior to the other two. Theile's experiment has been criticized because he did not use a control group which was asked to solve the problems without guidance. The analysis and vocabulary groups were not given an opportunity to actually solve the problem.

2. Factors of Intelligence, Reading Comprehension, Vocabulary, and Computational Skill

Investigations have shown that a positive correlation exists between intelligence and problem solving ability. The coefficient of .506 reported by Brueckner and Grossnickle is typical. Because of the fact that this relationship is not especially high, it has been observed that children whose mental abilities are similar may vary considerably in their ability to solve verbal problems, and vice versa.


Some of the intellectual factors which are closely related to the ability to solve verbal problems were reported by Johnson. He discovered that reasoning was second only to general vocabulary in importance in the ability of eighth-grade pupils to solve problems. This situation was reversed when problem scales without numbers were used instead of the regular problem scales.

Monroe and Engelhart experimented at the fifth-grade level with 26 classes in 13 schools. They obtained 181 pairs of pupils out of 600, who were matched on intelligence quotients, with their chronological ages kept the same. The groups also were equated with the New Stanford Reading Test and the New Stanford Arithmetic Test given at the start of the experiment. The control group was taught how to solve problems in the traditional manner. The experimental group was given further training in problem solving. They defined terms which dealt with processes; restated problems and composed new ones; and outlined the problems graphically. If the solution was not clearly evident, they were encouraged to read the problem again. The final tests, which paralleled those given initially, divulged no significant differences between the groups. However, it was disclosed that those with intelligence quotients below 100 gained more from systematic instruction.


than those with superior intelligence.

Fernald has reported that children of average intelligence and average reading ability fail in arithmetic because they lack computational skill even when they have chosen correct methods of solution, and they lack understanding of number.

Engelhart, in his study of verbal problems, found that intelligence, computation ability, and reading ability were related to the difficulty of solving the verbal problem. He noted that both mental ability and computational skills contribute to the difficulty and urged the provision for much instruction and drill.

In his work with sixth-grade children to find whether or not certain abilities could be linked with success in arithmetic word problems, Hansen discovered that those with excellent achievement in the solution of verbal problems were also superior in arithmetical factors, mental factors, and reading factors. Under arithmetical factors were considered the basic computational skills, the estimations of reasonable answers to examples and problems, the understanding of abstract numbers.


14/Carl W. Hansen, "Factors Associated with Successful Achievement in Problem Solving in Sixth Grade Arithmetic," Journal of Educational Research (October, 1944), 38:111-118.
the analysis of problems, the sequence of numbers, the quantitative concepts and relationships, the use of context clues, and the knowledge of arithmetic vocabulary. The following mental factors were discussed: the ability to reason, the discernment of likenesses and differences, the non-language factors, the analogous aspects, the memory span—both immediate and delayed, the effect of spacial relationships and imagery, and the arithmetical inference. The reading factors noted were: the ability to read graphs, charts, and tables, the general language ability, and the general knowledge of vocabulary.

Brueckner and Grossnickle have stated that "...the ability to read quantitative materials of many different kinds with understanding and for a wide variety of purposes is fundamental to success in arithmetic." They point out that quantitative materials have to be read very carefully to find basic information and relationships in order to solve problems, and have urged that pupils be given direct training in reading quantitative materials. Moreover, they stated that specialized reading abilities in arithmetic be developed since they neither result from general training in reading nor grow out of just practice in computation. Some of these skills necessary in order to read and solve textbook problems are:

"a. Comprehension of the meaning of the items and statements contained in a problem and the ability to visualize the situation presented.

15/Brueckner and Grossnickle, Making Arithmetic Meaningful, op. cit., p. 498.
b. The reading necessary in carrying out the steps usually followed in problem solving which are:
   (1) What question does the problem ask me to answer?
   (2) What facts are given in the problem? Is other information needed?
   (3) What steps must be taken to solve the problem?
   (4) Is my answer sensible?

c. Locating information not stated in the problem but necessary for its solution:
   (1) In accompanying tables, graphs, charts, pictures, etc.
   (2) In preceding problems and discussion
   (3) In reference books, catalogs
   (4) In appendix
   (5) In schedule forms, plans, maps.

d. Reading with understanding various formulas, equations and rules.16/

Among other causes of pupil difficulty in problem solving, Brueckner, in an earlier writing, listed failure to understand the problem in whole or in part due to poor reading ability, lack of ability to visualize, not enough practice in problem solving and the like, as well as carelessness in reading by omitting pertinent ideas, or misreading. Rehage has pointed out the importance of knowing at the outset the concept of the problem at hand so that the pupil may determine the relevance of the information gained through reading.


17/Leo J. Brueckner, "Improving Pupils' Ability to Solve Problems," Journal of National Education Association (June, 1932), 21:175-176.

Osburn and Drennan carried on an investigation to determine the worth of teaching cues to a group of third graders. They developed a series of problem cues, or language patterns, for each of the four processes. An initial test was given and then the cues were taught. A final test made up of cues that had not been taught was given to determine the amount of transfer. They found a great amount of transfer, even among those with low intelligence. They advocated the teaching of the most important problem types based on the results of their findings. However, no control was used in this experiment and no allowance was made for experimental errors.

Stevenson has found that a pupil has very often failed to solve a problem because he was unfamiliar with the meaning of one or more of the words. He further stated that the general reading vocabulary of students, as well as their knowledge of technical words used in textbooks, is poor.

Foran also has reported that there is little possibility that the child will choose the correct process for the solution of a problem if the meaning of important words in the problem is not known.


Treacy measured the problem-solving ability of 244 seventh-grade children and found that "...ability is definitely associated with a knowledge of vocabulary." He used the combined scores of the problem test sections of the Analytical Scales of Attainment and Public School Achievement Tests. Those used in one group were the 80 who had the highest combined scores. Those in the other group were the 80 with the lowest combined scores. The two groups were then compared. Treacy found that the good achievers were significantly superior to the poor achievers in several ways, among which were four reading skills associated with vocabulary.

Dresher studied the effects of concentrated drill in specific vocabulary of junior high mathematics by dividing 500 children into experimental and control classes. The experimental groups were given specific training in vocabulary. Lists of technical words and their meanings were given to these groups, while the control classes had no special training. The experimental classes showed greater gains, although these were not statistically significant.

Kramer found that children did better on problems that were factually stated in an interrogative form and expressed in simple language.


Using the Stanford Achievement Test and the National Intelligence Test as a basis for selection, Lutes equated four groups on their attainment. One group was used as a control group. The other three groups were taught by these methods: (a) "computation" method whereby drill was given on the computation skills which would be needed in problem solving the next day; (b) "choosing operations" method in which the pupils indicated the correct process and selected pertinent facts; and (c) "choosing solutions" method wherein three different solutions were presented for each problem and the children chose the correct one. The drills were given to the experimental classes one day each week and on the following day a problem test was administered. It was found that the gains were greatest when preliminary practice was given in computation.

Washburne made a study of the effect of the teaching of arithmetic mechanics on problem solving. Two groups were equated on problem-solving ability, skill in arithmetic mechanics, mental age, chronological age, and general working ability. The control group first learned computational processes and later applied them to problem situations. The experimental group learned the mechanics along with meaningful problems. No differences were noted between the groups at the end of the experiment.

25/ O. S. Lutes, An Evaluation of Three Techniques for Improving Ability to Solve Arithmetic Problems. University of Iowa Monographs in Education, First Series, No. 6, University of Iowa, Iowa City, 1926.
3. The Effect of Extraneous Number in Problems

Upon the Pupil's Ability to Solve Problems

Hardly any research is available on the effect of extraneous number upon the ability of pupils to solve problems. Therefore, the following resume must of necessity be brief.

According to Schaaf, one of the skills which children need to acquire is the ability to "...recognize facts that are superfluous or irrelevant in a problem." He has pointed out that problems met in real life do not contain exactly the required data, no more and no less, nor are they always "...tailored to suit set patterns that have been previously taught."

Stokes has pointed out that the underlying skills in problem solving are to read to grasp the idea of the problem, then to differentiate and discriminate to find the parts that belong to the situation, and finally to compute the problem.

Sanford has said that problems are more real when the parts necessary for their solution must be sifted from a mass of data which may seem relevant. She has pointed out that such problems have value.


28/ Ibid., p. 494.


because the student has to exercise judgment in differentiating between pertinent and irrelevant details. She has listed the following forms of extraneous data which may be present in problems: (a) descriptive details of name, place, time, etc.; (b) numerical details quite irrelevant to the problem; (c) numerical details which seem essential; and (d) quantitative relations stated redundantly. Details of a problem which have been included to give a realistic setting may distract the attention of the student to the problem. These have been termed descriptive details or irrelevant numerical details. The presence of numerical details which appear to be relevant to the problem presents real difficulties to the student. This is probably the most effective use of unnecessary data. The fourth type in which an essential relationship has been restated occurs hardly at all. Sanford warned that one must use discretion in including extraneous data in problems since such details may distract the child so that he cannot visualize the situation.

Cruickshank\footnote{William M. Cruickshank, "Arithmetic of Mentally Retarded Children: I. Ability to Differentiate Extraneous Materials from Needed Arithmetic Facts," \textit{Journal of Educational Research} (November, 1948), 42:161-170.} carried on an investigation to discover whether mentally retarded children of a given mental age are not as successful as normal children of a similar mental age because the mentally retarded group are unable to choose specific arithmetic elements which are needed in problem solving. He used 30 boys as subjects for this study. Fifteen boys used as the experimental group were students at Wayne
County Training School, Northville, Michigan. The fifteen in the control group were from the Adams Elementary School, Birmingham, Michigan. The chart which follows gives some statistical information about the experimental and the control groups.

<table>
<thead>
<tr>
<th></th>
<th>Group I (Experimental)</th>
<th>Group II (Control)</th>
</tr>
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<tbody>
<tr>
<td>Mean C.A.</td>
<td>14.29 yrs.</td>
<td>9.09 yrs.</td>
</tr>
<tr>
<td>Mean M.A.</td>
<td>10.06 yrs.</td>
<td>9.96 yrs.</td>
</tr>
<tr>
<td>Mean I.Q.</td>
<td>73.33</td>
<td>110.4</td>
</tr>
<tr>
<td>Mean Arithmetic Age</td>
<td>9.73</td>
<td>9.84</td>
</tr>
</tbody>
</table>

The t-ratio between the mean mental age and the mean arithmetic age for the experimental group was 1.169, which was significant at the 5 per cent level, while that of the control group was 1.265, which was significant at the 30 per cent level. It was noted that basic differences did not exist between the mental age and the arithmetic age. Furthermore, significant differences did not appear between the mental ages of the experimental and control groups or between the arithmetic ages of both groups.

The subjects of the experiment had arithmetic ability similar to that of third-grade children as measured by the results of Form Z, Stanford Achievement Tests, Primary and Advanced.

Tests were constructed made up of eight sets, each set containing three problems: A, B, and C. Problem A contained considerable superfluous data. Problem B had only verbal matter which pertained to the
problem. Extraneous matter was not present. Problem C was set up in the form of a simple computation. Each problem was typed on a large card and given individually. Series A of the eight exercises was given in one period. After a lapse of 48 hours the eight exercises in Series B were given. After another 48-hour lapse, series C was given. The examiner read the problems orally while the subject read them silently.

The results of the testing showed that the retarded pupils were inferior to the normal group in each phase of the testing. In Problem A series there was a better than 1 per cent level of significance for the difference between the groups. There were also significant differences between the responses of the two groups on Problem B series. Although a significant difference existed between the responses of the two groups on Problem series C, it was not at as high a level of confidence. This may be because the form of the exercise is concrete and, therefore, the performance is consistent.

Cruickshank found that the differences in mean scores for correctness in the first two series were significant for the experimental group, while they were not significant for the control group.

The differences between the mean scores of series A and C were significant at the 1 per cent level for both the experimental and control groups, although the difference of the experimental group was more than three times as great as that of the control group.

The differences in mean scores of Problem series B and C were not significant either for the experimental or the control groups.
In the experimental group the responses were significant between series A and B, but the differences between the means for A and C were much greater than between series A and B or between series B and C.

In the control group there was no significant difference between the responses to series A and B. The difference between the means for series A and C was significant at the 1 per cent level.

Cruickshank noted that the presence of extraneous materials in problems caused a great deal of confusion to both normal and mentally retarded boys, although the mentally retarded were more influenced by it. Mentally retarded boys could not differentiate as well as normal boys between pertinent and unnecessary facts. The normal boys did better than the retarded in working out the problems free of superfluous material.

4. Summary of Literature and Research in Problem Solving

I. Methods of Solving Problems

There is much doubt about the superiority of any one method over another. Systematic and persistent training may result in improvement, especially for those of limited abilities. For the brighter pupils the individual method seems most effective.

All of the following methods have been used by educators at one time or another:

A. Individual method

B. Graphic method

C. Analogies method
D. Formal analysis method.

II. Factors of Intelligence, Reading Comprehension, Vocabulary, and Computational Skill

Most educators are in agreement that the following factors have an important influence on the ability of pupils to solve problems, although they do not agree on the importance of one over another:

A. General vocabulary understanding
B. Ability to reason
C. Knowledge of computational skills
D. Understanding of abstract numbers
E. Analysis of problems
F. Quantitative concepts and relationships
G. Use of context clues
H. Visualization of the problem situation
I. Specific arithmetic vocabulary understanding.

General intelligence, as such, does not influence the pupil's ability to solve problems as much as some people have been led to believe.

III. The Effect of Extraneous Number in Problems Upon the Pupil's Ability to Solve Problems

The presence of extraneous number in problems presents difficulty to all students, especially those of lower mental abilities. However, extraneous number often exists in real-life problems.
CHAPTER III

PLAN AND PROCEDURE OF THE INVESTIGATION

Organization of the tests.-- Since the purpose of this study was to determine the extent to which the presence of extraneous number affects the ability of pupils to solve such problems, two tests were constructed. Both tests included one- and two-step problems involving easy computations of whole numbers through the four fundamental processes. Test I contained 20 problems without extraneous number, while in Test II fifteen of the twenty problems contained extraneous number. Five problems in Test II contained no extraneous number and were inserted as distractors so that pupils would not anticipate the presence of the extraneous numbers in every problem.

The following problems serve to illustrate the type used in each test:

Test I

Bill made these scores on four arithmetic tests: 90, 75, 80, and 100. What was his average score?

Test II

Helen is reading the story of Robinson Crusoe. The first week she read 24 pages on Monday, 45 pages on Tuesday, 39 pages Wednesday, 12 pages Thursday, and 17 pages Friday. There are 259 pages in the story. What was the average number of pages Helen read each day?

The format for both tests was similar. Each test contained four typed pages. Identical directions for the pupils were given on page one.
but the sample problem for Test I contained no extraneous number, while the sample for Test II included extraneous number. The problems were arranged in two columns on each page. There was a section provided for recording the choice of process by its initial letter as well as space for computing the problem.

**Administration of the tests.**-- Two sixth-grade classes from two different Arlington elementary schools totalling 61 pupils were used in the testing program. Test I was administered to Group A while Test II was given to Group B. Two weeks later Test II was given to Group A while Test I was administered to Group B. This was done to eliminate any practice effect.

The directions were read by the pupils and the teacher together, and the teacher explained the sample problem. Once the test was begun, no help was given to the children. There was no time limit and each child was allowed to finish the test.

**Scoring of the tests.**-- Two scores were recorded for each test. One score was for the total number correct in choice of process. The other score was for the total number correct in computation. No partial credit was allowed. The results of the tests were tabulated and four sets of differences were found. Two of these were differences between process and computation scores for Test I and Test II. The third was the difference between Test I and Test II results when the process scores were compared. The fourth difference was found when the computation scores for both tests were compared. Data from the administration of these tests are presented and analyzed in Chapter IV.
The I.Q.'s of all the children, based on the California Short-Form Test of Mental Maturity, El. 1950 S-Form, were available and were used in studying certain of the relationships discussed in Chapter IV.
CHAPTER IV

STATISTICAL ANALYSIS AND INTERPRETATION

This chapter contains seven tables which reveal the significant outcomes of the investigation to determine the extent to which the presence of extraneous number in problems affects the ability of pupils to solve such problems in Grade VI, as well as an analysis of the test items. Each table is preceded by a brief explanation of its content.

Table I shows the distribution of intelligence quotients for the 61 pupils involved in this study. These scores were derived from the California Short-Form Test of Mental Maturity, El. 1950 S-Form. The pupils' I.Q.'s have been arranged in intervals of five to include from the highest to the lowest scores of pupils tested. There was a wide range of scores, from the highest, which was 145, to the lowest of 84. The frequency of the number of cases in each interval is given in the second column opposite the I.Q.'s. The total number of cases tested was 61, while the mean score was 113.63. This is above average and accounts for the relatively high mean. The standard deviation was 15.53 because of the wide range and uneven distribution of I.Q.'s.
<table>
<thead>
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<th>Interval</th>
<th>Frequency</th>
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<td>140 - 144</td>
<td>2</td>
</tr>
<tr>
<td>135 - 139</td>
<td>3</td>
</tr>
<tr>
<td>130 - 134</td>
<td>7</td>
</tr>
<tr>
<td>125 - 129</td>
<td>4</td>
</tr>
<tr>
<td>120 - 124</td>
<td>5</td>
</tr>
<tr>
<td>115 - 119</td>
<td>4</td>
</tr>
<tr>
<td>110 - 114</td>
<td>7</td>
</tr>
<tr>
<td>105 - 109</td>
<td>9</td>
</tr>
<tr>
<td>100 - 104</td>
<td>8</td>
</tr>
<tr>
<td>95 - 99</td>
<td>6</td>
</tr>
<tr>
<td>90 - 94</td>
<td>1</td>
</tr>
<tr>
<td>85 - 89</td>
<td>3</td>
</tr>
<tr>
<td>80 - 84</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number 61</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean 113.63</td>
</tr>
<tr>
<td>Standard Deviation 15.53</td>
</tr>
</tbody>
</table>
Table II shows the results of Test I. The scores have been arranged from the highest to the lowest number of correct answers. The maximum score possible on each test was 20. Two sets of scores were tabulated, one for choice of process and one for carrying the solution to a correct conclusion. The frequency, based on the number of correct responses for each score, was listed for process and computation.

A mean process score of 17.00 was found for Test I, revealing that the pupils had little difficulty in choosing the correct process needed for solving each problem. The standard deviation for process scores was 2.46.

The mean of the computation scores was 15.18. This indicates that the pupils were better able to choose the right process than they were able to completely solve such problems correctly. The standard deviation of the computation scores for Test I was 3.07.
**TABLE II**

**DISTRIBUTION OF PROCESS AND COMPUTATION SCORES ON TEST I**

<table>
<thead>
<tr>
<th>Score Number Right</th>
<th>Frequency Process</th>
<th>Frequency Computation</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>19</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>18</td>
<td>11</td>
<td>4</td>
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<tr>
<td>17</td>
<td>15</td>
<td>8</td>
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<tr>
<td>16</td>
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<td>12</td>
</tr>
<tr>
<td>15</td>
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<td>10</td>
</tr>
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<td>14</td>
<td>1</td>
<td>7</td>
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<td>13</td>
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<td>7</td>
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<td>12</td>
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<td>11</td>
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<td>1</td>
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<tr>
<td>10</td>
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<tr>
<td>9</td>
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<tr>
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<tr>
<td>6</td>
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<td>3</td>
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<tr>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Number | 61            | 61                      |
Mean   | 17.00         | 15.18                   |
Standard Deviation | 2.46 | 3.07                   |
A format similar to that used in Table II was followed for Table III, which represents the frequency of the correct score in choosing the process and computing the problem in Test II. Again, the maximum score possible on each test was 20.

The mean of the process scores in Test II was 16.00, showing that the pupils had more difficulty in choosing the correct process than they had in Test I. The standard deviation for the process scores was 2.55.

The mean of the computation scores was 13.87 on Test II. These scores on the second test, which included extraneous number, were lower than the Test I results. The standard deviation for Test II computation was 2.98.
TABLE III
DISTRIBUTION OF PROCESS AND COMPUTATION SCORES ON TEST II

<table>
<thead>
<tr>
<th>Score Number Right</th>
<th>Frequency Process</th>
<th>Frequency Computation</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>19</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>18</td>
<td>6</td>
<td>2</td>
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<tr>
<td>17</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>16</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>15</td>
<td>4</td>
<td>13</td>
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<tr>
<td>14</td>
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<td>8</td>
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<td>13</td>
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<td>12</td>
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<td>11</td>
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<td>10</td>
<td>1</td>
<td>3</td>
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<tr>
<td>9</td>
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<td>2</td>
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<tr>
<td>8</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
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<td>2</td>
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<tr>
<td>6</td>
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<td>0</td>
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<tr>
<td>5</td>
<td>0</td>
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<td>4</td>
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</tr>
<tr>
<td>3</td>
<td>0</td>
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<tr>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Number 61 61
Mean 16.00 13.87
Standard Deviation 2.55 2.98
Table IV shows the distribution of differences for Test I and Test II when the pupil's computation score was subtracted from his process score for each test. These differences were arranged from the highest, a difference of 6, to the lowest, a difference of -1. The negative difference occurred when one pupil achieved a higher score on computation for Test II, the test with extraneous number, than for process choice. The number of cases corresponding to each difference in both Test I and Test II is given under the frequency column.

For Test I the number of cases tested was 61. The mean difference was 1.82 and the standard deviation of the difference was 1.58.

For Test II the number of cases tested was also 61, the mean difference was 2.13, and the standard deviation was 1.49.

These results show that more pupils achieved a greater difference between their process scores and their computation scores on Test II than on Test I. This finding might indicate that there was some factor which hindered their success in solving the problem correctly after the correct process was chosen. We might assume this factor to be the extraneous numbers involved.
TABLE IV
DISTRIBUTION OF DIFFERENCES:
PROCESS SCORES - COMPUTATION SCORES

<table>
<thead>
<tr>
<th>Difference Score</th>
<th>Frequency Test I</th>
<th>Frequency Test II</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>5</td>
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<tr>
<td>4</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>13</td>
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<tr>
<td>2</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>1</td>
<td>20</td>
<td>13</td>
</tr>
<tr>
<td>0</td>
<td>13</td>
<td>7</td>
</tr>
<tr>
<td>-1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Number</td>
<td>61</td>
<td>61</td>
</tr>
<tr>
<td>Mean</td>
<td>1.82</td>
<td>2.13</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>1.58</td>
<td>1.49</td>
</tr>
<tr>
<td>Difference</td>
<td>Frequency Process</td>
<td>Frequency Computation</td>
</tr>
<tr>
<td>------------</td>
<td>------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>1</td>
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<tr>
<td>6</td>
<td>1</td>
<td>1</td>
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<tr>
<td>5</td>
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<td>2</td>
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<tr>
<td>4</td>
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<td>3</td>
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<td>2</td>
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<tr>
<td>1</td>
<td>14</td>
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<td>0</td>
<td>9</td>
<td>5</td>
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<tr>
<td>-1</td>
<td>6</td>
<td>5</td>
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<tr>
<td>-2</td>
<td>3</td>
<td>7</td>
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<tr>
<td>-3</td>
<td>2</td>
<td>0</td>
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<td>-4</td>
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<td>-5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>-6</td>
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<td>0</td>
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<tr>
<td>-7</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Number</td>
<td>61</td>
<td>61</td>
</tr>
<tr>
<td>Mean</td>
<td>1.00</td>
<td>1.31</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>2.59</td>
<td>2.52</td>
</tr>
</tbody>
</table>
The following null hypotheses were the major ones tested in this study:

1. For the kinds of verbal problems used in this investigation, there is no difference between the ability to select the correct process to be used in solving such problems and the ability to carry the solutions through to successful completion, regardless of whether or not extraneous numbers are present.

2. For the kinds of verbal problems used in this investigation, the presence of extraneous numbers has no effect either on the ability to select the correct processes to be used in solving such problems or on the ability to completely solve such problems correctly.

The t-tests used in relation to these null hypotheses are summarized below in Table VI.
### TABLE VI
SUMMARY OF $t$-TESTS OF SIGNIFICANCE

<table>
<thead>
<tr>
<th>Kinds of Scores</th>
<th>Mean of Distribution of Differences</th>
<th>SD of Distribution of Differences</th>
<th>$SE_{diff}$*</th>
<th>$t$ **</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a. Difference in Test I Scores: Process - Computation</td>
<td>1.82</td>
<td>1.58</td>
<td>.20</td>
<td>9.10</td>
</tr>
<tr>
<td>1b. Difference in Test II Scores: Process - Computation</td>
<td>2.13</td>
<td>1.49</td>
<td>.19</td>
<td>11.21</td>
</tr>
<tr>
<td>2a. Difference in Process Scores: Test I - Test II</td>
<td>1.10</td>
<td>2.59</td>
<td>.33</td>
<td>3.03</td>
</tr>
<tr>
<td>2b. Difference in Computation Scores: Test I - Test II</td>
<td>1.31</td>
<td>2.52</td>
<td>.33</td>
<td>3.97</td>
</tr>
</tbody>
</table>

*Computed from the formula: $SE_{diff.} = \frac{SD \text{ of distribution of differences}}{\sqrt{N - 1}}$

**Computed from the formula: $t = \frac{\text{Mean of distribution of differences}}{SE_{diff.}}$
For df = 60, t must equal 2.66 to be significant at the 1 per cent level. Since all t-ratios in Table VI far exceed this value, we may reject each null hypothesis with a high degree of confidence. Thus we may conclude that:

1. There would appear to be a significant difference between the ability to select the correct process to be used in solving the verbal problem of the kind used in this investigation and the ability to carry the solution through to successful completion. The latter ability would appear to be significantly lower than the former, regardless of whether or not extraneous numbers are present.

2. The presence of extraneous numbers would appear to have a significantly detrimental effect on both the ability to select the correct processes to be used in solving verbal problems of the kind used in this investigation and on the ability to completely solve such problems correctly.

Since the presence of extraneous numbers appeared to affect problem solving significantly, it was decided to measure the relationship between this effect and intelligence. The following coefficients of correlation were computed:

Between I.Q. and the effect of extraneous number on choice of process (Test I - Test II): \( r = -0.06 \).

Between I.Q. and the effect of extraneous number on computation (Test I - Test II): \( r = 0.09 \).
Since \( r \) must equal 0.25, when \( df = 59 \), to be significant at the 5 percent level, we have no cause to reject the null hypothesis that the effect of extraneous numbers on both the selection of process and the complete solution of the problem was unrelated to I.Q.

**Analysis of test items.**-- The following item analysis shows the effect of extraneous number on the pupils' ability to completely solve such problems correctly. Only the problems which contained extraneous number have been considered. In nine of these fifteen problems in Test II more than half of the errors made were caused by the presence of extraneous number. In five of the six remaining problems, extraneous number caused some difficulty in the problem's solution. Of a total of 270 errors made, 156, or more than half of these errors, were caused by the presence of extraneous number in the problem.
TABLE VII
DISTRIBUTION OF FREQUENCY OF ERRORS CAUSED BY EXTRANEOUS NUMBER

<table>
<thead>
<tr>
<th>Problem Number</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Errors Caused by Extraneous Number</td>
</tr>
<tr>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>*</td>
</tr>
<tr>
<td>4</td>
<td>*</td>
</tr>
<tr>
<td>5</td>
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<tr>
<td>6</td>
<td>0</td>
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<td>8</td>
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<td>9</td>
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<td>13</td>
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<td>14</td>
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<td>15</td>
<td>25</td>
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<td>*</td>
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<td>17</td>
<td>4</td>
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<tr>
<td>18</td>
<td>*</td>
</tr>
<tr>
<td>19</td>
<td>21</td>
</tr>
<tr>
<td>20</td>
<td>13</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>156</strong></td>
</tr>
</tbody>
</table>

* Items which contained no extraneous number. The frequency of errors made on these five problems have not been listed since the problems were inserted as distractors.
CHAPTER V
SUMMARY AND CONCLUSIONS

Summary of the investigation. -- The purpose of this study was to discover, through testing, the extent to which the presence of extraneous number in problems affects the ability of pupils to solve such problems in Grade VI. Sixty-one pupils at the sixth-grade level in Arlington, Massachusetts, were used in this investigation. The group was made up of two classes in two different schools. The mean I.Q. of the group was 113.63 and the standard deviation was 15.53, showing a wide range.

Two tests, each containing 20 problems, were constructed. Test I contained problems of a general nature which dealt with whole number manipulations through the four fundamental processes, but contained no extraneous numbers. Test II contained problems similar to those in Test I, but extraneous number was injected in 15 of the 20 problems. These five problems were inserted as distractors so that pupils would not anticipate the presence of extraneous number in every problem. Test I was administered to Group A while Test II was given to Group B. Two weeks later Test II was given to Group A while Test I was administered to Group B. This was done to eliminate any practice effort. There was no discussion of the test with the class between the two testing periods.
Two scores were recorded for each test. One score was for the total number correct in choice of process. The second score was for the total number correct in computation. No partial credit was allowed. The two sets of scores for each test were then tabulated. A mean process score of 17.00 was found for Test I, and the standard deviation of the process scores was 2.46. The mean of the computation scores for Test I was 15.18, and the standard deviation of these scores was 3.07.

On Test II a mean process score of 16.00 was revealed, showing that the pupils had more difficulty in choosing the correct process than in Test I. The standard deviation for the process scores for Test II was 2.55. The mean of the computation scores on Test II was 13.87. These scores on the second test which included extraneous number were lower than the Test I results. The standard deviation for Test II computation was 2.98.

An item analysis of the 15 problems in Test II which contained extraneous numbers revealed that more than half of the errors made in these problems were caused by the extraneous numbers which they contained.

Four sets of differences were then found. Two of these differences were between process and computation scores for Test I and Test II. In each case the pupil's computation score was subtracted from his process score. A negative difference occurred when one child achieved a higher score on computation for Test II than for process choice. For Test I the mean difference was 1.82 and the standard
deviation of the difference was 1.58. For Test II the mean difference was 2.13 and the standard deviation was 1.49.

Two other differences were found when each pupil's Test II score was subtracted from his Test I score for both process and computation. Here, too, negative differences occurred when a pupil achieved a higher process or computation score on Test II than on Test I. The mean of the difference for process was 1.00 and the standard deviation for difference in process was 2.59. The mean of the difference for computation was 1.31 and the standard deviation for difference in computation was 2.52.

These four differences were tested for statistical significance. for df = 60, t must be equal to 2.66 to be significant at the 1 per cent level. All t-ratios far exceeded this value.

Coefficients of correlation were also computed to measure the relationship between the effect of the presence of extraneous numbers in problem solving upon the ability of children to solve such problems and their intelligence. Between I.Q. and the effect of extraneous number on choice of process (Test I - Test II): \( r = -0.06 \). Between I.Q. and the effect of extraneous number on computation (Test II - Test I): \( r = 0.09 \). Since \( r \) must equal 0.25, when df = 59, to be significant at the 5 per cent level, the effect of extraneous numbers on both the selection of process and the complete solution of the problem, for the type of verbal problem used, was unrelated to I.Q.
Conclusions.-- For the sixth-grade pupils tested and for the type of verbal problems used in this investigation, the following conclusions were reached:

1. There would appear to be a significant difference between the ability to select the correct process to be used in solving the verbal problem and the ability to carry the solution through to successful completion. The latter ability would appear to be significantly lower than the former, regardless of whether or not extraneous numbers are present.

2. The presence of extraneous numbers would appear to have a significantly detrimental effect on both the ability to select the correct processes to be used and the ability to solve such problems correctly.

3. The effect of extraneous numbers on both the selection of process and the complete solution of the problem appeared to be unrelated to I.Q. It is quite possible that a significant relationship might be observed if the problems used were at a higher level of difficulty.

Limitations of the study.--

1. The small number of pupils involved will not permit too broad an application of the conclusions which were drawn.

2. The 61 pupils tested were all at the sixth-grade level.

3. Whole number manipulations only were used in the test items.
Suggestions for further study.--

1. Use the suggested procedures of this investigation with a larger population, and at other grade levels.

2. Use the same type of test at the sixth-grade level, but include test items at higher levels of difficulty, such as common fraction and decimal fraction manipulations through the four processes.
APPENDIX
3. Kay's family took a 294-mile trip in their car. They started at 8:00 A.M. and arrived at 5:00 P.M., stopping two hours for lunch and rest. What was their average speed per hour?

In this problem I would

4. Bill made these scores on four arithmetic tests: 90, 75, 80, 100. What was his average score?

In this problem I would

5. What is the area of a rectangle 7 feet long and 6 feet wide?

In this problem I would

6. On a trip to Florida, John's family stopped at motels 3 different nights. It cost $8.50 each night. What was the total cost for motels on the trip?

In this problem I would

7. Six candy bars cost 25¢. How many could you buy for $1.25?

In this problem I would

8. Six boys were playing ball when they broke Mrs. Green's living room window. They decided to share the cost of its repair which was $3.60. What did each one pay?

In this problem I would
9. How much change will George's father receive from a $5.00 bill if he pays for 8 gallons of gasoline at $.27 a gallon?
   
   In this problem I would ________________

10. Jim had $4.00 in the bank and has saved $1.57 since then. How much more does he need to buy a camera which costs $6.98?
   
   In this problem I would ________________

11. On a sale, Arthur bought a $79.95 bicycle for $52.50. How much did he save?
   
   In this problem I would ________________

12. One basketball uniform costs $6.95. How much will the P.T.A. pay for 15 uniforms?
   
   In this problem I would ________________

13. How many boys' basketball teams with 5 on a team can be made from a squad of 35?
   
   In this problem I would ________________

14. If an automobile averaged 45 miles an hour and traveled a distance of 720 miles, how many hours did the trip take?
   
   In this problem I would ________________
15. How fast does a bus travel if it goes 240 miles in 4 hours?

In this problem I would __________

16. It costs 20¢ for children and 85¢ for adults at a local theater. How much will it cost for 1 child and 2 adults to attend a movie?

In this problem I would __________

17. Mary was born in 1939. How old is she?

In this problem I would __________

18. Jim bought 3 pounds of hamburg at $.79 a pound. The other food cost $1.65. What was the cost of all the food?

In this problem I would __________

19. Connie's book has 268 pages. She has read 196 of these. How many are left to read?

In this problem I would __________

20. A school has 503 pupils. Of these 349 are boys. How many are girls?

In this problem I would __________
PROBLEM-SOLVING TEST II

Directions:

Read each problem carefully. Then indicate in the box by letters which process or processes you are going to use in order to solve the problem. Then do the work in the space below each problem. Do all work on the paper.

Sample 1

A roast of beef costs $.85 a pound and ham costs $.75 a pound. How much would a 6 pound roast of beef cost?

In this problem I would [M]

$.85
x6
$5.10

1. Helen is reading the story of Robinson Crusoe. The first week she read 24 pages on Monday, 45 pages on Tuesday, 39 pages Wednesday, 12 pages Friday. There are 259 pages in the story. What was the average number of pages Helen read each day?

In this problem I would [ ]

2. Mary had $5.00 in her piggy bank. She bought a few gifts with some of her money; a comic book for $.15, a box of notepaper for $.89, a small kerchief for $.25 and a plastic truck for $.59. If she took $2.00 with her, did she have enough money for the gifts?

In this problem I would [ ]
3. If 2 cans of soup cost 29¢ how much will 6 cans cost?
   In this problem I would

4. Four girls gave a party for 12 of their friends. It cost $2.40. What was each one's share?
   In this problem I would

5. How many teams of girls, six on a team, can be made of a group of 42 pupils?
   In this problem I would

6. Jim is older than his 3 brothers. He was born in 1928. How old is he?
   In this problem I would

7. Three performances were given of the children's play. Tickets were 10¢ for youngsters and 35¢ for grownups. What was the cost of admission for 3 grownups and one child?
   In this problem I would

8. In one month George read 3 books. The book he is reading now has 285 pages. He has already read 193. How many are left to read?
   In this problem I would
9. Mary bought 3 yards of cloth at $.69 a yard. How much change did she receive from $3.00?

In this problem I would ___

10. John wants to frame 3 pictures of early trains. How many inches of framing will he need for each picture if it is 9 inches by 12 inches?

In this problem I would ___

11. Five boys contributed $1.50 each toward the cost of a $14.00 basketball. How much have they given?

In this problem I would ___

12. Susan has $3.50 in her piggy bank and received $2.00 for her month's allowance. She is saving to buy a new dress which costs $5.98. She already has eight dresses. How much more does she need to save to buy the dress?

In this problem I would ___

13. A train travels 60 miles an hour and goes a distance of 360 miles. There are twenty-four cars in all. How many hours did it take for the trip?

In this problem I would ___

14. There are 16 classes in a school. The total number of children attending is 408. If there are 187 boys, how many are girls?

In this problem I would ___
15. A bus which carried 44 passengers set out for New York from Boston, a distance of 220 miles, at 9:00 A.M. and arrived at 3:00 P.M. making stops amounting to one hour. What was the average speed of the bus?

In this problem I would ___

16. What is the area of a flower garden 3 ft. wide and 8 ft. long?

In this problem I would ___

17. There were six train sets placed on sale. Usually they cost $79.50 but the new price was $55.50. What was saved on each train set?

In this problem I would ___

18. How fast does a car travel if it goes a distance of 240 miles in 4 hours?

In this problem I would ___

19. Nine boys played on a baseball team. They won 4 games. Their uniforms cost $8.95. The school supplied 15 uniforms to a squad. How much did they cost?

In this problem I would ___

20. Agnes bought 3 lbs. of fish at $.59 a pound. She spent $1.56 for vegetables and groceries. She had $5.00 with her. How much did all the food cost?

In this problem I would ___
BIBLIOGRAPHY


