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An Analytic Study of Eight-Grade Pupil Performance As Revealed Through The Stanford Achievement Test in Arithmetic

Dominic J. Brungardt
Fort Hays Kansas State College

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AN ANALYTIC STUDY OF EIGHT-GRADE PUPIL

PERFORMANCE AS REVEALED THROUGH THE

STANFORD ACHIEVEMENT TEST IN ARITHMETIC

being

A thesis presented to the Graduate Faculty

of the Fort Hays Kansas State College in

partial fulfillment of the requirements for

the Degree of Master of Science

by

Dominic J. Brungardt, A. B.

Fort Hays Kansas State College

Date *April 6, 1949*　　　Approved *Robert T. McGrath*
　　　　　　　　　　　　　　Major Professor

F. W. Albertson
Chairman Graduate Council

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ACKNOWLEDGMENTS

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CHAPTER I

INTRODUCTION

During the writer's experience as a teacher in elementary
and later in the secondary schools of Kansas, there was much op-
portunity to observe the difficulties pupils encountered in handling
the four fundamental processes of arithmetic, especially when in
conjunction with working problems that required an understanding
of mathematical terms, interpretation of problems, and the ability
or lack of ability to choose the proper arithmetical processes in
sequential order to obtain correct answers to problems.

As further evidence of difficulties encountered by pupils in
solving arithmetic problems, teachers continuously reminded the writer
of pupil weakness in problem solving. Furthermore the writer, from
experience as a teacher of both algebra and general mathematics, be-
lieves such pupil weakness was more evident in algebra than in general
mathematics. This, of course, might be expected since pupils have had
more experience in arithmetic relations than in algebraic symbolism.
After consideration of pupil difficulties in arithmetic, it agreed
that giving mathematics entrance tests might point the way in eventu-
ally meeting some of the weaknesses, to which reference has been
made.

Since the State Department of Public Instruction in the State
of Kansas makes extensive use of standardized tests in measuring pupil
achievement in certain elementary school subject fields, it is in the

pupil responses made in these tests that the problem of the thesis finds itself rooted. The problem may be stated specifically thus:

An Analytic Study of Eight-Grade Pupil Performance as Revealed through the Stanford Achievement Test in Arithmetic.

A copy of the test in the appendix, consists of a number of parts: one part is arithmetic. Close study of the problems in the test yields a certain classification such as one-step and two-step problems; likewise a certain terminology evolves. Consequently there follows an explanation of terms and definitions inherent in the study of pupil performance. The refinement of some terms and definitions follows:

(a) By a one-step problem in arithmetic is meant a problem in which one, and only one arithmetical process must be used to obtain a correct solution no matter how complicated the reasoning and thinking may be in order to obtain the correct answer.

(b) By a two-step problem is meant a problem in which two arithmetical processes must be used to obtain the correct answer no matter how complicated the reasoning or thinking may be.

(c) By equated score is meant a device for reducing all the raw scores of the subtests to comparable terms thus making the units approximately equal at all points in the scale.

(d) By an arithmetical process is meant addition, subtraction, multiplication, or division.

Method and Scope

The test was administered to pupils in rural schools in Ellis, Russell, Trego and Ness Counties of west-central Kansas in the spring of 1942. The school terms were eight months in length as

distinguished from graded and village schools which were nine months
in length and, therefore, not included in the study. The specific
test used was the "Stanford Achievement Test, Advanced Battery-Complete,
Form H by Kelley, Ruch and Terman." It was given in designated rural
schools in the four counties. The teachers in districts near this
rural school center assembled to give the tests; they previously had
received instructions relative to their duties. After the tests had
been given, they were collected, assembled, and delivered to the
County Superintendent in each county for scoring. The scoring was
done by said officer or qualified assistants or both. All tests were
given on a single day through out the State of Kansas as previously
determined. The test papers, after being scored, were filed in the
office of each county superintendent, and served as one of several
measures for pupil promotion or retention. It should be pointed out
that other subject fields, as well as arithmetic, are included in
Advanced Battery-Complete Form H; but this study deals only with
arithmetic.

Purpose

The immediate purpose of the study were: (a) to determine
how closely the grade equivalents of two-hundred and sixty pupils
follow the normal curve; (b) to plot the results of the one-step
problems on a graph with an analytic explanation of the graph; (c)
to place the results of the two-step problems on a graph with an
analytic explanation of the graph; (d) to determine what types of

error were most prevalent; (e) to discover apparent causes of error; (f) to make suggestions helpful to teachers for improving pupil achievement.

Review of Related Research

The extent to which the teachers expended effort to improve pupil achievement in elementary school subjects is well recognized; especially is this true in arithmetic. Therefore attention is called to certain research studies in arithmetic which, in some respects, tie into the problem of this thesis. The first study to be mentioned was made by Washburne in 1927. His problem was a "Comparison of Two Methods of Teaching Pupils to Apply the Mechanics of Arithmetic to the Solution of Problems." Briefly, this experiment used two groups of pupils matched as nearly as possible in problem solving ability. Both groups were taught by the same teacher. Total teaching time, method, and content were kept uniform. In the experiment both groups were given the same problems and tests throughout the experiment. The problems were scored for correct process and accuracy. During the course of the experiment one group was taught mechanics of arithmetic without any relation or connection to the application of these mechanics to problems. The other group was taught the mechanics with practical applications to the problem involved.

Washburne concluded: "That teaching the mechanics of arithmetic facts and processes by themselves, and then applying them to the solution of practical problems does not lead to difficulty in making

practical application of the mechanics of the solution of problems."[1]

Erbaugh made another study in 1940. His problem was "The Difficulty of Arithmetic Problems as Conditioned by the Number of Steps Required and Mental Ages of Pupils." His particular problem was to discover the correlation of the mental age of a pupil with the number of steps involved in the solution of problems. Erbaugh based his mental age standard on the success of fifty per cent of the pupils in solving sixty per cent of the problems. He concluded: "That pupils with a mental age of thirteen can solve successfully two-step problems, and pupils with a mental age of fifteen years can solve three-step problems successfully."[2]

A third related study was made by Lutes in 1926. His particular problem was "An Evaluation of Three Techniques for Improving Ability to Solve Arithmetic Problems." Three days per week for a period of twelve weeks were used in conducting his experiment. The groups were as equal as possible in arithmetic ability. The first group received special drill in the computation which was to be used in the problems to follow. The second group was given special drill in choosing the correct operation. A third group was given special drill in choosing the correct solution after three solutions were given and the pupil had made the correct choice. The fourth group was the control group

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1. Carlton, W. Washburne, "Comparison of Two Methods of Teaching Pupils to Apply the Mechanics of Arithmetic to the Solution of Problems," Elementary School Journal XXVII (June, 1927), 758-767.

2. Robert E. Erbaugh, The Difficulty of Arithmetic Problems As Conditioned by the Number of Steps Required and Mental Ages of Pupil, Master's Thesis, University of Cincinnati, 1927.

which did nothing more than their regular work. Lutes' conclusions were: (a) "The group which was given special drill in computations made the most improvement in reasoning, (b) the control group was second in reasoning, (c) the choosing-solution group was third, and the choosing operation group was last." Lutes also found that all groups made considerable improvement measured by degrees of increased attainment measured in months. The lowest gain in ability in problem solving was 6.9 months and the highest 21 months. He thought that gains were attributed largely to the extra-motivation during the experiment.[3] The effects of the experiment in improvements were measured by standardized tests.

Winch made a fourth related study in 1911. His problem was "Further Work on Numerical Accuracy in School Children Does Improvement in Numerical Accuracy Transfer." In his experiment Winch used 72 boys to ascertain whether or not there was a transfer from numerical accuracy to problem solving ability. At the close of the experiment the following conclusions were stated:

The great improvement in accuracy of arithmetical computation seems to have produced no improvement whatever in the accuracy of arithmetical reasoning.

There exists high positive correlation between the two functions, numerical computation and arithmetical reasoning. This correlation does not appear to involve such a community of functions that improvement in the

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3. O. S. Lutes, "An Evaluation of the Three Techniques for Improving Ability to Solve Arithmetic Problems." University of Iowa Monograph in Education, Series I, No. 6, Iowa City, Iowa, University Press, 1926.

one operation involves improvement in the other.[4]

Reference should also be made to an investigation made by Ellsworth in 1939. His problem was to determine "What Arithmetic Children Use in their Out-of-School-life." Ellsworth maintained that a study of this kind involves the human element and cannot be considered as one hundred per cent accurate; yet he was certain that very definite facts may be deduced from his data concerning the usage of arithmetic by children. His experiment did not take into consideration preparation for higher formal education, but it was an attempt to find out what phases and processes of arithmetic children actually use in their out-of-school-life. His conclusions were:

Telling time, using United States money, reading, and writing numbers seem to be common usages of children.

The use of Roman numerals seem to justify the teaching of this item in the elementary schools for reading only.

Ability to measure length and small areas should be facilitated through practice.

The four fundamental processes of addition, subtraction, multiplication, and division are apparently necessary; and 100 per cent efficiency should be acquired by pupils.

The use of the processes involving fractions seem to be confined to those pupils who indulge in domestic and practical arts.[5]

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4. W. H. Winch, "Further Work on Numerical Accuracy in School Children Does Improvement in Numerical Accuracy Transfer," Journal of Educational Psychology, II, (May, 1911), 262-271.

5. Elmer E. Ellsworth, "What Arithmetic do Children Use in their Out of School Life." Master Thesis, Boston University, School of Education, 1939.

Reed, in his survey of the schools of Ellis County, Kansas, asserts: "That probably the most serious instructional problem in the county is in spellin, and that the second most serious one is in reading."[6] With this reading handicap, we could conclude from the result of this survey that there are some deficiencies in all subjects in which the skill in readin is essential. This means that, in verbal mathematical problems, pupils would have difficulty; and therefore a program for the improvement of instruction in reading should be worked out. If this could be done, pupils would receive help in an area in which they were deficient, and so achieve better results in all subjects.

From the citations above, it is clear that much research has been done in many phases of arithmetic. The cited research related if not direct, has a bearing on this problem and helps in creating an interest in the problem.

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6. Homer B. Reed, Report on the Survey of the Schools of Ellis County, Kansas, May, 1946. (Unpublished).

CHAPTER II

TOTAL PUPIL PERFORMANCE

This portion of the study deals with the presentation of the total performance of two hundred sixty pupils in the eighth grade in the four counties covered in the study. Had each pupil answered each problem in the test correctly, there would have been ten thousand four hundred correct responses. Such a performance is possible, but not probable, since it is to be observed that the test given was an achievement test and designed to measure achievement up to grade eleven. According to the standard for the test, a pupil answering thirteen problems correctly attains an eighth grade equivalence or educational achievement equal to fourteen years. BY grade equivalence is meant attaining a grade score equal to that achieved by a pupil who had attended school for a certain number of years and had made regular grade progress.

A convenient device employed to convey the over all performance is the graph. A performance graph for the two hundred sixty pupils is presented on page ten. The graph requires certain explanations among which are these: First, the number appearing on the left hand side of the graph reading from the bottom upward, that is, from "1 to 24", refer to pupils; and the numbers at the bottom of the graph reading from left to right refer to educational age attained by pupils. Graph No. I pictures total pupil performance with an explanation of performance.
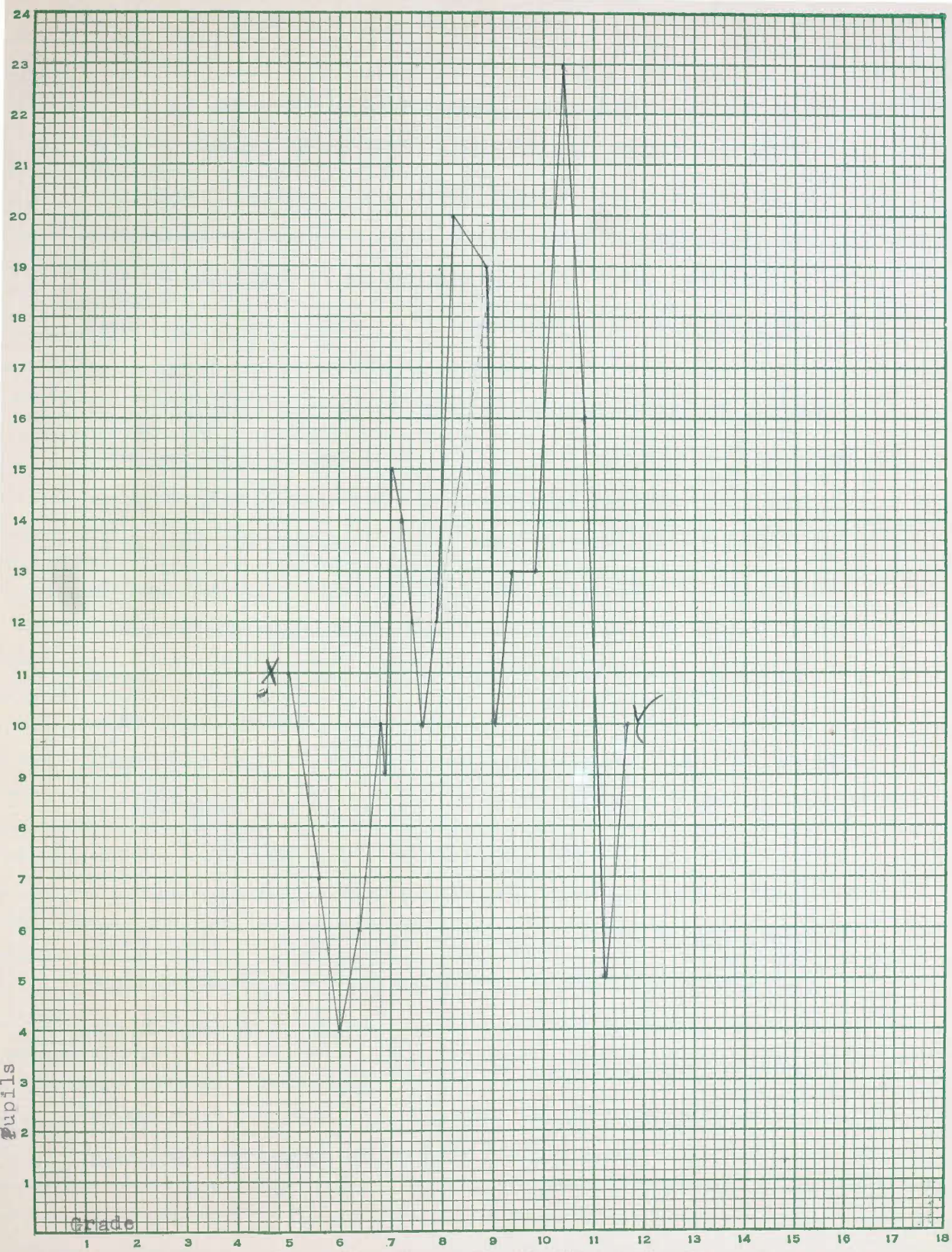
Graph NoI Total Pupil Performance

Pupils

Grade

The letter "x" at the intersection of a horizontal line to the right of number 11 and a certical line directly above the number 5 at the bottom means that 11 pupils of the 260 in the study attained a fifth grade achievement. The letter "Y", which is directly to the right of the number 10 and slightly below and to the right of "X", means that 10 pupils attained an achievement equal to grade eleven years and six months in their performance.

The graph further reveals that 11 pupils attained fifth grade level and six months, and seven attained grade $5\frac{1}{2}$ level; 4 pupils came up to the sixth grade; 6 pupils to the grade six plus four months; 10 to grade six plus eight months; and 9 to sixth grade plus nine months. Pupils who reached seventh grade attainment and came near to but did not attain eight grade were as follows: 15 reached seventh grade; 14 reached grade seven plus two months; 12, grade seven plus four months; 10, grade seven plus six months; and 12, grade seven plus nine months. Twenty pupils reached grade attainment of grade eight plus two months; and 19 reached grade eight plus nine months. Pupils who attained ninth grade were 10, only 13 made grade nine plus four months; and 13, grade nine plus nine months. Twenty-three reached tenth grade plus four months; and 16, grade ten plus eight months. Five pupils reached eleventh grade plus two months, and 10 pupils made grade eleven and eight months.

In general, close examination of pupil performance as revealed of the graph indicates that 110 pupils did not attain eight grade level, and 150 exceeded the eight grade test norm.

The purpose of the second part of the thesis was to discover how well pupils solved "one-step problems." This is shown on page 14 in Graph NO. II. However, this graph needs certain clarification since the color scheme used will also reappear in a third graph showing pupil success with "two-step problems." The red line in Graph Number II means the number of correct responses; the black line shows incorrect responses; and the green line the number of times pupils made no responses to a given problem.

For the most part study is given to only the first twenty-six problems in the test pupils attempted, because very few problems beyond the twenty-sixth in the series were attempted, furthermore a time limit of twenty-nine minutes was prescribed for the test.

Table No. I, and Graph No. II which follows, picture the quality of pupil performance in handling one-step problems.

Table No. I and Graph No. II portray the same findings, we present both because some readers may get a b tter mental picture from the table rather than from the graph. This is true also in regard to Table II and Graph III which appear on pages 17 and 18 respectively.

TABLE NO. I.   ONE STEP PROBLEMS

Problem Number	Number of Correct Responses	Number of Incorrect Responses	Unanswered
1	160	78	22
2	190	66	4
3	208	46	6
5	146	103	11
6	105	139	16
7	169	65	26
8	174	64	22
10	173	82	5
12	87	135	38
13	103	134	23
14	87	136	37
17	57	174	29
19	150	55	55
20	96	94	70
22	42	140	78
24	85	109	66
25	78	52	130
26	23	55	182
Total	2123	1727	830
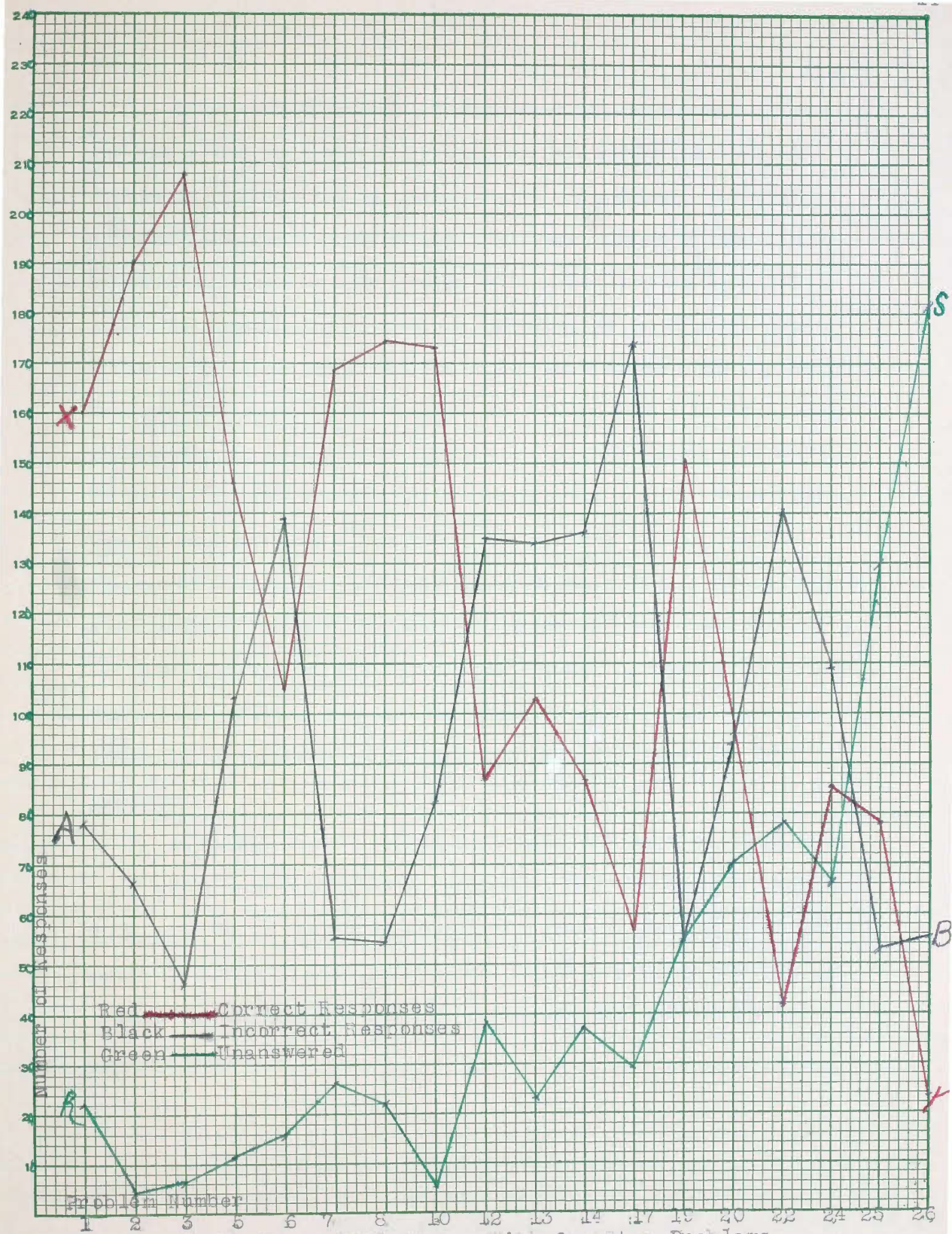
Graph No. 11 Performance With One Step Problems

In the reading of Graph II which shows the performance of the 260 pupils with the one-step problems, we should point out that the numbers 10 to 240 on the left hand side of the graph mean the number of pupil responses to each problem. The number at the bottom, 1 to 26, indicate the number of each problem as it appeared in the test. The letter "X" directly to the right of 160 and above number one at the bottom of the graph means that 160 pupils answered correctly the first problem. The letter "Y" to the right and between 20 and 30 and directly above number 26 means that 23 pupils answered correctly problem 26. The letter "A" to right and slightly below eight and directly above 1 means that 78 pupils responded incorrectly to the first problem; and the letter "B" to the right and above number 26 means that 55 pupils responded incorrectly to the 26th problem. The letter "R" just to the right of and between 20 and 30, and directly above number 1, means that 22 pupils did answer the first problem. The letter "S" to the right of number 180 and above number 26 means 182 pupils failed to answer the 26th problem.

In general when we look at Table No. I and Graph No. II we find pupil performance with one-step problems as follows: Out of a possible 100%, only 82% of the pupils attempted to respond. In other words 18% or nearly one-fifth of the possible total failed to give any sort of answer. Further more 57% of the responses made were correct and 45% were incorrect.

TABLE II.   TWO STEP PROBLEMS

Problem Number	Correct Responses	Incorrect Responses	Unanswered
4	128	111	21
9	171	82	7
11	179	73	8
15	119	101	40
16	124	82	54
18	127	91	42
21	104	84	72
23	37	117	106
Total	989	741	305
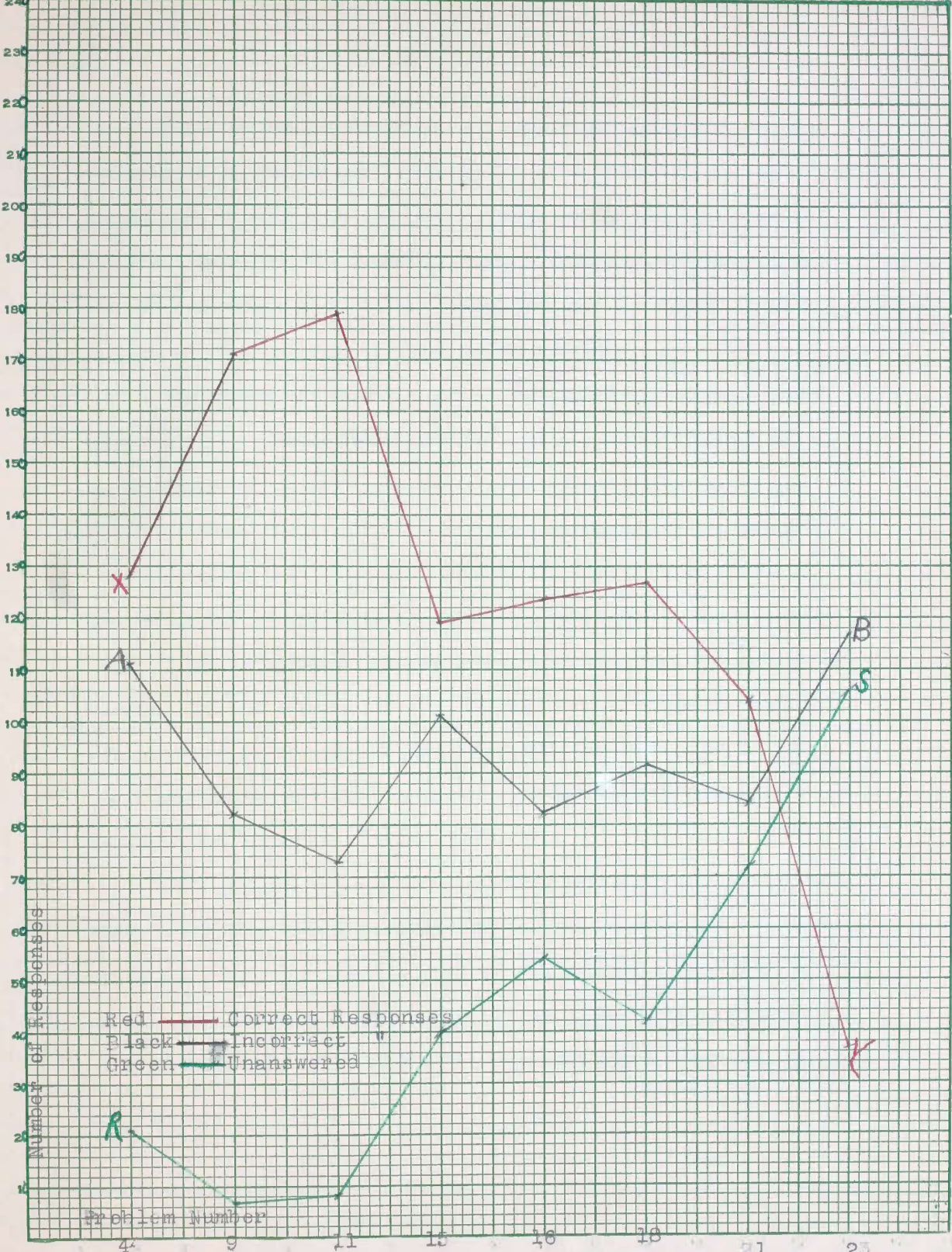
Graph No.LII Pupil Performance With Two-Step Problems

While in reading Graph NO. III on page 17 which pictures the performance of the 260 pupils on the two-step problems, the reader should keep in mind that the numbers 10 to 240 on the left side of the graph represent the number of responses to each problem, while the numbers from 4 to 23 at the bottom indicate the number of each problem as it appears in the test in the appendix.

The Letter "X" to the right of number 128 and directly above number 4 at the bottom means that 128 pupils answered problem No. 4 in the test; "Y" to the right and slightly above number 20 in the first left hand column and directly above number 23 at the bottom of the graph shows that 37 pupils answered the 23rd problem correctly. The letter "A" to the right of 110 and directly above number 4 means that 111 pupils answered problem number 4 incorrectly; the letter "B" to the right and between 110 and 120 and directly above 23 means that 117 responses to problem 23 were incorrect. The letter "S" to the right and between the numbers 110 and 110 and above 23 means that 106 pupils failed to answer problem number 23.

Of the eight two-step problems that were analyzed in the test there could have been a possible 2080 correct answers; but this did not happen. Out of a possible 2080 correct responses only 1730, or an 83% pupil responses, were made; and 17% of the time no answers were given at all. Of the 83% that responded, 48% or 989 were correct, and 35% were incorrect.

CHAPTER III

THE ANALYSIS OF INCORRECT ANSWERS

This part of the study is devoted to analyzing incorrect pupil responses problem by problem. We will emphasize the most frequent types of errors. In the analysis, however, there was no opportunity to observe the pupils at work when they took the test. This means that we have assumed the most plausible reasons for the cause of certain types of incorrect answers. The purpose of the analysis is to discover the more frequent type of errors.

The incorrect answers were divided into three classes, namely: first, mechanical errors or errors in fundamental processes; second, errors due to poor reasoning or in choice of process; and third, scattered errors or miscellaneous, that is, those that do not classify as errors in mechanics or reasoning. An error in a fundamental process is one in which the answer indicates a pupil's computation is incorrect. An example of a mechanical error is 2 plus 9 equals 10. Errors listed as reasoning or in choice of wrong process are those in which the answer indicates that a pupil used the wrong arithmetical process, such as addition when multiplication should have been used. Errors that do not permit classification as mechanical or reasoning are designated as scattered or miscellaneous.

From here on study will be given to analyzing individual pupil performance of problems in the test. In the analysis the method will be: first, to state each problem; second, to show composite pupil performance; third, to classify the incorrect responses; and fourth, to list incorrect answers.

TABLE III. PERCENT OF TWO HUNDRED SIXTY PUPILS ANSWERING PROBLEMS

Problem	Percent Answering Correctly	Percent Answering Incorrectly	Percent Not Answering
1	62	30	8
2	73	25	2
3	80	18	2
4	49	43	8
5	56	40	14
6	40	54	6
7	65	25	10
8	66	24	10
9	65	32	3
10	67	32	1
11	69	28	3
12	33	52	15
13	39	52	9
14	33	52	15
15	46	39	15
16	48	31	21
17	22	67	11
18	49	35	16

TABLE III. (Continued)

Problem	Percent Answering Correctly	Percent Answering Incorrectly	Percent Not Answering
19	57	21	22
20	36	36	28
21	40	33	27
22	16	54	40
23	14	45	41
24	32	40	28
25	30	20	50
26	9	21	70

Problem 1.   Eighteen hours are what fraction of a day,
             in simplest form?

        Close study of pupil performance with problem one yields the

following distribution of pupil responses:

    160 pupils answered correctly;
     78 pupils gave incorrect responses;
     22 pupils did not answer at all.

        The 78 incorrect answers may be classified as follows:

No incorrect answers because of mechanical errors.
No incorrect answers because of faulty reasoning.
78 incorrect answers were widely scattered.

        The frequencies of the miscellaneous errors are:

1/3 appeared 13 times   1/6 appeared 1 time
2/3   "   7 "   4/8   "   1 "

1/4 Appeared 6 times				9/30 appeared 1 time		
3/10	"	5	"	8/24	"	1 "
4	"	5	"	7/24	"	1 "
7/8	"	4	"	32	"	1 "
16	"	4	"	3/12	"	1 "
9/24	"	3	"	1/8	"	1 "
6	"	3	"	2/9	"	1 "
5	"	3	"	3/8	"	1 "
1/2	"	2	"	18	"	1 "
18/24	"	2	"			

It was difficult to classify the errors into mechanical or reasoning errors. The responses made by the 260 pupils to problem one seem to indicate that pupils did not give sufficient time to the analysis of the problem, therefore incorrect responses are listed as miscellaneous.

Problem No. 2.   Mary pasted together 4 cards, each $10\frac{1}{2}$ in. long, to make a poster. How many inches long was the poster?

Close study of pupil performance with this problem yields the following answers:

190 pupils answered correctly;
 66 pupils gave incorrect answers;
  4 pupils did not answer at all.

The 66 incorrect answers are classified as follows:

Errors in mechanical processes are:

$40\frac{1}{2}$ appeared 7 times.

Errors caused by faulty reasoning are:

2 5/8 appeared 3 times
$14\frac{1}{2}$ "   4 "

Incorrect errors that are widely scattered are:

45 appeared 7 times			82 appeared 2 times		
41	"	5 "	47	"	1 "
44	"	4 "	82	"	1 "

81 appeared 4 times				51 appeared 1 time		
66	"	3	"	5	"	1	"
84	"	2	"	21	"	1	"
18	"	2	"	43	"	1	"
4	"	2	"	6	"	1	"
60	"	2	"	88	"	1	"
80	"	2	"	85	"	1	"
48	"	2	"	10	"	1	"
20½	"	2	"	40	"	1	"

The answer 2 5/8 given by 3 pupils seems to indicate that the pupils divided 4 into 10½, while the answer 14½ probably was reached by adding 10½ and 4; such answers will be listed as reasoning errors. The answer 40½. which was given 7 times, probably was attained by multiplying 4 x 10 and then adding ½. This type of error is designated as mechanical error. The remaining 52 responses do not permit classifying as reasoning or mechanical and are listed as unclassified or scattered.

Problem No. 3. Helen read 14 pages in her history book in 42 minutes. That was an average of how many minutes per page?

Study of pupil performance with problem three gives the following picture:

208 pupils answered correctly;
46 pupils gave incorrect answers;
6 pupils did not answer at all.

The 46 incorrect answers are divided as follows:

Errors because of mechanical difficulties are:

4 appeared 3 times.

Errors caused by poor reasoning are:

588 appeared 3 times
56 " 2 "
28 " 2 "

Incorrect responses that are widely scattered are:

58 appeared 4 times				1 appeared 2 times			
36	"	2	"	36	"	2	"
20	"	2	"	1 1/6	"	1	"
$21\frac{1}{2}$	"	2	"	33 14/24	"	1	"
65	"	2	"	12	"	1	"
$3\frac{1}{4}$	"	2	"	3	"	1	"
$1\frac{1}{2}$	"	2	"	23	"	1	"
3 1/7	"	2	"	840	"	1	"
81	"	2	"	17	"	1	"
				18	"	1	"

The answer 588 indicates that the pupils multiplied instead of dividing; the response, 56, could be attained by adding 42 and 14; the answer, 28, could be reached by subtraction. If the above assumptions account for the errors, analysis would show that 9 errors were due to reasoning. The response, 4, indicates that the pupils made a mistake in computation in the division. Out of the 46 incorrect responses, 32 will be listed as scattered because the responses made do not permit classification and analysis into mechanical or reasoning errors.

Problem No. 5.   A packing box is 3' $4\frac{1}{2}$' 6'. What is its capacity in cubic feet.

Pupil performance with problem number 5 is as follows:

146 pupils answered correctly;
103 pupils answered incorrect answers;
  6 pupils did not answer at all.

The 103 incorrect answers are divided as follows:

Errors due to mechanics are:

71 appeared 9 times

Errors due to faulty reasoning are:

$13\frac{1}{2}$ appeared 4 times.

Incorrect answers that are widely scattered:

9	appeared	8 times		11	appeared	1 time	
30	"	8	"	450	"	1	"
54	"	6	"	$62\frac{1}{2}$	"	1	"
40	"	5	"	36	"	1	"
27	"	3	"	57	"	1	"
74	"	3	"	1 4/5	"	1	"
56	"	3	"	$87\frac{1}{2}$	"	1	"
13 2/7	"	2	"	82	"	1	"
2 1/4	"	2	"	230	"	1	"
18	"	2	"	13	"	1	"
72	"	2	"	7	"	1	"
101	"	2	"	187	"	1	"
6 3/4	"	2	"	63	"	1	"
8	"	2	"	86	"	1	"
45	"	2	"	39	"	1	"
72.5	"	1	"	2	"	1	"
6	"	1	"	1	"	1	"
36	"	1	"	34	"	1	"
78	"	1	"	75	"	1	"
$40\frac{1}{2}$	"	1	"				

Nine pupils gave the answer 71, this indicates that the pupils mistake was made in the mechanical operation. The four pupils that gave $13\frac{1}{2}$ as the correct answer could have arrived at that answer by adding, and consequently the error will be shown as a reasoning error. This leaves 90 answers that are not classified as mechanical or reasoning errors and will be shown as scattered errors.

Problem No. 6. Mr. Barnes invested $4000 at $4\frac{1}{2}$% interest. How much interest does this investment earn for him each year?

Close study of problem six yields the following analysis of pupil performance:

105 pupils answered correctly;
139 pupils gave incorrect answers;
16 pupils did not answer at all.

We classify the 139 incorrect answers as follows:

Errors due to mechanics are:

18,000 Appeared 12 times
$18000   "   11   "
$1,800   "   9   "
18   "   7   "

Errors because of faulty reasoning are:

888 appeared 5 times.

Incorrect answers that are widely scattered are:

160.00	appeared	17	times		240	appeared	1	time
15.00	"	13	"		120	"	1	"
100	"	14	"		1.00	"	1	"
28	"	11	"		22,000	"	1	"
216	"	10	"		8000	"	1	"
50	"	7	"		800	"	1	"
34000	"	7	"		14000	"	1	"
980	"	5	"		98%	"	1	"
110.00	"	4	"		400	"	1	"
620	"	4	"		28000	"	1	"
178	"	1	"		320.00	"	1	"

The answers show that 33 pupils misplaced the decemial point.
Errors due to faulty reasoning seem to indicate that the pupils'
mistake was in the inverting of the divisor in the process of
multiplication. The 95 responses that are not listed as reasoning
or mechanical errors will be shown as scattered errors because the
responses made by the pupils did not permit analysis.

Problem No. 7. Fred ruled a sheet of paper $5\frac{1}{4}$ in. wide
into columns 3/8 in. wide. How many
columns did he have?

Close study of problem seven yields the following analysis of
pupil performance:

169 pupils answered correctly;
 65 pupils gave incorrect answers;
 26 pupils did not answer at all.

The 65 incorrect answers are classified as follows:

Incorrect answers due to mechanics are:

1 31/32 appeared 6 times.

Incorrect answers due to reasoning are:

```
5 5/8  appeared 3 times.
14 2/3    "     3   "
 8        "     3   "
25 2/3    "     3   "
19        "     3   "
3½        "     2   "
```

Of the 7 responses that were incorrect because of faulty reasoning, 6 answers seem to indicate that the pupil did not invert the divisor, or that he multiplied instead of dividing; this resulted in a response of 1 31/32. This response of 5 5/8 could possibly be derived by adding $5\frac{1}{4}$ and 3/8. Analysis reveals that 44 responses are not classified as reasoning or mechanical errors and will therefore be listed as scattered errors.

Problem No. 8. A floor plan is marked 1" = 16'. A line $2\frac{1}{4}$ inches long on this floor plan represents - - _____Feet.

Close study of problem eight yields the following analysis of pupil performance:

164 pupils answered correctly;
 64 pupils gave incorrect answers;
 22 pupils did not answer at all.

The 64 incorrect answers are classified as follows:

Incorrect answers due to mechanics are:

```
32¼     appeared 6 times
32        "      5   "
38        "      2   "
32½       "      2   "
35        "      2   "
33        "      2   "
33 3/12 "        1   "
```

Incorrect answers because of poor reasoning:

$18\frac{1}{4}$ appeared 2 times.

Frequent errors that are classified as scattered errors. None.

Of the list of 20 mechanical errors, 6 pupils gave $32\frac{1}{4}$ as the correct response; this answer could possibly be arrived at by multiplying $2 \times 16 + \frac{1}{4}$. The remainder of the mechanical errors seem to indicate that pupils multiplied but made a mistake in their computation. Two answers seem to indicate that the pupil used the wrong process; namely, one of addition when they should have used multiplication. The remaining 42 unaccounted answers will be shown as scattered errors, because they do not fall in the mechanical or reasoning class.

Problem No. 10.   The diameter of a circular window is 42
inches. What is the circumference in
inches. (Use 3 1/7 for π)

Close study of problem ten yields the following analysis of pupil performance:

173 pupils answered correctly.
72 pupils gave incorrect answers.
5 pupils did not answer at all.

The 72 incorrect answers are classified as follows:

6 incorrect answers were due to mechanical errors.
6 incorrect answers were due to faulty reasoning.
65 incorrect answers were widely scattered.

Frequent error or errors that permit analysis:

Incorrect answers due to mechanics are:

138 appeared 5 times
133   "   1 "

Incorrect answers due to poor reasoning are:

13 4/11 appeared 5 times.
13 7/11   "   1   "

Frequent errors that are classified as scattered errors:

$10\frac{1}{2}$ appeared 6 times.
13 4/11   "   5   "
53   "   4   "
15   "   3   "
264   "   2   "

Pupil responses to problem ten are widely scattered; in the analysis 6 answers are classified as mechanical errors because the response made by the pupils seems to show that the right process was used, but that a mechanical error was made. 6 responses seem to reveal that the pupils divided; therefore this leaves 65 pupil responses listed as scattered because they did not fall into the classification of mechanical and reasoning errors.

Problem No. 12. A factory owner discharged 1/5 of his
employees, or 115 men. How many men did
he employ before these men were discharged.

Close study of problem twelve yields the following analysis of pupil performance:

87 pupils answered correctly.
135 pupils gave incorrect answers.
38 pupils did not answer at all.

The 135 incorrect answers are classified as follows:

Incorrect answers due to mechanics are:

460 appeared 6 times.

Incorrect answers due to poor reasoning are:

23 appeared 47 times.

Frequent errors that are classified as scattered errors:

460 appeared 6 times   510 appeared 1 time
138   "   6   "   115   "   1   "
15   "   3   "   238   "   1   "

Forty-seven pupils gave the answer 23 as correct; this seems to reveal that the pupil multiplied 115 by 1/5 and arrived at the answer of 23; so we listed the response of 23 as a reasoning error. Six pupils gave 460 as a response; this answer could be arrived at by multiplying and then subtracting from 575 which is the answer they got when they multiplied. These errors apparently were due to mechanical difficulties. 80 could not be classified as mechanical or reasoning errors and will therefore be listed as scattered errors.

Problem No. 13. Mrs. Roberts has paid $360 of a $480 debt. What per cent of the debt has she paid?

Close study of pupil performance with problem 13 yields the following analysis of pupil performance:

103 pupils answered correctly.
134 pupils gave incorrect answers.
 23 pupils did not answer at all.

The 134 incorrect answers are classified as follows:

Incorrect answers due to mechanics are:

$7\frac{1}{2}$ appeared 3 times.
73   "   2   "
77   "   1   "

Incorrect answers due to poor reasoning are:

120 appeared 21 times.
840   "   5   "
 25   "   5   "
3 1/3 "   2   "

Of the responses that are listed as mechanical, three pupils responded with $7\frac{1}{2}$; one pupil gave 77; and two listed 73 as correct answers; these responses indicate that the pupils were using the right process but possibly made a mistake in their computation. Twenty-two of the errors were due to reasoning because the pupils

subtracted and showed $120 as their answer; five added, getting 840 as the correct response. Two pupils divided 360 into 480 getting 1 1/3. Eleven gave 25 as a response; these pupils possibly divided 480 into 360 which resulted in getting 75; but they subtracted that from 100 and obtained 25 as a correct answer. These results show that 95 of the pupil responses fall in the scattered classification.

Problem No. 14. A model XX-r radio sells for $75. The cost is .6 of the selling price. What is the cost?

Close study of pupil performance with the problem yields the following analysis of pupil performance:

87 pupils answered correctly.
136 pupils gave incorrect responses.
37 pupils did not answer at all.

The 136 incorrect answers are classified as follows:

Incorrect answers due to mechanics are:

450 appeared 15 times.

Incorrect answers due to poor reasoning are:

79.50 appeared 5 times.
 1.25   "   4   "
12.50   "   5   "
70.50   "   7   "
70.40   "   1   "

Incorrect errors classified as scattered errors are 98:

120 appeared 13 times.
70.40   "   1   "
45.00   "   3   "
70.000   "   1   "
12½   "   1   "

The mechanical errors all seem to be the result of misplacing the decemial point, since the computation was correct. Of the 24 errors caused by faulty reasoning, 8 responses seem to indicate that the pupil multiplied $75 by .6 and got the answer $4.50; this in turn they added to $75 and arrived at $79.50 as the correct answer. Nine pupils evidently divided .6 into $75, for 9 got 1.25, while the other 5 gave 12.50 as a correct answer. 6 multiplied 75 by .6 and then subtracted getting $70.50; and two multiplied and then subtracted, getting $70.40 and $70.50. We now have 94 incorrect answers falling in the scattered class because the responses did not belong in the mechanical or reasoning class.

Problem No. 17. The day train to Weston leaves at 7:45 A. M. and arrives at 4:15 that afternoon. How many hours does the trip take?

Close study of pupil performance with problem seventeen yields the following analysis of pupil performance:

57 pupils answered correctly.
174 pupils gave incorrect answers.
29 pupils did not answer at all.

The 174 incorrect answers are classified as follows:

Incorrect answers classified as scattered errors:

3:30	appeared 43 times		11.60	appeared 5 times	
9:30	"	19 "	8:30	"	3 "
9	"	13 "	$7\frac{1}{2}$	"	5 "
$3\frac{1}{2}$	"	6 "	12	"	4 "

The response, 3:30, which was given by 43 pupils seems to reveal that subtraction was used, while the answer of 11:60 which was given by 5 pupils might have been reached by addition.

Problem number seventeen is one dealing with time. The analysis shows a large variation of answers, none of which will be listed as errors due to mechanical or reasoning errors. It seems to indicate that too many incorrect answers were given and that the pupils should receive more supervision in the working of problems which deal with the handling of time.

Problem No. 19. The perimeter of a square is 96 feet. What is the length of a side in feet?

Close study of pupil performance yields the following analysis of pupil performance:

150 pupils answered correctly.
55 pupils gave incorrect answers.
55 pupils did not answer at all.

The 55 incorrect answers are classified as follows:

Incorrect answers due to mechanics are:

19 appeared 2 times.

Incorrect answers due to poor reasoning are:

48	appeared	6	times.
384	"	3	"
32	"	7	"
192	"	2	"

Frequent errors that are classified as scattered:

23	appeared	2	times.
31	"	2	"
28	"	1	"

Two responses made by the pupils seem to reveal that the pupils choose the correct process but made a mistake in the mechanics of the problem. Six pupils who responded with 48 as the correct answer could have arrived at that answer by dividing $96 \div 2 = 48$. Three gave 384;

this answer could possibly be arrived at by 96 x 4 - 384; two multiplied 96 x 2 = 192; while 7 responded with 32, and this showed that they divided 96 ÷ 3 = 32. This resulted in 35 answers being listed as scattered errors because they did not fall in either the mechanical or reasoning classification.

Problem No. 20. The rainfall this year was 24 in. Last year it was 30 in. Compare this year's rainfall with last year's as a decimal fraction.

Close study of pupil performance yields the following analysis of pupil performance:

96 pupils answered correctly.
94 pupils gave incorrect answers.
70 pupils did not answer at all.

The 94 incorrect answers are classified as follows:

No incorrect answers due to mechanics:

Incorrect answers due to poor reasoning:

4/5 appeared 24 times.

Frequent errors that are classified as scattered errors are:

```
.06 appeared 16 times.
.80     "      2    "
1.25    "      2    "
1/5     "      2    "
```

Among incorrect pupil responses to problem 20 a great variation appeared, and it was difficult to classify them as mechanical or reasoning errors. Twenty-four answers seem to indicate that the pupils did not understand the meaning of the problem because they responded with the 1/5 as the correct answer. The remainder of the 70 answers will be listed as scattered errors.

Problem No. 22.   Mr. Brown has an investment of 6% that
pays him $90 interest per year. How
much money does he have in this investment.

Close study of pupil performance with problem 22 yields the

following analysis of pupil performance:

    42 pupils answered correctly.
    140 pupils gave incorrect responses.
    78 pupils did not answer at all.

The 140 incorrect answers are classified as follows:

Errors due to mechanics are:

150 appeared 3 times.
 15   "   4   "
1516   "   2   "

Incorrect answers due to poor reasoning are:

5.40 appeared 82 times.
95.40   "   8   "

This problem required the finding of the total investment. The

analysis reveals that 82 pupils multiplied 90 x .06 = getting 5.40 as

the answer; this is a reasoning error. Eight pupils added 5.40 to $90,

arriving at $95.40 as their correct answer; these incorrect responses

will therefore be listed as reasoning errors. While the answer, 150,

which appeared 3 times, and the answer, 15, which appeared 4 times,

and 1516 which appeared 2 times are also listed as reasoning errors.

Problem No. 24.   If 85 represents a point 85 miles north
of St. Louis and 65 represents a point
65 miles south of St. Louis; how many
miles apart are the two points?

Close study of pupil performance with problem twenty-four yields

the following analysis of pupil performance:

    85 pupils answered correctly.
    109 pupils gave incorrect responses.
    66 pupils did not answer at all.

The 109 incorrect answers are classified as follows.

Errors in mechanics are:

140 appeared 2 times.
120   "   2   "
130   "   2   "
170   "   2   "

Errors due to poor reasoning are:

20 appeared 61 times.

In problem twenty-four, 109 responded incorrectly. Of these 109 incorrect answers, 61 responses seem to indicate that the pupils subtracted 65 from 85 and got 20 as the correct answer; the response, 20, will therefore be listed as a reasoning error because the wrong process was selected; namely, subtraction instead of addition. THree responses given were close to the correct answer and will be shown as mechanical. The analysis shows the remaining 40 answers as scattered because they fell in neither the reasoning or mechanical classification.

Problem No. 25. Mr. Burns brought 5400 sq. ft. of sod. His
               lot is 60 feet wide. If he starts at the
               front of the lot and sods the full width., for
               how many feet back can he sod the lot?

Close study of problem 25 yields the following analysis of pupil performance:

78 pupils answered correctly.
52 pupils gave incorrect answers.
130 pupils did not answer at all.

The 52 incorrect answers are classified as follows:

Errors due to mechanics are:

80 appeared 5 times.
 9   "   5   "

Errors due to poor reasoning are:

324 appeared 9 times.
5340   "   6   "

Frequent errors classified as scattered errors:

36 appeared 2 times.
 6   "   2   "

In the study of the incorrect pupil responses, nine seem to indicate that pupils multiplied instead of dividing, while 6 subtracted 60 from 5400. This would mean that 15 incorrect responses were the result of wrong reasoning. In ten cases the answers reveal that the pupils made mistakes in their reasoning. The analysis would therefore show 27 answers as scattered errors.

Problem No. 26. Mr. North had r dollars and then earned
                t dollars more. How many dollars did he
                have then?

Close study of problem twenty-six yields the following analysis of pupil performance:

23 pupils answered correctly.
55 pupils gave incorrect responses.
182 pupils did not answer at all.

The 55 incorrect answers are classified as follows:

No errors due to mechanics.

No errors due to reasoning.

55 errors are classified as scattered:

R appeared 11 times.   3 appeared 2 times.
20   "   9   "   30   "   3   "
25   "   2   "   150   "   4   "

The answers given to this problem varied so greatly and had so little similiarity to the correct response that no logical analysis is possible and will show all the errors as scattered errors.

Two-Step Problems

The final section of this chapter will be devoted to the study of pupil performance with two-step problems. The analysis will follow the same pattern that was used in the one-step problems.

Problem No. 4. At the rate of $7\frac{1}{2}$ miles in 15 minutes, how many miles will a train go in an hour?

Close study of pupil performance with problem four yields the following analysis of pupil performance:

128 pupils answered correctly.
111 pupils gave incorrect responses.
 21 pupils did not answer at all.

The 111 incorrect answers are classified as follows:

Errors due to mechanics are:

None.

Errors due to faulty reasoning are:

$112\frac{1}{2}$ appeared 15 times.
  2   "   5   "
450   "   11   "

Frequent errors that are classified as scattered:

15 appeared 5 times.
120   "   4   "
45   "   3   "

The first two-step problem in the test was number 4. Solving the problem required one to find the length of time in which a train would travel one mile if it travels at the rate of $7\frac{1}{2}$ miles in 15 minutes. We accomplish this by dividing the number of minutes into the number of miles. The analysis shows that 5 pupils did that, but they failed in the second step, namely, dividing 2 into 60 to get the

number of miles a train would travel in an hour at that speed. 15

multiplied 15 x 7½ and did not proceed to the second process. While in

eleven cases the answer indicates that the pupils multiplied 15 x 11 =

and then multiplied the answer by 2. The study therefore shows 35 errors

due to reasoning; no response seems to indicate that the answer was

incorrect because of a mechanical error. The remaining 70 incorrect

answers will be listed as scattered.

    Problem No. 9. Mrs. Stone's bills for the first 4 months of
                this year were: $145, $174, $162 and $183.
                What was the average of her bills for these
                4 months?

    Close study of problem nine yields the following analysis of

pupil performance:

    171 pupils answered correctly.
     82 pupils gave incorrect responses.
      7 pupils did not answer at all.

    The 82 incorrect answers are classified as follows:

Errors due to mechanics are:

```
163.50 appeared 3 times.
161       "     3   "
164       "     2   "
```

Errors due to faulty reasoning:

```
$664 appeared 26 times.
 665    "      4   "
 654    "      2   "
 674    "      2   "
```

    Problem nine was the second of the two-step problems; in the

analysis we discovered that 34 of the incorrect answers resulted be-

cause the pupils did not carry out the second step required for the

working of the problem. These 34 incorrect responses also seem to

indicate that the pupils apparantly had chosen the right first process.
Of 8 responses listed as mechanical errors, the answers seemed to
indicate that the pupils made faulty calculations. This classification
would result in 40 responses being listed as scattered errors.

        Problem No. 11. On January 1 Mary's savings were $4.18 and
                    Ann's savings were $5. Mary spent $1.35
                    for a ring and Ann spent $2.69 for a
                    sweater. How much more money did Mary have
                    left than Ann?

        Close study of the problem yields the following analysis of
pupil performance:

        179 pupils answered correctly.
        73 pupils gave incorrect responses.
        8 pupils did not answer at all.

        The 73 incorrect answers are classified as follows:

        Errors due to mechanics are:

        45 appeared 8 times.

        Errors due to poor reasoning are:

        1.35 appeared 5 times.

        Frequent errors classified as scattered are:

        48 appeared 4 times.
        55   "   4   "
        1.53   "   3   "
        2.83   "   2   "

        The study of the pupils responses reveal that 8 incorrect
responses were because of faulty mechanics; the answers indicate
that the correct process has been chosen. Five incorrect responses
seem to show that the pupils used only one-step in solving the
problem; they subtracted 1.35 from 2.69 receiving 1.34 as the
correct response. This leaves 60 responses classified as scattered

because they fell in neither the reasoning or mechanical classification.

Problem No. 15. The height of a trapezoid is 3 mi.
The bases are $1\frac{1}{2}$ mi. and $2\frac{1}{2}$ mi. The area
is 9/6 sq. mi. (use the formula

$$A = \frac{b + d}{2} \ xh. \quad)$$

Close study of problem reveals the following analysis of pupil

performance:

119 pupils answered correctly.
101 pupils gave incorrect answers.
 40 pupils did not answer at all.

The 101 incorrect answers are classified as follows:

No incorrect answers because of mechanical errors.
No incorrect answers because of faulty reasoning.
101 incorrect answers were widely scattered.

Frequent errors classified as scattered:

$11\frac{1}{4}$ appeared 12 times.   8 appeared 5 times.
24   "   6   " $22\frac{1}{2}$ "   2   "
12   "   10   " $5\frac{1}{2}$ "   3   "

The responses made by the pupils seem to give no indication

that the errors were due to faulty reasoning or wrong computation on

the part of the pupils. The study reveals no logical analysis, and

therefore the responses will all be listed as scattered errors.

Problem No. 16. A factory building was valued at $20,000
for tax purposes. The rate was $42.50 per
$1000. What was the amount of the tax?

Close study of the problem yields the following analysis of

pupil performance:

124 pupils answered correctly.
 82 pupils gave incorrect answers.
 54 pupils did not answer at all.

The 82 incorrect answers are classified as follows:

Errors due to mechanics are:

8500 appeared 25 times.

Errors due to faulty reasoning:

None.

Frequent errors that permit analysis:

840 appeared 2 times.
950   "   1   "
525   "   1   "

The study reveals that 25 responses made by the pupils were mechanical and were caused by misplacing the decimal point; had they placed the decimal point correctly their answers would have been right. None of the responses permit analysis as reasoning errors. This would result in 57 being listed as scattered errors.

Problem No. 18.   A side of a barn is 15' 30'. Only a rectangular section 6' 10' has been painted. How many square feet are yet to be painted?

Close study of the pupil performance with problem eighteen yields the following analysis of pupil performance.

127 pupils answered correctly.
 91 pupils gave incorrect responses.
 42 pupils did not answer at all.

The 91 incorrect answers are classified as follows:

Errors due to mechanical mistakes:

None.

Errors do to poor reasoning are:

510 appeared 4 times.

Frequent errors that permit analysis as scattered errors:

```
950 appeared 7 times.
 20    "     6   "
360    "     5   "
 29    "     3   "
490    "     2   "
```

In the study of the pupil performance in this problem great difficulty was met in the attempt to classify the errors into mechanical or reasoning errors. Out of the 91 incorrect responses only 4 answers seem to indicate that the pupils' reasoning was wrong; the pupils could arrive at 510 as the correct response by working the first step correctly; but they made the mistake of adding instead of subtracting in the second step. This would leave 87 answers being listed as scattered errors because they do not fall in either the reasoning or mechanical classification.

Problem No. 21. How much is the annual premium on a $500 life insurance policy based on a premium rate of $30 per $1000?

Close study of the pupils performance on problem 21 yields the following analysis of pupil performance.

```
104 pupils answered correctly.
 84 pupils gave incorrect responses.
 72 pupils did not answer at all.
```

The 84 incorrect answers are classified as follows:

Errors due to mechanics are:

19.50 appeared 23 times.

Errors due to reasoning are:

None.

Frequent types of errors classified as scattered:

```
30 appeared 30 times.
186    "     2   "
214    "     2   "
750    "     2   "
190    "     2   "
```

In the study of the pupil performance of the problem the responses made by the pupil seem to indicate that 23 errors were caused by incorrect placement of the decimal point; had the decimal point been placed correctly, the answer would have been correct. None of the responses permit analysis into reasoning errors; therefore those not listed as mechanical errors will be classified as scattered errors.

Problem No. 23. A radio costing $60 was sold for $100. The dealer figured his overhead at $30. What was his per cent of profit, figured on the selling price?

Close study of pupil performance yields the following analysis of pupil performance:

```
37 pupils answered correctly.
117 pupils gave incorrect responses.
106 pupils did not answer at all.
```

The 117 incorrect answers are classified as follows:

Errors due to mechanics are:

None.

Errors due to poor reasoning are:

```
40 appeared 11 times.
30    "      8   "
60    "      7   "
70    "      6   "
10    "      6   "
```

The response to this problem indicates that no answer can be classified as mechanical errors; 28 pupils reasoned that the problem was a one-step problem and arrived at various answers. In eleven cases

the pupils would have arrived at their answers by subtracting 100 - 60 = 40, and then dividing that into 100, 6 could have arrived at 70 as their answer by subtracting 100 - 30 and then dividing 100 into 70; while 7 divided 100 into 60, and 8 divided 100 into 30. The remaining incorrect responses will be listed as scattered.

In conclusion it is clear that the most frequent type of error was misplacing the decimal point. Pupils did not seem to know how to handle it properly.

CHAPTER IV

SUMMARY AND CONCLUSION

Out of a possible 6760 answers to the first 26 problems of the test 5580 responses were made; and, of those 5580 answers, 3312 were correct and 2468 were incorrect. Further analysis shows that of the 2468 incorrect answers 282 were wrong because of faulty computation, and 312 were incorrect because of poor reasoning. Also 1974 of the wrong answers fall into the scattered error group.

The cause of frequent reasoning errors appears to be as follows: (a) In the multiplication or division of a whole number and a fraction, the pupil seemed to be in doubt when to invert the divisor; (b) In problems that required division, the responses seem to indicate that pupils were misled by the word "difference", and subtracted when they should have divided; (c) Another type of reasoning error seemed to arise when there was a choice of addition or multiplication to be made. Pupils would use addition when they should have used multiplication. In the two-step problems the most frequent difficulty seemed to be that pupils did not complete the second step. Pupils took the first step in solving the problem, but failed to proceed to the second. This seems to show that they thought it was a one-step problem.

Errors because of mechanics were very difficult to locate because the computation involved in working the problems was not shown. However one mechanical error easily detected was that of misplacing the decimal point. This happened 104 times. Had pupils not

made this mistake again and again, answers would have been correct.

All in all, from the study as a whole, certain values and recommendations which may be helpful to teachers appear: (a) More stress should be given in teaching children how to handle the decimal point. (b) Pupils would receive more training in problems in which a whole number and a fraction are to be multiplied or divided. (c) Problems where the time factor enters need more attention. (d) More emphasis should be given to reasoning through a problem. (e) Less emphasis on location of cue words. (f) Arithmetic program should be such as to meet the needs of the pupils that are weak or below average.

It is the writer's hope that teachers of arithmetic will be more aware of the more common errors in arithmetic, and find ways and means to reduce them where possible. When this is done pupils will reap the benefit of this and similar studies.

Due to the great variation of pupil achievement the arithmetic problems should be varied to meet the need of all.

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