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THE READING-ARITHMETIC-SKILLS PROGRAM, A RESEARCH PROJECT IN READING AND ARITHMETIC.

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PUB DATE 64
EDRS PRICE MF-$0.18 HC-$2.40 60P.

DESCRIPTORS- *READING SKILLS, *ARITHMETIC, GRADE 4, GRADE 5, GRADE 6, *ELEMENTARY SCHOOL STUDENTS, *RELATIONSHIP, *ACHIEVEMENT RATING, WORD PROBLEMS, T RATION, CORRELATION, TESTS OF SIGNIFICANCE, CALIFORNIA READING TEST, CALIFORNIA ARITHMETIC TEST, VERBAL READING ARITHMETIC SKILLS PROGRAM (RASP), UNIVERSITY PARK

AN INVESTIGATION WAS MADE TO DETERMINE WHETHER STUDENTS WHO RECEIVED SPECIFIC ASSISTANCE WITH READING SKILLS IN ARITHMETIC SHOWED SUPERIOR ACHIEVEMENT IN THEIR READING AND ARITHMETIC WHEN COMPARED WITH A SIMILAR GROUP WHO DID NOT RECEIVE SUCH ASSISTANCE. FIFTEEN SCHOOLS WERE SELECTED FROM APPROXIMATELY 70 MEMBER SCHOOL DISTRICTS OF THE PENNSYLVANIA SCHOOL STUDY COUNCIL. TWO FOURTH-, FIFTH-, AND SIXTH-GRADE CLASSES WERE SELECTED FROM EACH SCHOOL. ONE CLASS SERVED AS THE EXPERIMENTAL GROUP AND THE OTHER AS THE CONTROL. DATA FOR EACH OF THE EXPERIMENTAL AND CONTROL CLASSROOMS ARE INCLUDED. ALTERNATE FORMS OF THE CALIFORNIA READING TEST, THE CALIFORNIA ARITHMETIC TEST, AND THE RASP TEST DEVELOPED BY THE INVESTIGATORS WERE ADMINISTERED AS PRE- AND POST-TESTS IN 10 READING COMPETENCIES BELIEVED TO BE NECESSARY FOR SOLVING VERBAL ARITHMETIC PROBLEMS. CLASSROOM TEACHERS WERE GIVEN DIRECTIONS FOR THE INSTRUCTIONAL PERIODS. MEAN GAINS, CORRELATIONS, FACTOR ANALYSIS, AND EIGENVALUE WERE USED TO ANALYZE THE DATA. ON EACH ACHIEVEMENT TEST, THE MEAN GAIN IN SCORES FROM PRE- TO POST-TEST WAS GREATER FOR THE EXPERIMENTAL GROUPS. CORRELATIONS BETWEEN SUBTESTS WERE POSITIVE. THE SIZE OF THE CORRELATION INCREASED AT EACH GRADE LEVEL. A GENERAL FACTOR ACCOUNTED FOR 72 PERCENT OF THE VARIANCE. CONCLUSIONS, RECOMMENDATIONS, AND IMPLICATIONS ARE PRESENTED. A BIBLIOGRAPHY AND TABLES ARE INCLUDED. (BK)

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1964

RE 000 053

THE READING-ARITHMETIC SKILLS PROGRAM

A Research Project

in

Reading and Arithmetic

by

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Published by

The Pennsylvania School Study Council

University Park, Pennsylvania

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THE READING-ARITHMETIC SKILLS PROGRAM

Chapter I

The Study Outline

The elementary school curriculum has many outstanding features, two of which are noteworthy because of their pertinence to this paper. First, the curriculum presents an array of semi-isolated areas of content which rarely enjoy a high degree of deliberate articulation. Second, each content area is heavily dependent upon the communication skills, largely reading, for the transmission of its body of knowledge to the learner.

It is widely acknowledged that each content field presents unique reading tasks to the learner, and there is some evidence that specific assistance in meeting these demands enables the pupils to achieve greater understanding of the subject matter.

The purpose of this investigation was to determine whether students in grades four, five, and six who received specific assistance with reading skills in the field of arithmetic showed superior achievement in their reading and arithmetic when they were compared with a similar group of students who did not receive such assistance. The study sought to answer five specific questions:

1. Are reading skills related to the solution of verbal problems?
2. Does instruction in specific reading skills improve the 4th, 5th, and 6th grade pupils' abilities to solve verbal problems?
3. Are there significant differences in reading and arithmetic test scores between pupils who have been taught experimentally and those who have not been so taught?
4. Can teaching materials be prepared which will enable teachers to provide for effective instruction in these reading-arithmetic skills?
5. Can a test be developed which will measure a pupil's competencies in the use of reading-arithmetic skills?

<u>The need for the study</u>. -- The need for such a study as this one has been established in several different ways: the experiences of the investigators with elementary teachers and with elementary pupils; the literature and the previous research which helped them to identify the problem; and an examination of textbook materials currently in use in elementary schools.

For many years teachers have repeatedly noted that the solution of verbal or word problems constitutes the major stumbling block in the elementary school arithmetic program. Most of them have felt that there were no particular problems in teaching the number facts and the fundamental operations of addition, subtraction, multiplication, and division. . Teaching children how to interpret a word problem, however, and when to apply the fundamental processes were different matters.

Serious research into the matter of problem solving, which will be noted later, has pointed up the fact that verbal problem solving needs further investigation. Some of these studies have intimated that reading competency may be a major factor in solving word problems, in fact some of them have recommended that special attention be given to the relationship between the two skills. Actually, very few studies have done this, and any study of the effect of elementary school pupils' reading skills upon their verbal problem solving will add to the limited knowledge which teachers find available in this area.

An examination of the verbal problems in several arithmetic textbooks which are currently being used in the elementary schools led the investigators to several conclusions:

1. Many of the problems were phrased in statements which obscured the meaning of the problem.
2. In numerous cases key words such as equal, shared equally, exactly, etc., were omitted from the problem.
3. The reader of the problem was often forced to make risky assumptions of what the author of the problem actually intended.
4. If the child followed the problem literally, he might arrive at an incorrect solution.
5. The problem solver often was forced to supply information which was not written in the problem.

The investigators concluded that a child could actually be penalized by having his answer marked incorrect if he interpreted some of the problems in his textbook as the author wrote them. At times the author appeared to be so engrossed in teaching one of the basic arithmetic concepts through the use of a verbal problem that he sacrificed accuracy of expression and damaged the communication set up by the problem. Such omissions and distortions of meaning can raise innumerable questions in the minds of children, and if these questions are unanswered, they can lead to definitely undesirable reading habits.

Even though a search of the literature did not provide answers to these problems, it did lead the investigators to the postulation of two hypotheses:

1. Certain reading competencies are directly related to verbal problem solving.

2. Emphasis upon these reading competencies while the teacher is teaching verbal problem solving will result in greater achievement in the solution of verbal arithmetic problems.

The nature of these hypotheses suggested the existence of a number of identifiable and teachable reading skills which could be related to a program of instruction in verbal arithmetic problem solving under controlled experimental conditions. These competencies are identified in Chapter III.

The limitations of the study.-- Although the study was conducted under controlled circumstances, the investigators recognize the following as constituting possible bias and limitations:

1. The methods of selection used in choosing the participating schools and teachers.

2. The possible variation that might occur in the amount and the quality of instruction given the participating children.

3. Pre-conceived ideas or prejudices on the part of teachers or pupils for or against the program.

4. The error in measurement instruments selected for evaluation of the results of the study.

5. Weaknesses of the teaching materials, suggestions to teachers, and the unit tests provided for instructional purposes.

6. Any inconsistencies in the experimental design of the study.

Definition of terms. -- In order to maintain consistency in the report of this investigation, it is necessary to define certain terms used frequently in the study:

1. Verbal problem -- a word description of a mathematical situation which either calls for a quantitative solution or raises questions to be answered by reasoning, or both.

2. Reading competency -- a reading skill, the use of which enables the reader accurately to interpret a verbal or a quantitative expression of an idea.

3. RASP -- an abbreviation for the title of the experimental program, the Reading-Arithmetic Skills Program.

4. Experimental materials -- the specially prepared pupils' books, teachers' manuals, and tests prepared by the investigators for use in this study.

All other terms and expressions are to be interpreted as they are commonly used without special reference to this study.

Procedures followed in the study. -- Fifteen schools were selected from approximately seventy member school districts of the Pennsylvania School Study Council. In each of these schools two fourth grade classes, two fifth grade classes, and two sixth grade classes were selected by the elementary principal or elementary supervisor of that district. One of each pair of classes was designated by the school district as an experimental class and the other as a control class following the investigators' request to keep the classes as nearly alike as possible. Three tests were administered before the investigation began, the California Arithmetic Test, the California Reading Test, and the RASP Test developed by the investigators. A twenty-week instructional program, with a recommended quota of one lesson per week, was provided for the pupils in the experimental classes. The control classes received their normal program of arithmetic instruction, and the children were not told of the program being conducted in the experimental classes.

The instructional program provided the experimental classes consisted of twenty lessons which were developed by the investigators to teach the ten reading competencies which the investigators believed would be needed by the pupils for effective reading of verbal arithmetic problems. A manual of instructions gave the teacher specific directions for presenting the ideas to her pupils, and a pre-experimental meeting with the teachers provided specific help in interpreting this material. Each participating teacher was visited at least once during the twenty-week teaching period.

At the end of twenty weeks, the children in both the experimental and the control groups were retested, using alternate forms of the California Test of Arithmetic and the California Test of Reading and the RASP Test.

Chapter II

Review of the Related Literature

> The problem is not concrete to the child unless he is able to form a clear mental image of the situation described. It may be that he has not read the problem carefully, or that he may have read it carefully and yet, through lack of experience in the situation described, he may not be able to form a picture of the situation.

More than forty years ago Stone[1] expressed this opinion, and since that time numerous other writers have given their support to Stone's belief. Brueckner[2] suggested that emphasis on mastery of facts and skills alone does not meet the children's needs:

> The most commonly recognized goal of arithmetic teaching, that of mastery of the facts and skills of arithmetic has been accorded such importance that the social significance of arithmetic has often been neglected. The value of facts and skills cannot be denied, but the possession of these without the ability to use them in quantitative situations which life offers is evidence that the school is not meeting the needs of those whom it seeks to educate.

Brownell and others[3] advised that "Some item seems to have been missing from our teaching, and that item, we are coming to believe, is understanding." Sueltz and others[4] agreed that it is the presence of factors of meaning and understanding that raises the performance of the pupil above that of a computing machine. He continues:

> The measurement of meanings and understandings is beginning to creep into arithmetic. Of twenty-seven studies examined, eight showed that the author was deliberately trying to measure beyond the scope of problem solving and computation. New procedures in teaching and evaluation will have to be developed as the schools broaden their vision of the function and scope of arithmetic.

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1. Stone, J. C. The Teaching of Arithmetic. Chicago: Benjamin A. Sanborn, 1922. Page 170.
2. Brueckner, L. J. and others. The Changing Elementary School. Report of Regents' Inquiry. New York: Inor Publishing Company, 1939. Page 329.
3. Brownell, W. A.; Kuehner, K. G.; and Rein, W. C. Learning as Reorganization. Durham, North Carolina: Duke University Press, 1939. Page 72.
4. Sueltz, Ben A.; Boynton, H.; and Sauble, Irene. "The Measurement of Understanding in Elementary School Mathematics." The Measurement of Understanding. The forty-fifth Yearbook. National Society for the Study of Education. Chicago: University of Chicago Press, 1946. Page 141.

In the 1920's a number of experiments were reported in which research in problem solving received attention. One of these was a small-scale experiment by Bradford[5] which should probably be repeated in enlarged form. His results pointed out the necessity of developing a critical attitude toward problems. He gave twelve- and thirteen-year-old children in English schools five unsolvable problems, one being the following:

> A boy is five years old and his father is 35 years old. If his uncle is 40 years old, how old will his cousin be?

The pupils were told that if they could work the problem, they were to show their work on one side of the paper; if they were unable to work the problems, they were to put the reasons for this inability to do so on the other side of the paper. A numerical answer to all of the five impossible problems was supplied by 57% of the pupils and to some of the problems by 75% of the pupils. The study reflects something of the pressure upon the pupils to supply some sort of answer to all problems they attack.

Washburne and Osborne[6] compared three different methods of teaching problem solving in the area of arithmetic:

1. Giving systematic practice in solving many problems.
2. Using formal analysis of problems into what is given, what is the process to be used, and what other steps must be taken.
3. Using analogy to keep pupils aware of the relationships between simple oral problems and more difficult written problems.

The authors favored the first method, but they showed that good gains were made by all of the methods with no significant differences between them.

Daily[7] experimented with ninth grade pupils in a study of relevant and irrelevant materials in verbal problems in algebra. He found that the ninth grade texts currently in use included little of the irrelevant data commonly

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5. Bradford, E.J. G. "Suggestion, Reasoning, and Arithmetic," Forum of Education, 1925. Pages 3-12.

6. Washburne, C.W., and Osborne, R. "Solving Arithmetic Problems," Elementary School Journal, 1926. Pages 219-26, 296-304.

7. Daily, B. W. "The Ability of High School Students to Select Essential Data in Solving Problems," Teachers College Contributions to Education, No. 190. 1925. Page 276.

found in practical situations. He identified the following competencies as part of the problem-solving ability of ninth graders:

1. The ability to get a problem clearly in mind and to keep it in mind in the midst of abundant data and tempting side leads.

2. The ability to realize the sufficiency and the insufficiency of data.

3. An unwillingness to proceed without additional facts when these facts are needed.

Daily found it [illegible]ible, by means of special instruction, to teach pupils to exercise these desirable functions.

In the 1930's research studies continued to probe the area of verbal problem solving. White[8] placed arithmetic problems in settings ranging from some which were entirely outside their experiences to settings which were quite familiar to the pupils. As long as the settings were easy, the settings made little difference in the ability of the pupils to work them. As the problems became more difficult, unfamiliar vocabulary settings became more of a handicap in the pupils' efforts to solve them. The study by White confirmed an earlier study by Brownell and Stretch[9] who had reported that unfamiliar settings probably did not make problems more difficult for children, except in these instances:

1. When the problems contained numerical relationships of an intermediate degree of difficulty.

2. The number of times the pupil had met a given operation.

3. When the pupil was limited in the amount of time he could spend.

As the result of the above investigation, the authors concluded that if a teacher used only language with which the child was familiar in presenting arithmetic problems, there would be little opportunity for him to grow in vocabulary and its usage and application.

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8. White, H.M. "Does Experience in the Situation Involved Affect the Solving of a Problem?" Education, 54. April, 1934. Pages 451-5.

9. Brownell, W.G., and Stretch, L. B. The Effect of Unfamiliar Settings Upon Problem Solving. Durham: The Duke University Press, 1931. Page 86.

Doty[10] conducted an investigation in the early 1940's in which he interviewed 151 fourth grade and 31 sixth grade pupils, to find what methods these pupils used as they solved verbal problems in arithmetic. He found the following procedures which usually resulted in an incorrect solution:

1. Determining the solution from the numbers in the problems and from the verbal clues.

2. Neglecting the questions asked.

3. Disregarding the data given.

4. Selecting a process appropriate to only one part of the problem.

5. Working one of the steps before reading aloud.

6. Estimating the size of the answer and then jiggling the figures to get that answer.

More positively, six procedures led to correct solutions:

1. Rereading the problem before computing the answer as a check of comprehension.

2. Checking correctness by a final glance at the whole problem.

3. Labelling answers.

4. Evaluating work as to its reasonableness.

5. Visualizing the problem.

6. Recalling analogous problems.

The investigator found that one third of the solutions were decided upon immediately, and he concluded that children did not employ problem solving in the psychological manner described by Dewey. His investigation points to the need for a more subtle analysis of problem solving behavior if successful teaching in this area of thinking is to result.

10. Doty, R.A. " A Study of Children's Procedures in the Solution of Verbal Problems," Unpublished Doctoral Dissertation, Duke University, 1940.

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Johnson[11] experimented with seventh grade pupils in the use of vocabulary-teaching materials as a technique for improving success in arithmetic. He found that teaching vocabulary terms improves arithmetic vocabulary as well as the solutions of problems involving that vocabulary. The use of vocabulary learnings does not, however, bring about a general improvement in arithmetic learnings, nor is there any evidence of transfer of training between words taught and other words not taught. Teachers who use vocabulary aids can bring about greater growth than if the aids are not used. Experienced teachers are not necessary for the successful use of Johnson's material; and regular and systematic use of vocabulary material brings best results.

Gans[12] studied a method of teaching problem solving, and she concluded that intermediate grade children could be taught to select the material which was relevant to the problem on hand.

Klugman[13] investigated the success of fourth, fifth, and sixth grade children who worked on problem solving in pairs as compared with the same grade level children who worked alone. The children working in pairs solved significantly more problems than did those who worked alone, but they took longer to do it. The investigator believed that this result may be attributed to the presentation, discussion, rejection, and acceptance of a large number of solutions by the paired children.

Burch[14] tested 305 pupils in grades 4, 5, and 6 on four important questions:

1. What does the problem tell?
2. What is to be found?

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11. Johnson, H.C. "The Effect of Instruction in Mathematics Vocabulary on Problem Solving in Arithmetic," Journal of Educational Research, 38. October, 1944. Pages 97-110.

12. Gans, Roma. " A study of Critical Reading Comprehension in the Intermediate Grades, " Teachers College Contributions to Education, No. 811, 1940.

13. Klugman, S.F. " Cooperative vs. Individual Efficiency in Problem Solving," Journal of Educational Psychology, 35. 1944. Pages 91-105.

14. Burch, R. L. " An Evaluation of Analytic Testing in Arithmetic Problem Solving," Unpublished Doctoral Dissertation. Durham: Duke University, 1949.

3. What is to be done?

4. What is the best answer?

Some children did the formal analysis and then solved the problems; others reversed the process. Burch concluded that the "formal analysis test is of dubious value as a measure of problem-solving ability," and that no single step of formal analysis seems to be essential to success in setting up the algorism. He did state, however, that although the problem-analysis technique has definite limitations, it may still have some value, particularly in the what-to-do step.

Sutherland[15] analyzed the one-step, two-step, and three-step verbal problems contained in four series of arithmetic books which were prepared for grades 3 through 6, inclusive. She showed that these verbal-numerical problems can be broken down into 38 one-step patterns -- four in addition, ten in subtraction, eight in multiplication, and sixteen in division. Subtraction, for example, includes the remainder idea, the building-up idea, the comparison idea, and the separation into parts idea. Sutherland's analysis is not only of interest to teachers of arithmetic, but it also suggests the error of considering all problem solving as a single pattern. Thus, there is need for a mode of attack which will analyze specifically just what the problem is.

In the middle 1940's, Johnson reviewed the literature of problem solving which had appeared in the earlier part of that decade. This research had indicated to Johnson that six areas were related to problem-solving ability:

1. Reading ability
2. Knowledge of specialized vocabulary
3. Language and situation of the problem
4. Ability to analyze problems

15. Sutherland, Ethel. " One-Step Problem Patterns and their Relation to Problem Solving in Arithmetic, " Teachers College Contributions to Education, No. 925, 1947.

16. Johnson, H.C. " Problem Solving in Arithmetic--A Review of the Literature, " Elementary School Journal, 44. 1944. Pages 396-403, 476-482.

5. Experience in problem solving

6. The ability to correct procedures at the point of the error

More recent studies in elementary mathematics have amplified earlier problem-solving investigations and have identified new areas of concern. Burack[17] in 1953 reviewed current research in the area of elementary arithmetic problem solving and arrived at the following conclusion. There is no single royal road to problem-solving success in arithmetic or in other fields. Perhaps because children and problems vary so much, there is no one technique which will improve the process generally. Every study quoted, however, showed that an active attack on methods of problem solving does pay off. Some pupils make gains when they improve their computation, others profit from help in their reading of verbal problems, others need experiential background to understand the problems, and some may profit from an analysis which concentrates on choosing the correct operation or on judging the accuracy of a possible answer. If there is a single key to the improvement of problem solving abilities, it seems to lie in instruction for a varied attack on problems.

Corle[18] studied the characteristics of good and poor sixth grade arithmetic problem solvers. Approximately 50 good problem solvers and 50 poor problem solvers worked eight verbal problems each in individual interviews with the investigator. The interviews were tape recorded so that all of the pupils' verbalizations could be preserved. He concluded that as a result of the study:

1. Good problem solvers are superior as a group to poor problem solvers in the insight shown into a problem situation.

2. Both good and poor problem solvers, individually, may develop a clear, a partially clear, or a doubtful insight into any given problem.

3. Insight into a problem is closely related to the ability of a pupil to recall background experiences and to apply those experiences to the problem.

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17. Burack, B. " Methodological Aspects of Problem Solving," Progressing Education, 30. 1953. Pages 134-138.

18. Corle, C.G. " The Characteristics of Good and Poor Problem Solvers in Sixth Grade Arithmetic, " Unpublished Doctoral Dissertation. University of Cincinnati, 1953.

4. Good problem solvers, more frequently than poor, apply social situations in choosing a method of attacking a problem.

5. On certain kinds of problems, individuals from both good and poor groups will deviate from their normal patterns and perform well, or poorly, depending upon the problem being considered. Thus, a poor problem solver may show unusual insight into a given problem, while a good problem solver may find no logical approach to solving the same problem.

6. Computational errors, compared with wrong choice of method, accounted for only a small part of the incorrect solutions submitted by both good and poor problem solvers.

A later study by Corle[19] showed that of eight verbal problems solved by each of 75 sixth graders, only 43% were solved correctly. In less than half (20%) of the correct solutions, however, there was no evidence that the problem solver understood the meaning of the problem or the social significance of the problem statement. Approximately half of the correct solutions were correct apparently because the pupils were able to follow word and number clues and make a considered guess of the appropriate method to be used. In the same study, pupils were asked to evaluate all of their solutions, whether they were right or wrong. Although only 43% of the solutions were actually correct, the pupils reported that they believed 68% of them to be right. This evidence of confidence in their own solutions was more than 50% higher than the actual level of accuracy demonstrated by the pupils.

Feldhausen and Klausmeier[20] correlated reading achievement scores and arithmetic scores and found a substantial correlation. Mazzei[21] studied the effectiveness of estimating answers in verbal problem solving. He reported that although estimating answers produced only slight gains in achievement, the procedure led to thoughtful analysis, resulting in better understanding.

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19. Corle, C.G., "Thought Processes in Grade Six Problems," Arithmetic Teacher, 5. October, 1958. Pages 193-204.

20. Feldhausen, I.F., and Klausmeier, H.J. " Achievement in Counting and Addition," Elementary School Journal, 59. April, 1959. Pages 388-93.

21. Mazzei, R. " A Technique for Preventing Errors in Arithmetic," School Science and Mathematics, 59. June 1959. Pages 493-97.

Chase[22] reported that there are few academic skills and intellectual factors necessary to problem solving, the most important being ability to compute, ability to observe detail, and knowledge of fundamental concepts. A number of secondary variables are related - such as knowledge of generalizations which underlie the number system and the ability to apply reading skills to a variety of purposes.

Sister Josephine[23] conducted a research project which dealt with teaching mental arithmetic in the fifth grade. She tested two techniques of presenting mental arithmetic to the pupils, and she reported that pupil performance was better when the problem was read from the book and then looked at than when the problem was presented orally by the teacher.

Bassham[24] surveyed the relationship between teacher understanding of mathematical activities and that of the pupils in these teachers' classes. He correlated scores made by sixth grade teachers in a Test of Basic Mathematical Understanding with the scores made by their sixth grade pupils in their classes. He found significant relationships between the teacher scores on the paper-and-pencil test and pupil ability to master arithmetic as measured in an unmodified classroom. The understanding of basic mathematical concepts by the teacher was demonstrated to be significantly related to pupil efficiency in learning.

Riedesel[25] compared the effectiveness of the use of specific verbal problem-solving procedures in connection with the provision of two levels of problem difficulty with the problem-solving program followed in arithmetic textbooks. He prepared thirty problem solving lessons, each written at two levels of difficulty, with materials provided for pupils above and below average in problem solving

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22. Chase, C.I. "The Position of Certain Variables in the Prediction of Problem solving in Arithmetic " Journal of Educational Research, 54. September, 1960. Pages 9-14.

23. Sister Josephine. "Mental Arithmetic in Today's Classroom," Arithmetic Teacher , 9. April, 1960. Pages 199-200.

24. Bassham, H. "Teacher Understanding and Pupil Efficiency in Mathematics-- A Study of Relationships," Arithmetic Teacher, 9. November, 1962 . Page 383.

25. Riedesel, C. Alan. "Procedures for Improving Verbal Problem-Solving Ability in Arithmetic," Unpublished Doctoral Dissertation, University of Iowa. 1962.

ability. The lessons made use of the following specific problem-solving procedures:

1. Writing the number question
2. Using drawings and diagrams
3. Pupil formulations of problems
4. Orally presented problems
5. Problems without numbers

The investigator concluded that:

1. Teachers and others who prepare arithmetic materials will enhance the educational value of their teaching materials by developing problem solving materials of multi-level difficulty.

2. Greater use should be made of specific procedures in problem-solving programs; e.g., writing the number question, use of drawings and diagrams, etc.

3. The tape recorder has promise as a device to be used in test presentation. Further use should be made of this device.

4. The pupils enjoyed working the foreign and old U.S. problems. Curriculum workers will find it profitable to include problems of this type as a means of increasing pupil interest.

Another side of the verbal problem solving puzzle has been examined by writers and researchers whose primary interests were the skills of reading. Many writings and investigations have shown the close relationship and the heavy influence of reading ability upon the interpretation of written arithmetic problems.

In an early study of fundamental reading habits, Buswell[26] concluded that an approach to reading instruction which emphasizes thoughtful reading attitudes and meaningful experiences promotes greater interest in reading content material than does an approach which emphasizes the mechanics of word attack and word meaning.

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26. Buswell, Guy T. Fundamental Reading Habits: A Study of Their Development, University of Chicago, 1922. 150 pp.

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Somewhat later McCallister[27] became interested in reading in the content fields and after considerable study he classified the reading difficulties in the content fields into the categories of:

a. the pupil's method of attack
b. inability to recognize relationships
c. lack of knowledge of subject matter
d. reading inaccuracies
e. lack of clarity in directions given to children.

The greatest interest in the problems of reading content materials has been shown in the last 30 years. It had long been acknowledged that reading development was of high importance to successful study of content subjects, but little serious investigation had been conducted prior to the 1930's.

The more recent studies of content reading have pointed out several interesting and significant generalizations.

1. There is a great deal in common between reading in a single content field and reading in general.[28] This generalization implies the importance of the development of good general reading skills such as word perception and comprehension.

2. Specific skills in reading have different predictive values for various content fields.[29] In other words, the fact that a child shows competence in word attack skills is no assurance that he will read equally well in social studies, arithmetic, or science.

3. There is a need for developing specific kinds of reading skills for the various content areas. The presence of general reading ability is apparently no guarantee of equal success in the various content areas.[30]

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27. McCallister, James M., "Guiding Pupils' Reading Activities in the Study of Content Subjects," Elementary School Journal, 31. October, 1930.Pages 191-201.

28. Traxler, Arthur E., and Townsend, Agatha. Another Five Years of Research in Reading: Summary and Bibliography, Educational Records Bureau, 1946. 192 pp.

29. Encyclopedia of Educational Research, Third Edition, edited by Chester Harris, New York: The MacMillan Company, 1960. Pages 1122-1127.

30. Ibid., 1126.

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While at first these generalizations may seem somewhat contradictory, or possibly even repetitive, a closer examination reveals the distinctive quality of each and also the strong implications for developing a reading skills program in each area of content.

To support such implications, the studies reported by Fay[31] and Artley[32] have shown that significant gains in achievement are obtained when special attention is given to teaching reading comprehension, vocabulary and word meaning, reading and study skills, the perception of relationships, and the development of experiential background in each of the areas of arithmetic, social studies, and science.[33]

As a basis for developing teacher-led experimentation with reading skills instruction in the content areas, Fay reviewed the pertinent research findings and authoritative writings regarding the problems of content reading.[34] A summary of those findings follows:

1. The ability to effectively use content materials of increasing complexity and difficulty is dependent upon continued growth and maturity in the basic reading skills.

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31. Fay, Leo. ' Responsibility for and Methods of Promoting Growth in Reading in the Content Areas," Better Readers For Our Times, International Reading Association Conference Proceedings, Volume I, 1956. Page 92.

32. Artley, A.S. "A Study of Certain Relationships Existing Between General Reading Comprehension and Reading Comprehension in the Subject Matter Areas, " Journal of Educational Research, 37. February, 1944. Pages 464-473.

33. Fay, Leo. "What Research Has to Say About Reading in the Content Fields," Reading Teacher, 8. December, 1954. Pages 68-72.

34. Fay, Leo. Improving the Teaching of Reading by Teacher Experimentation, Bulletin of the School of Education, Indiana University, volume 34, no. 5, September 1958, Page 104.

2. Reading skills which are directly related to the successful mastery of a content area are best taught and learned within the framework of that content area.

3. Good reading, good study, and high achievement in any content area are largely dependent upon the interest a teacher is able to generate. Mechanical instruction, regardless of how good the form, is no competitor with creative, enthusiastic, and understanding teaching.

4. There are unique comprehension problems in each area of content and they each need special attention. The comprehension problems of arithmetic content are different from those of the social studies, science, and literature.

5. The body of basic facts and ideas and the way of organizing them in each of the content areas should be developed. The children must learn to synthesize, assimilate, and interrelate this basic information into knowledge, understanding, and principle. Then they must react to what they read, rather than merely parrot the information.

6. Lack of understanding of word meanings is a major block to successful content reading. Teachers must strive to avoid the tendency to assume that word meanings are obvious and to ignore them in their instruction.

7. Differences in materials in the different content areas are sources of confusion to many children primarily because:

    a. Fact and concept are often unduly heavy.

    b. Striking format variations within some areas and from one area to another often lead to confusion.

    c. Children often find the material in the content areas dull and uninteresting, especially in some of the "skeleton" textbooks which have compressed tremendous amounts of information into a minimum of space.

    d. Content materials are often significantly harder than basic readers and literary materials.

    e. Authors of content books often assume greater background than the typical pupil possesses.

8. Extensive reading makes a valuable contribution to learning in the content areas, largely because of the broadening of the pupils' experiential background.

9. The nature of the assignment and the directions for study are significant factors in determining the quality of learning.

A four-month experiment in teaching the reading skills of comprehension, vocabulary, and word meaning to a 45-pupil fourth-grade arithmetic class was conducted in Bloomington, Indiana, with the following results on a standardized reading-arithmetic achievement test:[35]

1. The class median gain in paragraph meaning was six months. Almost 35 per cent of the class made a gain of 1.1 to 4.1 years in the .4 year that the work was carried on.

2. The median gain for the class in arithmetic reasoning was nine months, which was equal to twice the time spent in the experiment. Twenty children, or 46 per cent of the class, made a gain of 1.1 to 2.0 years. Four of these children were in the slower group and would not have been expected to make a normal gain of four months during the period of the experiment.

Experimentation in the other areas of content has shown similar results. That is, when well-planned instruction is given in the uses of the content materials, the technical vocabulary and the unique tasks and devices which each area of content demands of its readers, the performances of the pupils show a significant improvement. In the field of arithmetic there is a continued need for direct attention to the structure of the problem statement, the terminology of the problem, the perception of relevant clues, and the interpretation of the general and literal meaning of the problem.[36]

Weber[37] noted that cursory knowledge of the words and symbols of arithmetic problems is not enough to insure accurate interpretation. One of the principal

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35. Ibid., pp. 15-18.

36. Coulter, Myron L., "Changing Concepts of Reading Instruction in the Content Areas," Changing Concepts of Reading Instruction, International Reading Association Conference Proceedings, vol. 6, 1961. Pages 35-38.

37. Weber, Martha Gesling, "The Demon of Arithmetic-Reading Word Problems," Monograph for Elementary Teachers, No. 71, New York, Harper & Row, Publishers, Inc. Pages 1-3.

reasons why pupils have difficulty with word problems is their inability to understand the ideas underlying the fundamental processes--an inadequacy in reading comprehension. Weber recommends that word problems might be written with a vocabulary level which is at least one grade below the grade placement of the symbols and concepts being developed.

The implications of these studies. -- Research in elementary school mathematics covering the past half century has established the importance of language in arithmetic problem solving. Studies have agreed that critical thinking can take place only when the pupils understand what they are doing and why it is done that way. Conclusions reached by many of these investigators show that competency in reading, knowledge of quantitative vocabulary, and the ability to think effectively are essential to the learner's growth in problem-solving skills. Those who prepare the mathematics curriculum for elementary pupils cannot overlook such evidence; they must consider each element of it as they plan for children's learning activities and materials. The textbook image has possessed educators and many accept the text not only as infallible, but also as an omniscient source of mathematical wisdom.

A careful look at the elementary school arithmetic programs convinces the observer that a great deal is being done by teachers to improve the computational skills and to an extent the arithmetic reasoning skills of their pupils. And, barring carelessness, the pupils do a reasonably good job with the fundamental processes. The conspicuous weakness of most programs is the pupils' incompetence in interpreting the written problem.

The studies reviewed for this paper have repeatedly shown that even superficial attention to the reading skills in arithmetic has produced favorable results. Yet, the problem persists. The question immediately raised is, "Why won't teachers do something about it?" The answer may lie in the fact that there are few, if any, tested materials or techniques for teaching these skills. The studies examined only define the problem and describe the research design; they actually give the classroom teacher very little specific assistance. It is one thing to discover that a problem exists, another to provide the means for overcoming it. Therefore, the present study has its perimeters defined: one, to further study specifically reading-arithmetic skills under controlled conditions; two, to test materials and examinations for teaching these skills in the content of arithmetic.

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Chapter III

Procedures Used in the Study

The preparation of materials. -- Earlier studies in verbal problem solving have revealed that many intermediate grade pupils seem unable either to understand essential information given by the problem statement or to use this information successfully for interpreting problems. These pupils appeared rather to select word or number clues and then leap to some obvious solution without considering the real meaning set forth by the problem. In many cases the answer to the problem was merely a number, and the pupils who arrived at that number seldom gave any thought to the social significance of that answer.

Poor performance in verbal problem solving is characteristic of so many elementary school pupils that teachers feel a genuine concern about why children solve problems so poorly. Although the causes of difficulty are easily identified, simple identification alone is not very helpful to classroom teachers. At least five areas of general competency can be identified, any of which when applied, will improve the reading and interpretation of verbal problems:

1. Making an accurate interpretation of the problem statement, understanding the literal meaning, and relating that meaning to the appropriate computational process or processes. The use of this skill requires a careful analysis of the problem statements and the ability to criticize improperly or poorly worded verbal problems. Textbook writers have often been careless in the preparation of verbal problems, and many teachers have been passive in their reactions to such carelessness. A good problem solver, for example, should have something to say about the meanings of verbal problems such as those indicated below:

   a. Charles wished to set 30 tomato plants in his garden. If he sets the plants in six rows, how many plants will he put in each row? (This problem actually cannot be solved as it is written, for it fails to specify whether or not the rows are to be equal rows.)

   b. John saw nine airplanes fly over the school house and Joe saw seven airplanes fly over the school house. How many airplanes flew over the schoolhouse? (The correct answer, if there is one, is probably not 16 airplanes.)

c. How many gallons of milk will fill 36 quart bottles? (Since the author of this problem omitted the word "exactly" from the problem, any number of gallons equal to or greater than 9 could be the answer.)

2. Understanding the words used in the verbal problem statement. Such words are of two kinds, those which describe the problem situation and those which direct the pupil toward his choice of a solution. For example, one sixth-grade girl solved a verbal problem incorrectly because she failed to understand the meaning of the word "profit." She solved a problem which required her to compute the profit on an item by adding two cost items together. She later defined the word "profit" as "the total cost of something." Another sixth-grade pupil was unable to compute a day's receipts for the school cafeteria because she defined "receipts" as "slips of paper which showed that each child had paid for his lunch." Large numbers of sixth grade children defined the word "average" as "when you add and then divide."

3. Evaluating the facts supplied by a problem statement. If more facts are presented than the pupils need for a solution, each must select those which provide the essential data. If information is missing from the statement and can be supplied, the problem solver must be resourceful in providing the needed data. For example, the following problem contains extraneous material; it does not supply enough information for the solver to complete it; and it leaves the reader in doubt about the real intentions of the problem maker.

> Gerald lives 1 1/2 miles from school. He rides his new $40 bicycle to and from school each day. How far does he ride his bicycle in one week? (The $40 is extraneous; the missing information of five school days per week can be supplied; but the question of how far a boy would ride on his new bicycle in one week is one for conjecture.)

4. Understanding the quantitative facts used in the problem statement. Pupils must be able to understand numbers, interpret simple measures, and to make reasonable approximations of the outcomes of their solutions. Only a small percentage of a group of college juniors realized that the quantitative facts in

the following problem had purposely been distorted. They solved the problems as the directions indicated and announced the improbable answer with no apparent awareness of the answer's inappropriateness. An example of such a problem is the following:

> Terry owned a female cocker spaniel dog which was the mother of five six-week-old puppies. If the mother dog weighed 105 pounds and the puppies 65 pounds each, what was the total weight of the six dogs?

Since cocker spaniels seldom weigh more than 25 pounds, the young puppies would perhaps weigh only three or four pounds each. Yet, college juniors seemed willing to accept the assumptions made about the weight of the dogs without indicating any concern about the realism of the announced weights.

5. The application of social and economic knowledge to the interpretation of problems. Pupils who can think vicariously about a problem are in a more favorable position to understand what that problem means. The following example illustrates the fact that pupils can give a verbal description of a problem activity without really understanding the meaning of the problem itself.

> To pass a swimming test, Bob was told that he must swim twice the length of a pool without stopping. If the pool was 90 feet by 60 feet, how far must Bob swim in order to pass his test?

A wide variety of solutions appeared when a large number of sixth graders worked this problem, only a few of whom added 90 feet and 90 feet. Those who multiplied 90 x 60, or who added 90 + 60 + 90 + 60, or who presented some other incorrect solution were asked to explain their interpretation of the problem by showing what they meant using a piece of paper to represent the surface of the pool. In response to the question, "What do you think Bob did? " many replied, "He jumped in here, swam to the other end, swam back, and got out." After making such an explanation, almost all of the children who solved the problem incorrectly rejected an invitation to reconsider their solution to the problem, indicating that they believed their solution was correct.

The purpose of this investigation, as outlined in Chapter I was threefold. Specifically, it seeks answers to the following questions:

1. Are reading skills related to the solution of verbal problems?
2. Does instruction in specific reading competencies improve the pupils' abilities to solve verbal problems?
3. Are there significant differences in reading and arithmetic achievement between groups of pupils at fourth, fifth, and sixth grade levels who received special instruction in interpreting verbal problems and groups of pupils who did not receive that instruction.

An attempt to answer the above questions could be made only if two more specific questions could be answered. The first of these was whether or not the reading competencies of fourth, fifth, and sixth-grade children could be identified, and the second was whether or not the competencies, once identified, could be measured. Therefore, a group test for measuring verbal-problem reading skills was developed, and a series of lessons was prepared which would enable the investigators to study more specifically the function of these skills in children's reading activities.

<u>Development of the test.</u> -- The measuring instrument consisted of sixty items and was entitled the <u>Reading Skills in Verbal Problem Solving Test.</u> This test presented thirty verbal problems with two four-item multiple-choice questions about each problem. The questions asked the pupils to interpret the meanings of the problems rather than to find mathematical solutions to them. Some of the test problems were distorted in meaning, others lacked necessary information, and several of them contained facts which could not be used to find a solution. A number of the problems, however, had been written correctly, and the meanings of these problems were clearly and definitely stated.

The test items were divided into ten groups, each representing a specific reading competency believed to be needed by children when they try to interpret verbal problems. These ten reading competencies were derived from the five areas of general competence described earlier in this chapter:

1. To determine the literal meaning of the problem.

2. To relate the literal meaning of the problem to an appropriate computational process.
3. To understand the descriptive words used in the problem statement.
4. To understand the procedural words used in the problem statement.
5. To recognize extraneous material given by the problem and to make proper disposition of such material.
6. To identify missing information which can be supplied from one's own knowledge or experiences.
7. To identify missing information and to recognize the fact that such information cannot be supplied from one's knowledge or experiences.
8. To perceive accurate quantitative concepts, utilizing previous knowledge or experiences.
9. To comprehend numbers of greater magnitude.
10. To apply social or economic knowledge or experiences to the interpretation of verbal problems.

Six items were developed to measure each of the ten specific competencies. The six items were coded into the test, so that each question whose number ended in a certain digit represented one of the competencies. For example, Items 1, 11, 21, 31, 41, 51, tested competency number 1. Items 2, 12, 22, 32, 42, and 52 tested competency number 2, etc..

Although the test was used with grades 4, 5, and 6, the fourth grade teachers using the material reported that the reading difficulty and the mathematical involvement of the problems was more suitable to the fifth and the sixth grade levels.

Before the test was written in its final draft, preliminary forms were administered to more than 100 college juniors, almost 100 experienced elementary teachers, and about fifty elementary school children in grades 4 - 6. The college juniors and the teachers submitted written criticisms of the test items and suggested improvements for many of them. The final draft of the test appeared in booklet form for use with IBM answer sheets.

Preparation of the teaching materials. -- An important consideration in the investigation was the series of lessons which would be presented to the children in the experimental classes. Each teacher of the experimental classes taught twenty special lessons in verbal problem solving, one lesson per week in place of a regular assignment. For this purpose, two detailed lesson plans were developed to present each of the ten competencies described earlier in the chapter. The lessons consisted of verbal problems, somewhat like those used in the Reading Skills in Problem Solving Test. The first lesson covering each competency (the odd-numbered lessons) included specific instructions for children, questions, and points to be discussed relative to the problems. The second lesson (the even-numbered lessons) simply presented a list of problems and left the analysis of these problems strictly up to the pupils and their teacher.

A manual for teachers which accompanied the lessons provided information of both general and specific interest to the teachers. The suggestions for teaching were presented lesson-by-lesson, although teachers were reminded from time to time that it was not mandatory that they follow explicitly the directions in the manual.

Five unit tests, each covering a set of four lessons, provided a followup of the teaching procedures. The tests consisted of five verbal problems with two multiple-choice questions upon each problem. Thus, each ten-item test measured the two reading competencies which had been presented in the four lessons which immediately preceded the test. Results of the tests were graphed by the pupils, but no statistical use was made of these scores.

The population for the study. -- The Pennsylvania School Study Council provided partial financial support of the RASP project. Member schools also offered their elementary school classes as experimental centers for developing the teaching and the testing program. The investigators chose fifteen of the Council's 59 school districts for the experiment, choosing those districts which seemed to offer a wide variety of geographical, social, economic, and cultural backgrounds for the study.

The classrooms. -- The elementary supervisor in each of the fifteen districts chose a fourth, a fifth, and a sixth grade class which the supervisor designated as the experimental class. He also chose another fourth, another fifth, and another sixth grade as control classes. The supervisor chose, as best he could, equivalent classes with comparably competent teachers for the experimental and the control classes. The investigators accepted in every case the selections made by the supervisors. Thus, 45 experimental classrooms (fifteen for each grade) and

45 control classrooms began the experimental program. Two of the districts returned incomplete test data, and these districts were dropped from the study. Hence, this report includes data from 39 experimental and 39 control classrooms in 13 school districts in Central Pennsylvania.

The teachers. -- The instructions given to the school district supervisors suggested the selection of typical classroom teachers, both for the experimental and the control classes. One qualification which was considered important in the choice of teachers was that the teacher be willing to accept her responsibility for a part in the investigation.

The teachers and the supervisors of the experimental classes met with the investigators before the experimental period began. The investigators distributed the tests and the teaching materials and explained the purpose and the use of these materials. Control class teachers received none of this information. A member of the investigational staff made at least one followup visit to each school district during the instructional period for conferences with the experimental class teachers.

The administration of tests. -- The participating schools administered three tests to all pupils in both the experimental and the control classes before the teachers began teaching the prepared lessons in verbal problems. These tests included the *California Arithmetic Test*, and the *California Reading Test*, Forms W and Z, and the RASP test prepared by the investigators. Form W was used in half of the school districts and Form Z in the other half of the districts during the pretest. For the post test, the districts exchanged tests and used the alternate form at that time.

When the experimental classes had completed the twenty lessons assigned them, all of the experimental and control classes received a second administration of the *California Reading Test*, the *California Arithmetic Test*, and the RASP Test. As stated above, alternate forms of the California tests were given at the end of the investigational period.

Chapter IV
The Data

One purpose of this study, as set forth in Chapter I, was to determine whether pupils in Grades 4, 5, and 6 who received special assistance with reading skills showed superior achievement in reading and arithmetic when they were compared with a similar group of pupils who did not receive such assistance. The investigators sought to answer this question through the experimental use of teaching materials which they had prepared to supplement the regular Grade 4,5,6 arithmetic program. The teachers of the thirty-nine classes taught to the 1008 pupils in these classes twenty lessons from this material, presenting one such lesson per week. Thirty-nine control class teachers taught only the lessons normally presented to children of these three grades.

In October, 1962, the California Arithmetic Test, the California Reading Test, and the RASP Test were administered to all of the experimental and control classes. In March, 1963, at the end of the twenty-week instructional period, alternate forms of the two California Tests and the RASP Test were administered to both the experimental and the control pupils.

The results of the total test battery were analyzed by use of the t test for the significance of the differences in means before and after instruction, between experimental and control pupils, and at the various grade levels. Coefficients of correlation showed the interrelations of the RASP Test and the sub tests of the California Achievement Tests. Factor analysis of the post test scores indicated those factors which seemed to contribute most to the variance of these scores. All conclusions were drawn from consideration of the data described by the above procedures.

Table I shows the mean scores, grade placement level, and the t ratio between experimental and control scores for 337 experimental and 312 control 4th grade pupils on the pre-tests and the post-tests. The scores on the California Arithmetic Test were reported for each section of that test--arithmetic reasoning and arithmetic fundamentals. The scores on the California Reading Test were reported for each section of that test--reading vocabulary and reading comprehension.

The fourth grade control classes scored significantly higher (at the .02 level of confidence) on all five sections of the pre-test. The mean scores for the control group on the post-test were slightly higher for the California Tests, but only the reading vocabulary section was significantly higher (.02 level of confidence) than the experimental group scores. The post-test RASP mean score, however, was significantly higher for the experimental classes than it was for the control classes.

TABLE I. MEAN SCORES, GRADE PLACEMENT, AND t RATIOS FOR 337 EXPERIMENTAL FOURTH GRADE CHILDREN AND 312 CONTROL FOURTH GRADE CHILDREN (PRE- AND POST - TEST RESULTS) ON THE CALIFORNIA ARITHMETIC TEST, THE CALIFORNIA READING TEST AND THE RASP TEST

Test reported	Exper.	Pre-test Control	t ratio	Exper.	Post-test Control	t ratio
Arith. reasoning						
Mean	20.3	22.4	4.191	28.1	28.9	1.917
G.P.	4.7	5.0		6.1	6.3	
Arith. fundamentals						
Mean	20.4	23.7	6.577	31.8	32.2	0.696
G.P.	4.4	5.0		5.7	5.7	
Reading vocabulary						
Mean	27.3	29.0	2.537	34.4	35.9	2.442
G.P.	5.4	5.7		6.2	6.5	
Reading comprehension						
Mean	35.7	38.3	2.811	46.7	48.2	1.700
G.P.	5.2	5.4		6.4	6.5	
RASP						
Mean	15.9	17.3	3.336	22.1	20.2	3.601

t ratio 1.960 significant at the .05 level of confidence.
t ratio 2.576 significant at the .01 level of confidence.

Table II presents the comparable test data for fifth grade experimental and control pupils. On the pre-test, the fifth grade pupils' mean scores were higher in the control classes than in the experimental classes for all of the four sections of the California Tests. On only two of the sections, however, the arithmetic reasoning and fundamentals, was the difference significant. The differences in

RASP scores made by the two groups was not significant for the pre-test. There were no significant differences between the mean scores of experimental and control pupils on the California Tests when taken as the post-test. The experimental classes made a significantly higher mean score on the RASP Test than the control classes made.

TABLE II. MEAN SCORES, GRADE PLACEMENT AND t RATIOS FOR 314 EXPERIMENTAL FIFTH GRADE CHILDREN AND 344 CONTROL FIFTH GRADE CHILDREN (PRE- AND POST - TEST RESULTS) ON THE CALIFORNIA ARITHMETIC TEST, THE CALIFORNIA READING TEST AND THE RASP TEST

Test reported	Exper.	Pre-test Control	t ratio	Exper.	Post-test Control	t ratio
Arith. reasoning						
Mean	28.1	29.1	2.254	32.2	32.8	1.342
G.P.	6.1	6.3		6.9	7.1	
Arith. fundamentals						
Mean	31.3	33.2	3.327	42.2	42.3	0.166
G.P.	5.6	5.8		6.5	6.5	
Reading vocabulary						
Mean	35.3	35.5	0.250	39.6	39.6	0.001
G.P.	6.4	6.5		7.1	7.1	
Reading comprehension M.	46.7	47.5	0.158	54.4	53.6	0.999
G.P.	6.5	6.5		7.2	7.2	
RASP						
Mean	20.0	19.6	0.872	27.8	22.5	8.015

t ratio 1.960 significant at the .05 level of confidence
t ratio 2.576 significant at the .01 level of confidence

Comparable data for the sixth grade experimental classes, pre- and post-tests, are presented in Table III. The mean scores made by the experimental and the control classes on the pre-test were not significantly different although the experimental mean scores were higher on all tests except reading vocabulary.

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On the post-test, however, the experimental classes made higher mean scores on all five sections of the tests, and the means were significantly higher on three of these tests: arithmetic fundamentals, reading comprehension, and the RASP Test.

TABLE III. MEAN SCORES, GRADE PLACEMENT AND t RATIOS FOR 357 EXPERIMENTAL SIXTH GRADE CHILDREN AND 337 CONTROL SIXTH GRADE CHILDREN (PRE-AND POST-TEST RESULTS) ON THE CALIFORNIA ARITHMETIC TEST, THE CALIFORNIA READING TEST AND THE RASP TEST

Test reported	Exper.	Pre-test Control	t ratio	Exper.	Post-test Control	t ratio
Arith. reasoning						
Mean	32.5	32.3	0.556	36.4	36.1	0.806
G.P.	6.9	7.1		8.1	8.1	
Arith. fundamentals						
Mean	42.4	42.0	0.613	59.6	57.2	2.836
G.P.	6.4	6.5		8.4	8.0	
Reading vocabulary						
Mean	40.0	40.0	0.082	43.1	42.5	1.215
G.P.	7.1	7.1		7.8	7.8	
Reading comprehension						
Mean	54.8	53.9	1.195	59.4	58.0	2.352
G.P.	7.4	7.2		7.9	7.7	
RASP						
Mean	23.6	22.5	1.938	32.1	25.4	10.086

t ratio 1.960 significant at the .05 level of confidence
t ratio 2.576 significant at the .01 level of confidence

When all of the pupils in the experimental classes were added together, the sum was 1008 pupils. The total number of control pupils was 993. When the mean scores of all experimental and of all control pupils were computed, those means gave a somewhat different picture. In each of the pre-test means, the control groups scored higher than the experimental groups with the exception of the RASP

Test means. The arithmetic reasoning and arithmetic fundamentals means, however, were significantly higher for the control groups. Table IV shows these data. Table IV also shows that there were no significant differences between the scores made by experimental and control pupils on any of the sections of the California Tests when the means of the test scores on the post-test were compared. The RASP Test, again, showed significantly higher means for the experimental classes on the post-test.

TABLE IV. MEAN SCORES, GRADE PLACEMENT, AND t RATIOS FOR 1008 EXPERIMENTAL FOURTH, FIFTH, AND SIXTH GRADE CHILDREN AND 993 CONTROL FOURTH, FIFTH, AND SIXTH GRADE CHILDREN (PRE-AND POST-TEST RESULTS) ON THE CALIFORNIA ARITHMETIC TEST, THE CALIFORNIA READING TEST, AND THE RASP TEST

Test reported	Exper.	Pre-test Control	t ratio	Exper.	Post-test Control	t ratio
Arithmetic reasoning						
Mean	27.1	28.0	3.09	32.4	32.7	1.408
G.P.	5.9	6.1		6.9	7.1	
Arithmetic fundamentals						
Mean	31.6	33.2	3.13	44.9	44.2	1.072
G.P.	5.7	5.8		6.7	6.7	
Reading vocabulary						
Mean	34.3	35.0	1.615	39.1	39.4	1.047
G.P.	6.2	6.4		7.0	7.0	
Reading comprehension						
Mean	46.2	46.8	1.019	53.6	53.4	0.432
G.P.	6.2	6.4		7.2	7.1	
RASP						
Mean	19.9	19.9	0.123	27.4	22.8	12.027

t ratio 1.960 significant at the .05 level of confidence
t ratio 2.576 significant at the .01 level of confidence

The data in Tables I, II, and III on the pre-tests indicate that the control classes performed significantly better on seven of the fifteen independent tests. Five of the seven significantly different mean scores occurred at the fourth grade level. Two occurred at the fifth grade and none at the sixth.

On the RASP post-test, the mean scores for the experimental classes at all grade levels were significantly higher than the mean scores for the control classes. These differences were not surprising, however, for a definite effort was made to teach the experimental children the material from which the test was prepared. The twelve remaining post-test mean scores (Tables I, II, and III) revealed very little difference between the experimental and the control groups. Two of the twelve were significantly different; one favored the experimental and one favored the control group.

When all of the experimental and control classes were combined (Table IV), the total groups appeared to be equated except for the arithmetic reasoning and arithmetic fundamentals. Again, the differences favored the control groups, possibly some of it carrying over from the rather substantial difference shown by the fourth grade pupils. The comparison of total groups (Table IV) on the post-test results, showed no significant differences on any of the California Test results.

Exactly what weight should be given to the superiority of the control classes, and particularly that of the fourth grade, will be hard to say. In fact, the data indicate that control pupils did generally better than experimental pupils in the pre-test, although at the fifth and sixth grade levels these differences were not always significant. One, sixth grade reading comprehension (Table III), showed a higher mean score for experimental than for control, but the pre-test means were higher also for the experimental groups.

Differences in mean gains. -- The mean gains for each of the five tests, experimental and control, were computed by subtracting the mean score of the pre-test from the mean score of the post-test. This was done at each grade level and also for the combined grades. The differences in mean gains were found by subtracting the mean gain of the experimental and the mean gain of the control classes. The t ratio for significance of the difference in mean gains indicated those gains which were significant. In every one of the tests, and for all three grades, the experimental classes showed greater but not always significant gains in mean scores than the control classes.

Table V shows the differences in mean gains for fourth grade on each of the five sections of the tests:

TABLE V. MEAN SCORES, GRADE PLACEMENT, MEAN GAIN, GREATER EXPERIMENTAL GAIN, AND t RATIOS FOR SIGNIFICANCE OF THE DIFFERENCE OF MEAN GAINS FROM PRE-TO POST-ADMINISTRATIONS OF THE CALIFORNIA ARITHMETIC TEST, THE CALIFORNIA READING TEST, AND THE RASP TEST TO 337 EXPERIMENTAL AND 314 CONTROL FOURTH GRADE PUPILS

Test reported	EXPERIMENTAL			CONTROL			Greater	
	Pre-test	Post-test	Mean Gain	Pre-test	Post-test	Mean Gain	Exper. Gain	t ratio
Arith. reasoning								
Mean	20.3	28.1	7.8	22.4	28.9	6.5	1.3	3.434
G.P.	4.7	6.1	1.7	5.0	6.3	1.3	.4	
Arith. fundamentals								
Mean	20.4	31.8	11.4	23.7	32.3	8.6	2.8	4.935
G.P.	4.4	5.7	1.3	5.0	5.7	.7	.6	
Reading vocabulary								
Mean	27.3	34.4	7.1	29.0	35.9	6.9	.2	0.506
G.P.	5.4	6.2	.8	5.7	6.5	.8	.0	
Reading Comprehension								
Mean	35.7	46.7	11.0	38.3	48.2	9.9	1.1	1.692
G.P.	5.2	6.4	1.2	5.4	6.5	1.1	.1	
RASP								
Mean	15.9	22.1	6.2	17.3	20.2	2.9	3.3	6.299

t ratio 1.960 significant at the .05 level of confidence
t ratio 2.576 significant at the .01 level of confidence

Fourth grade experimental pupils made a higher mean gain than the fourth grade control pupils on all tests, although only three of the gains were significantly higher. This fact was true in spite of the fact that the fourth grade control group was significantly higher than the experimental group in tests in the preliminary administration.

Table VI shows the differences in mean gain for fifth grade pupils on each of the five sections of the tests:

TABLE VI. MEAN SCORES, GRADE PLACEMENT, MEAN GAIN, GREATER EXPERIMENTAL GAIN, AND t RATIOS FOR SIGNIFICANCE OF THE DIFFERENCE OF MEAN GAINS FROM PRE - TO POST - ADMINISTRATIONS OF THE CALIFORNIA ARITHMETIC TEST, THE CALIFORNIA READING TEST, AND THE RASP TEST TO 314 EXPERIMENTAL AND 344 CONTROL FIFTH GRADE PUPILS

Test reported	EXPERIMENTAL			CONTROL			Greater	t ratio
	Pre-test	Post-test	Mean Gain	Pre-test	Post-test	Mean Gain	Exper. Gain	
Arith. reasoning								
Mean	28.1	32.2	4.1	29.1	32.8	3.7	.4	1.230
G.P.	6.1	6.9	.8	6.3	7.1	.8	.0	
Arith. fundamentals								
Mean	31.3	42.2	10.9	33.2	42.3	9.1	1.8	3.160
G.P.	5.6	6.5	.9	5.8	6.5	.7	.2	
Reading vocabulary								
Mean	35.3	39.6	4.3	35.5	39.6	4.1	.2	0.380
G.P.	6.4	7.1	.7	6.5	7.1	.6	.1	
Reading comprehension								
Mean	46.7	54.4	7.7	47.5	53.6	6.1	1.6	1.169
G.P.	6.5	7.2	.7	6.5	7.1	.6	.1	
RASP								
Mean	20.0	27.8	7.8	19.6	22.5	2.9	4.9	9.776

t ratio 1.960 significant at the .06 level of confidence
t ratio 2.576 significant at the .01 level of confidence

A comparison of the gains made by fifth grade pupils in experimental and control classes shows that experimental classes gained more than control classes on all five of the tests, although this gain was significant on only two of the tests. This gain, with the exception of the arithmetic fundamentals test and the RASP Test, probably was chance gain. There is no evidence that it could have occurred as the result of the experiment.

Table VII shows the differences in mean gains for sixth grade pupils on each of the five sections of the tests:

TABLE VII. MEAN SCORES, GRADE PLACEMENT, MEAN GAIN, GREATER EXPERIMENTAL GAIN, AND t RATIOS FOR SIGNIFICANCE OF THE DIFFERENCE OF MEAN GAINS FROM PRE- TO POST - ADMINISTRATIONS OF THE CALIFORNIA ARITHMETIC TEST, THE CALIFORNIA READING TEST, AND THE RASP TEST TO 357 EXPERIMENTAL AND 337 CONTROL SIXTH GRADE PUPILS

Test reported	EXPERIMENTAL Pre-test	Post-test	Mean Gain	CONTROL Pre-test	Post-test	Mean Gain	Greater Exper. Gain	t ratio
Arith. reasoning								
Mean	32.5	36.4	3.9	32.3	36.1	3.8	.1	0.026
G.P.	7.1	8.1	1.0	7.1	8.1	1.0	.0	
Arith. fundamentals								
Mean	42.4	59.6	17.2	42.0	57.2	15.2	2.0	3.219
G.P.	6.5	8.4	1.9	6.5	8.0	1.5	.4	
Reading vocabulary								
Mean	40.0	43.1	3.1	40.0	42.5	2.5	.6	1.271
G.P.	7.1	7.8	.7	7.1	7.7	.6	.1	
Reading comprehension								
Mean	54.8	59.4	4.6	53.9	58.0	4.1	.5	1.232
G.P.	7.4	7.9	.5	7.2	7.7	.5	.0	
RASP								
Mean	23.6	32.1	8.5	22.5	25.4	2.9	5.6	11.652

t ratio 1.960 significant at the .05 level of confidence
t ratio 2.576 significant at the .01 level of confidence

Sixth grade experimental classes gained more than control classes, but only two of these gains were significantly higher than the control gains. The higher gains in the other three areas of the tests, like those of fourth and fifth grade classes, probably are only chance gains, although the persistence of the experimental gain indicates that some factor other than chance might have been operating.

Table VIII shows the differences in mean gains when all of the experimental and all of the control classes of fourth, fifth, and sixth grades are combined:

TABLE VIII. MEAN SCORES, GRADE PLACEMENT, MEAN GAIN, GREATER EXPERIMENTAL GAIN, AND t RATIOS FOR THE SIGNIFICANCE OF THE DIFFERENCE OF MEAN GAINS FROM PRE-TO POST-ADMINISTRATIONS OF THE CALIFORNIA ARITHMETIC TEST, THE CALIFORNIA READING TEST, AND THE RASP TEST TO 1008 FOURTH, FIFTH, AND SIXTH GRADE EXPERIMENTAL AND TO 993 FOURTH, FIFTH, AND SIXTH GRADE CONTROL PUPILS

	EXPERIMENTAL			CONTROL				
Test reported	Pre-test	Post-test	Mean Gain	Pre-test	Post-test	Mean Gain	Greater Exper. Gain	t ratio
Arithmetic reasoning								
Mean	27.1	32.4	5.3	28.0	32.7	4.7	.6	3.078
	5.9	6.9	1.0	6.1	7.1	1.0	.0	
Arithmetic fundamentals								
Mean	31.6	44.9	13.3	33.2	44.2	11.0	2.2	6.293
G.P.	5.7	6.7	1.0	5.8	6.7	.9	.1	
Reading vocabulary								
Mean	34.3	39.1	4.8	35.0	39.4	4.4	.4	1.275
G.P.	6.2	7.0	.8	6.4	7.0	.6	.2	
Reading comprehension								
Mean	46.2	53.6	7.4	46.8	53.4	6.6	.8	1.232
G.P.	6.2	7.2	1.0	6.4	7.2	.8	.2	
RASP								
Mean	19.9	27.4	7.5	19.9	22.8	2.9	4.6	15.888

t ratio 1.960 significant at the .05 level of confidence
t ratio 2.576 significant at the .01 level of confidence

Table VIII has shown that the mean gains of the total experimental classes were greater than the mean gains of the total control classes. On three of the five tests, these mean gains were significantly higher, and on two of the tests the gains might have been higher by chance. Since the gains persisted throughout the experimental groups, it is possible that some factor or factors other than chance were operating to produce this consistent gain.

The elementary supervisors in the participating school districts attempted to select experimental and control classes which were approximately alike in achievement and ability. Tables I, II, III and IV show that they were not entirely successful in the latter choice, for the control pupils appear to have performed better on a number of the preliminary tests. After a twenty-week period of instruction, however, the mean scores of experimental and control classes failed to show these differences (Tables V, VI, VII, and VIII). The experimental classes on every test had shown greater mean gain, with gain on seven of fifteen tests in the three grade levels significantly higher than those of the control classes. This gain was sufficiently large to bring the experimental post-test mean scores almost up to, and sometimes beyond the control mean scores. At all grade levels, and for the entire group as well, the experimental RASP Test mean scores, which had been approximately equal to the control RASP Test mean scores on the preliminary tests, were significantly higher for the post-test. This difference should have been predicted, for the experimental pupils received twenty weeks of instruction in the problems covered by the RASP Test, and the control pupils did not.

Fourth grade teachers had been especially critical of the questions on the RASP Test and of the teaching materials they had been asked to use. The major complaint was that the materials were more suitable to the fifth and sixth grades. Yet, the fourth grade experimental mean gains in arithmetic achievement exceeded those of experimental fifth and experimental sixth in three of the four scores on the tests (Tables V, VI, VII). Furthermore, fourth grade experimental pupils made greater mean gains in reading achievement than those made by either fifth or sixth grade experimental pupils. Since the fourth grade experimental classes showed significantly lower mean scores on the preliminary tests, some learning factor other than chance must account for this growth in arithmetic and reading achievement during the experimental period.

The mean scores of the sixth grade pupils might not be a fair measure of the performance of either the experimental or the control pupils. A random observation of the preliminary test scores reveals that on one or more of the California Test subscores, perhaps ten percent of the experimental and a comparable number of control pupils achieved at or near the maximum score. The number of pupils who were able to perform as well on the final tests increased noticeably. Since for these pupils the test ceiling precluded any possible indication of gain, the statistics for the sixth grade may be somewhat less valid than those for the other two grades.

The investigators believe that a substantial portion of the mean gain shown by the experimental pupils did not occur by chance. Some learning factors must have been in operation when a thousand pupils who had received special instruction showed greater gains than pupils who had not received this teaching. The Hawthorne effect cannot be overlooked, because repeated experiments of this nature reveal that when subjects know that they are participating in some kind of experiment, they tend to give better performances than subjects who do not know. The teacher factor, likewise, has not been entirely eliminated. The method of selection, however, by local district supervisors, and the number (78) of teachers taking part in the project have given the investigators reason to believe that the teacher variable to some extent has been accommodated. The pupil variable could have been a factor in the final results, for the control classes on the whole did better than the experimental classes on the preliminary tests. Whether this performance was the result of superior intelligence, different teaching the preceding year, or some error in test administration is not known. No record was kept of the time teachers spent in teaching arithmetic during the twenty-week experimental period. The investigators assumed, however, that experimental and control teachers complied with instructions to use the normal amount of time for arithmetic.*

The intent of this study was to learn whether or not pupils of Grades 4, 5, and 6 will increase their achievement in reading and arithmetic when these pupils receive special assistance in certain reading competencies. This fact could be established only by teaching a group of children and then by measuring their achievement. If the gains in test scores favored the experimental pupils over an equivalent number of non-experimental pupils, one might conclude that the independent variable, that of classroom instruction in certain reading competencies, had been a factor in producing such an increase.

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* A question may be raised as to why intelligence test scores were not considered in the present study. Since the major concern of this investigation was the differences in the measured performances of elementary pupils after one half of them had received carefully controlled experimental instruction, it was felt that performance rather than ability was the primary criterion. The differences in pupil performance were measured by achievement tests at the beginning and at the conclusion of the study.

The correlations of RASP scores with Achievement Test Scores.--When pupils' raw scores were examined, the RASP Test scores appeared to be in general agreement with the scores made on the achievement tests. For example, a pupil who made a score above the mean appeared, likewise, to score above the mean on the RASP Test. Before any generalizations were made from these observations, however, symmetric correlations between the four subtests and the RASP Test were computed. Tables IX, X, XI, and XII show these coefficients of correlation. Table IX presents the correlation between the RASP scores made by the experimental pupils on the pre-test and their scores on the pre-test of arithmetic and reading achievement.

TABLE IX. CORRELATIONS BETWEEN PRE-TEST RASP SCORES AND PRE-TEST ACHIEVEMENT SCORES FOR EXPERIMENTAL PUPILS

		RASP with			
Grade	N	Arithmetic Reasoning	Arithmetic Fundamentals	Reading Vocabulary	Reading Comprehension
Fourth	337	.267	.125	.353	.389
Fifth	314	.474	.411	.395	.519
Sixth	357	.512	.548	.415	.533
Total	1008	.565	.575	.518	.598

Each correlation was positive, indicating that to a certain extent the experimental pupils' success on the RASP pre-test followed their performance on the achievement pre-tests. The correlations increased with the grade level, with the highest correlations occurring in the sixth grade.

Table X shows the correlations between the RASP pre-test scores made by control pupils and their scores on the pre-test of arithmetic and reading achievement.

TABLE X. CORRELATIONS BETWEEN PRE-TEST RASP SCORES AND PRE-TEST ACHIEVEMENT SCORES FOR CONTROL PUPILS

		RASP with			
Grade	N	Arithmetic Reasoning	Arithmetic Fundamentals	Reading Vocabulary	Reading Comprehension
Fourth	312	.233	.254	.236	.281
Fifth	344	.494	.417	.440	.517
Sixth	377	.508	.506	.441	.541
Total	993	.501	.518	.465	.534

All correlations of RASP with arithmetic and reading scores for the control group pre-test were positive. Like the correlations for the experimental pre-tests, the correlations between RASP and the arithmetic and reading tests increased with each higher grade level.

In Table XI are the correlations between the experimental post-test RASP and the post-test scores on each section of the arithmetic and reading tests.

TABLE XI. CORRELATIONS BETWEEN POST-TEST RASP SCORES AND POST-TEST ACHIEVEMENT SCORES BY EXPERIMENTAL PUPILS

		RASP with			
Grade	N	Arithmetic Reasoning	Arithmetic Fundamentals	Reading Vocabulary	Reading Comprehension
Fourth	337	.578	.558	.538	.606
Fifth	314	.579	.552	.617	.637
Sixth	357	.629	.651	.647	.660
Total	1008	.674	.658	.654	.683

The correlations given in Table XI show the r's between experimental post-test RASP and achievement test scores. These r's are somewhat higher than the pre-test correlations for the same group of pupils. The greatest change appears, however, at the fourth grade level, where the r's for all four tests increased substantially. The cnange at the fifth and sixth grade levels also was noticeable, for the post-test correlation brought the r's much closer together, as well as closer to the r for the total group.

Table XII presents the correlations between the control post-test RASP and the post-test scores on each section of the arithmetic and reading tests.

TABLE XII, CORRELATIONS BETWEEN POST-TEST RASP SCORES AND POST-TEST ACHIEVEMENT TEST SCORES BY CONTROL PUPILS

		RASP with			
Grade	N	Arithmetic Reasoning	Arithmetic Fundamentals	Reading Vocabulary	Reading Comprehension
Fourth	312	.437	.418	.502	.509
Fifth	344	.427	.386	.416	.544
Sixth	337	.543	.543	.458	.586
Total	993	..527	.511	.502	.582

The correlations in Table XII have increased substantially for fourth grade pupils, but they remain at or near pre-test levels for grades 5 and 6 and for the total group. The changes in r's for the control groups, however, were somewhat less than the changes in r's for the experimental pupils when the pre-test and post-test correlations were compared.

The correlations between RASP scores and achievement test scores provide some interesting information for the study. First, the preliminary use of the RASP Test appears to be more successful as the grade level becomes higher. This fact was true of both the experimental and control classes. Second, the correlations rose at the end of the twenty week period, both in the experimental and in the control groups. Correlations tend to become higher as the range of scores increases, and the period of instruction allowed time for both groups of pupils to improve their scores. The greater increase in the experimental fourth grade subjects, however, might indicate a more effective development of the elements of understanding measured by the RASP Test. Since substantially higher gains in achievement were made by the experimental pupils, this fact also might account for the higher r's in the experimental post-test results. Third, the correlation between RASP pre-test and post-tests showed somewhat the same tendencies as they showed between RASP and achievement. The r's rose sharply, both for experimental and control groups in the fifth and sixth grades. Table XIII shows the r's between pre-and post-test RASP scores made by all of the experimental and all of the control classes.

TABLE XIII, CORRELATIONS BETWEEN PRE-AND POST-TEST RASP SCORES MADE BY 1008 EXPERIMENTAL AND 993 CONTROL PUPILS.

Grade		Experimental		Control
	N	r	N	r
Fourth	337	.350	312	.477
Fifth	314	.685	344	.618
Sixth	357	.692	377	.710
Total	1008	.682	993	.660

The r's increase with the grade level for both the experimental and the control pupils. The correlations appear to be approximately the same for the two groups of pupils.

The lower r's for the experimental pupils might have been explained by the fact that the mean score made by experimental pupils on the RASP pre-test was significantly lower (1.4 score points) than that made by the control pupils. The experimental pupils gained significantly more than the control pupils on the RASP Test over the experimental period (3.3 score points). Thus, the correlations between their pre-and post-test scores on the RASP Test would tend to be lower than those for the control pupils.

<u>Factor analysis of post-test scores.</u>-- Five sub-test scores (arithmetic reasoning, arithmetic fundamentals, reading vocabulary, reading comprehension, and the RASP Test) were reported for each of the 2001 subjects included in the post-test results. The intercorrelations of subtests scores (Tables IX-XIII) indicated that certain interaction between test items had apparently taken place. A substantial part of the variance in the pupils' scores, however, could not be explained by these r's. Hence the investigators completed a factor analysis of pupils' scores to study those factors which appeared to account for some of the variance in these scores. In the first analysis, five factors were identified and they appeared in the following proportions: Factor 1 accounted for 72% of the variance in the post-test scores made by all of the pupils: Factor 2, 9.7%; Factor 3, 9.1%; Factor

4, 4.2%; and Factor 5, 3.9%.

Since the factors which induce variance in pupils' test performances are not readily identifiable, they must be interpreted intuitively. Therefore, the investigators completed the varimax rotation, which uses a rotated matrix of factor loadings, to determine which of the tests comprising the post-test battery were most closely related to each factor. Table XIV reports these factors, the percent of variance each accounts for, the tests which appear to be most clearly related to each of the factors, and the weight which that test contributed to that factor.

TABLE XIV. FACTOR ANALYSIS OF POST-TEST SCORES ON THE CALIFORNIA ARITHMETIC TEST, THE CALIFORNIA READING TEST, AND THE RASP TEST BY 2001 FOURTH, FIFTH, AND SIXTH GRADE PUPILS, USING FIVE FACTORS

Factor	Eigenvalue	% of total	Present to greatest degree in the test of	Factor loading of principal test in each factor	Share of the total test battery borne by the indicated test
1	3.64967	72.4	Reading vocabulary	0.85080	50%
2	0.48755	9.7	RASP	0.90800	8%
3	0.45662	9.1	Arith. Fundamentals	0.87085	6%
4	0.20961	4.2	Arith. Reasoning	0.77868	3%
5	0.19656	3.9	Reading Comprehension	0.76914	2%

The fourth and the fifth factor accounted for a very small part of the variance, and these two were dropped from consideration. A second analysis of the data, using only Factors 1, 2, and 3, indicated that other than a slight rise in the loading of Factor 1, there were no changes in the factors nor in the loadings of these factors within the various tests. Table XV presents the data cited above:

TABLE XV. FACTOR ANALYSIS OF POST-TEST SCORES ON THE CALIFORNIA ARITHMETIC TEST, THE CALIFORNIA READING TEST AND THE RASP TEST BY 2001 FOURTH, FIFTH, AND SIXTH GRADE PUPILS, USING THREE FACTORS

Factor	Eigenvalue	% of total	Present to greatest degree in test of	Factor loading of principal test in that factor	Share of the total test battery borne by the indicated test
1	3.64967	72.4	Reading vocabulary	0.88533	57%
2	0.48755	9.7	RASP	0.90856	8%
3	0.45662	9.1	Arithmetic fundamentals	0.88801	6%

A third study of the data, using only Factors 1 and 2, likewise did not materially change the results obtained in the previous analyses. (Table XVI).

TABLE XVI. FACTOR ANALYSIS OF POST-TEST SCORES ON THE CALIFORNIA ARITHMETIC TEST, THE CALIFORNIA READING TEST AND THE RASP TEST BY 2001 FOURTH, FIFTH, AND SIXTH GRADE PUPILS, USING TWO FACTORS

Factor	Eigenvalue	% of total	Present to greatest degree in test of	Factor loading of principal test in that factor	Share of the total test battery borne by the indicated test
1	3.64967	72.4	Reading vocabulary	0.88267	56%
2	0.48755	9.7	RASP	0.91571	8%

Factor 1, sometimes called the G factor, accounted for 72.4% of the total variance in all of the test scores. Although the G factor is not identifiable as a single word, it probably can be described as being a combination of general intelligence, recognition and use of words, basic knowledge of arithmetic facts, and skill in the use of language. Factor 1 was most closely identified with the California Test of Reading Vocabulary, and this test accounted for 72% of the variance in that factor. Since vocabulary is essential to any form of written testing, skill in the recognition and interpretation of words was undoubtedly an important part of Factor 1. Certainly, general learning ability, whatever it is, made a significant contribution (about 50% of the total) to the scores made by the 2001 pupils on the

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post-test. The test battery was made up of five tests, and the subjects performances on each of these tests reflected the influence of the G factor. About 80% of the variance on the test of arithmetic reasoning, 69% of the variance on the test of arithmetic fundamentals, 74% of the variance on the test of reading vocabulary, 81% of the variance on the test of reading comprehension, and 59% of the variance on the RASP Test can be attributed to this factor.

Factor 2 accounted for 9.7% of the total variance, or about one-third of the variance left after factor 1, (the G factor) had been removed. Specifically, Factor 2 accounted for 82% of the remaining variance found in the RASP Test. Since the G factor accounted for 59% of the RASP Test variance, 82% of the remaining 41% equals 34%. Hence, Factor 2 accounted for 34% of the RASP variance. Factor 2 was unique to the RASP Test, an independent factor, not present in other tests.

The investigators had hypothesized that a new ingredient could be introduced into the area of arithmetic problem solving, that of critical and discriminating reading of verbal problems. They prepared teaching material which they believed would help children develop this reading skill and they wrote a test which they felt would measure achievement in such interpretative reading. The data just presented establish the fact that one of the three factors which accounted for variance in pupil performance in all of the parts of the post-test also contributed heavily to the variance in the new RASP Test scores. It is reasonable, therefore, to assume that Factor 2, which accounted for almost one-tenth of the variance in pupils' scores on the post-test, is an important factor in the RASP Test. Factor 2, then, might be described as some form of learned behavior which enables pupils to read arithmetic problems understandingly.

Factor 3 accounted for 9.1% of the total variance on the post-test scores, and the test of arithmetic fundamentals most closely related to this factor. Since a considerable share of the items on the test battery required knowledge of computational operations, Factor 3 probably relates most closely to children's skill in number operations.

Internal factors of the RASP Test -- The RASP Test was constructed (as described in Chapter III) with each of the ten reading competencies represented by six questions. The authors arranged the sixty items so that they could select related sets of six from the total test for specific examination. They then chose two procedures for studying the RASP scores made by the 2001 pupils on the post-test. (1) They intercorrelated each of the ten sections of the test with the others, and then correlated the scores on each section with the total score. (2) They prepared a factor analysis, and isolated some of the factors believed to have produced variance in the post-test scores. Table XVII shows the intercorrelations between sections and the correlations of each section with the total score.

TABLE XVII. INTERCORRELATIONS OF THE TEN SECTIONS OF THE RASP TEST WITH EACH OTHER. CORRELATIONS OF EACH OF THE TEN SECTIONS WITH THE TOTAL SCORE FOR 2001 FOURTH, FIFTH, AND SIXTH GRADE PUPILS

	1	2	3	4	5	6	7	8	9	10
2	0.617									
3	0.308	0.230								
4	0.406	0.396	0.317							
5	0.398	0.340	0.318	0.343						
6	0.380	0.311	0.326	0.331						
7	0.494	0.439	0.258	0.318	0.336	0.346				
8	0.412	0.386	0.245	0.287	0.351	0.311				
9	0.320	0.245	0.322	0.396	0.332	0.343	0.258	0.233		
10	0.374	0.281	0.321	0.285	0.353	0.29[illegible]	0.292	0.307	0.399	
Total	0.745	0.664	0.563	0.638	0.661	0.626	0.649	0.606	0.617	0.616

Relatively low positive correlations between the various sections of the RASP Test show consistently that these sections did not measure identical reading-arithmetic competencies. The correlations between each section and the total RASP score indicate that each part of the test is positively related to the total, with r's of similar size.

The first clue that the RASP Test contained some unique measuring items came when the factor analysis of the entire post-test battery was completed. The RASP Test appeared (Page 45) to be closely identified with Factor 2, and Factor 2 accounted for approximately one-third of the variance in scores after the G factor was removed. Further exploration of the nature of the items contributing to Factor 2 was possible through a factor analysis of the scores made by the pupils on the various parts of the RASP Test. A preliminary study of these scores began with the identification of ten factors. Table XVIII presents these data:

TABLE XVIII. FACTOR ANALYSIS OF RASP TEST OF PARTIAL SCORES OF 2001 FOURTH, FIFTH, AND SIXTH GRADE PUPILS, USING THE ROTATED MATRIX OF FACTOR LOADINGS AND TEN FACTORS

Factor	Eigenvalue	% of Total	Present to the greatest degree in section	Name of section	Factor loading of principal section in the factor	Share of the total test borne by the indicated section
1	5.10127	46.4	2	Understanding the process in use	0.90648	37.5
2	1.04952	9.5	6	Missing, but available information	0.93309	8.2
3	0.75546	6.9	8	Understanding Quantity	0.93757	5.9
4	0.73040	6.6	10	Relating problems to Everyday Life	0.93874	5.6
5	0.68591	6.2	3	Vocabulary Discriptive Words	0.95180	5.1
6	0.62409	5.7	4	Vocabulary Procedural Words	0.93008	4.9
7	0.59814	5.3	5	Extraneous material	0.92460	4.6
8	0.56592	5.1	7	Understanding quantitative terms	0.92[illegible]99	4.3
9	0.51255	4.6	9	Numbers of greater magnitude	0.93751	4.0
10	0.36673	3.3	1	Literal meaning of the problem	0.86190	2.4

Factor 1, the G factor, accounts for less than half (46%) of the variance in the post-test RASP scores. The remaining 54% of the variance is divided somewhat evenly among nine other factors with only one approaching 10% of the total variance. Test No. 2, "Understanding the Process We Use" accounts for 82%

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of the variance within that factor, or 37.5% of the total variance. Each of the nine factors is particularly identified with a different section of the test, and this section appears to dominate the small portion of the total variance attributed to that factor.

When scores on ten separate tests of only six items each are analyzed, it is very unlikely that all of the factors producing variance in these scores can be positively identified. A forced choice among ten factors complicates the distribution of contributing factors and may obscure the specific importance of any or all of them. When the number of factors to be studied is reduced, the loadings of these factors should indicate more accurately those factors' contribution to the variance found in the test scores. To illustrate this fact, four different factor analyses were made using two, three, four, and five factors. Results of these factor analyses may be seen in Table XIX.

TABLE XIX.FACTOR ANALYSIS OF RASP POST-TEST PARTIAL SCORES BY 2001 FOURTH, FIFTH, AND SIXTH GRADE PUPILS USING THE ROTATED MATRIX OF FACTOR LOADINGS AND VARYING NUMBERS OF FACTORS

Factor	Eigenvalue	Greatest loading Present in Test of	% of Variance in test scores produced by that factor.
		Two Factors	
1	5.10127	1. Literal meaning of problems	58
		2. Understanding the process	64
2	1.04952	9. Numbers of Greater Magnitude	58
		Three Factors	
1	5.10127	1. Literal Meaning of Problems	49
		2. Understanding the Process	53
		7. Missing information	50
2	1.04952	3. Vocabulary -Descriptive Words	44
3	0.76546	4. Vocabulary-Procedural Words	58
		Four Factors	
1	5.10127	1. Literal Meaning of Problems	51
		2. Understanding the Process	55
2	1.04952	6. Missing but Available Information	57
3	0.76546	4. Vocabulary-Procedural Words	60

Table XIX (Continued)

4	0.73040	10. Social and Economic Information	74
		Five Factors	
1	5.10127	1. Literal Meaning of Problems 2. Understanding the process	56 62
2	1.04952	10. Social and Economic Information	74
3	0.76546	4. Vocabulary-procedural words	58
4	0.73040	6. Missing but available information	70
5	0.68591	3. Vocabulary-descriptive words	88

Table XIX shows clearly that regardless of the number of factors chosen for analysis, that Tests 1 and 2, "Literal Meaning of the Problems" and "Understanding the Process," are always those most closely identified with Factor 1. We can be less certain of the identity of Factor 2, for as the number of factors changed, the factor loadings appeared to shift from test to test. Factor 3 remained rather consistent, however, with Test 4, "Vocabulary-Procedural Words," carrying the heaviest factor loading of Factor 3 in each analysis.

Considerable evidence points to the fact that the RASP Test measured some unique skills found in the children who took the test. This fact was demonstrated when factor analysis showed that the RASP test had functioned effectively as a part of the total test battery. The data in Table XVIII and XIX indicate that the various sections of the RASP Test also served some useful purpose in accounting for the variance in pupils' scores on that test. Just what part each of the sections served would be difficult to say, but certain clues persist when the factor loadings of several of the subtests are considered.

Although one of the purposes of this study had been that of developing an instrument for measuring arithmetic-reading competencies, there was no thought that this purpose would be achieved with the first draft and the first administration of the instrument. The preliminary studies made of the RASP Test, however, indicate that this test not only performed effectively in the total study but merits further development and study as a useful instrument for arithmetic teachers.

Reactions of teachers and pupils -- After all of the test data had been returned by the schools, each teacher who taught an experimental class completed a brief questionnaire on which she could indicate her reaction to the study. A few of the teachers expressed reservations about the program, several accepted it as an interesting but somewhat futile endeavor, while a substantial number expressed enthusiasm about it. Generally, the fourth grade teachers felt it was too difficult for their children, but teachers of older pupils seemed to react more favorably.

Chapter V

Summary and Conclusions

The Reading-Arithmetic Skills Program sought answers to five questions:

1. Are reading skills related to the solution of verbal problems?
2. Does instruction in specific reading skills improve the 4th, 5th, and 6th grade pupils' abilities to solve verbal problems?
3. Are there significant differences in reading and arithmetic test scores between pupils who have been taught experimentally and those who have not been so taught?
4. Can teaching materials be prepared which will enable teachers to provide for effective instruction in these reading-arithmetic skills?
5. Can a test be developed which will measure a pupil's competencies in the use of reading-arithmetic skills?

Answers to these questions were provided through a study of approximately 1000 fourth, fifth and sixth grade pupils who received the experimental treatment and 1000 similar pupils who did not receive this treatment. The experimental teaching required selected classroom teachers to present one lesson weekly for twenty weeks. These lessons, prepared by the investigators, placed considerable emphasis upon developing skill in verbal problem reading. The control classes followed normal arithmetic learning procedures. The data resulting from the investigation may be summarized as follows:

Although the investigators hoped to work with equated performance groups, certain differences appeared, especially at the fourth grade level. The fourth grade control classes scored significantly higher on the pre-tests than the experimental classes, and the fifth grade control classes scored significantly higher on the pre-tests than the experimental classes in arithmetic achievement. These differences, however, were reduced substantially on the post-test.

On every test of achievement, the mean gain in scores from pre-test to post-test was greater for the experimental groups than for the control groups. On seven of the fifteen subtests (five subtests per grade) the gains were significantly higher for the experimental pupils.

All correlations between subtests were positive. The size of the r increased at each grade level, with fifth grade r's higher than fourth and sixth grade higher than fifth. Post-test coefficients of correlation were higher than those for the pre-test, and experimental post-test r's were higher than control post-test r's. The range of differences between grade level r's tended to diminish somewhat on the post-test. Although the correlations indicated some homogeniety in measurement, the r's were not so high that all tests appeared to measure the same skill.

Factor analysis of scores made by all of the 2001 pupils on the total test battery showed the operation of a general factor which accounted for 72.4% of the variance in the scores. This factor was most closely identified with the test of reading vocabulary, and perhaps can be described best as general intelligence or skill in communication. A second factor, accounting for about one-third (9.7% of the total) of the remaining variance, was related most closely to the RASP Test. The RASP Test accounted for 8% of the variance in total scores, and appeared to be effective as a measure of some kind of learned behavior which is related to reading-arithmetic competency.

The RASP Test was subdivided into ten sections of six items each. Factor analysis of the variance in RASP scores showed that a number of factors contributed to the variance. Examination first of ten factors, then five, four, three, and two factors, provided certain clues to their identification, although positive identity could hardly be established on the basis of a single treatment. The factor analysis did indicate, however, that the separate sections of the test, designed to measure specific competencies, might have functioned somewhat as planned. This part of the study, however, needs further attention.

As the result of these findings, the following conclusions have been reached:

1. Certain reading skills which enable intermediate grade children to interpret verbal arithmetic problems have been identified, taught, and their influence measured to a substantial degree. The skills which appear to have the greatest influence are closely related to vocabulary development, literal interpretation of the problem statement, and selection of the proper solution process.

2. Children who receive special instruction in reading arithmetic problems show greater gains in both reading and arithmetic achievement than pupils who do not receive this instruction.

3. Experimental procedures of this study were effective at all three intermediate grade levels and with children of varying levels of achievement. Likewise, the experimental instructional materials appear basically suitable for classroom use, although to a lesser degree at the fourth grade than at fifth and sixth grade levels.

4. The RASP Test contributed substantially to the measurement of the reading-arithmetic competencies of the pupils.

5. The division of the RASP Test into ten sections made it possible to identify more accurately some of the competencies which are related to effective reading of verbal arithmetic problems.

A careful analysis of the results of this study has revealed to the investigators several pertinent implications and recommendations which are applicable to teachers, administrators, and researchers who are interested in the problems of content reading. These are:

1. Elementary school programs should place greater emphasis upon instruction in the skills of content reading.

2. Specific instruction in the reading-arithmetic skills which improve children's interpretations of verbal problems should be a part of the intermediate grade arithmetic program, and should begin not later than the fourth grade.

3. The skills of technical vocabulary development and critical interpretation of verbal problems should receive increased attention in the elementary school arithmetic program.

4. Further study is needed to determine:
   a. the feasibility of such programs at the primary and junior high school levels.
   b. which types of instructional materials are most suitable at the various grade levels.
   c. the most efficient skills programs at the various grade levels.
   d. whether long-term instruction is more effective than strategically developed instruction over a shorter period.

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DATE FILMED- 8-31-67