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ABSTRACT

Research on routine problem solving (e.g. the typical "story" problem) was reviewed to facilitate the identification and dissemination of promising practices for teaching routine problem solving, and to provide suggestions and directions for further research in the area. Promising teaching practices which were identified included giving attention to processes involved in solving routine problems (e.g., write an equation, make a chart) and devoting time to developing the meanings of mathematical vocabulary and symbols. Areas identified as warranting further research included studies that examine the role of language variables (both syntactic and semantic) in the "decoding" phase of solving a routine problem. Appendix C contains a coded bibliography which may be of great value to researchers in problem solving. (MK)

A REVIEW OF RESEARCH ON SOLVING ROUTINE PROBLEMS IN PRE-COLLEGE MATHEMATICS

Larry Sowder
Jeffrey C. Barnett
Kenneth E. Vos

1979

SUMMARY

This project reviewed the research on routine problem solving (e.g., the typical "story" problem) with an aim toward (a) identifying and disseminating promising practices for teaching routine problem solving and (b) suggesting directions for further research in the area. The investigators surveyed relevant dissertations, journal articles, and files of research studies. Products of the work include a chapter in a National Council of Teachers of Mathematics yearbook oriented toward teachers, and chapters in two monographs oriented toward educational researchers. Various talks at meetings for teachers and researchers have also been scheduled.

Practices which might improve the teaching of routine problem solving include these:

1. Give attention to <u>processes</u> involved in solving routine problems (e.g., write an equation, make a chart).

2. Devote time to developing the meanings of mathematical vocabulary and symbols.

3. Teach that reading of a mathematical problem is different from reading less technical prose, and requires multiple readings with attention to vocabulary and relationships among variables.

4. Have the learners make up, and solve, their own word problems.

Areas in which further research and development seem warranted include these:

5. Instrumentation is needed for process-analysis studies, both for protocol coding and process measurement.

6. Studies that examine the role of language variables (both syntactic and semantic) in the "decoding" phase of solving a routine problem should contribute to our knowledge of teaching problem solving.

7. Whether different ways of presenting problems--objects, pictures, words--help children of different ages and mental characteristics needs examination.

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A Review of Research on Solving Routine Problems in Pre-College Mathematics

Objective

The aims of the project were as follows:

1. Review and evaluate research on routine problem solving in pre-college mathematics.

2. To identify directions for further research on routine problem solving in mathematics.

3. To make the findings about routine problem solving available to classroom teachers and researchers.

Some of the terms in the objectives do not have standard meanings. Here are explanations of how the terms were used in the project:

Problem--A problem is a task which does not immediately suggest to the solver a systematic procedure for resolving the task (i.e., an algorithm). Thus, a person's knowledge of algorithms determines whether a given task is a problem for that person. Multiplying with multi-digit numerals would be a problem for third graders but not a problem for most seventh graders.

Routine vs nonroutine--The routineness of a problem may, in a rough way, be defined by the nature of its solution. The solution of a nonroutine problem requires considerable analysis, synthesis, and perhaps some novelty of approach. On the other hand, the solution of a routine problem requires only a relatively small amount of analysis and no unusual insights. The typical verbal problem in pre-college mathematics books is an example of a routine problem. Such problems usually require only the selection of an appropriate computation. In elementary school book, problems described as "challenges" or "brainbusters," are usually nonroutine problems.

Rationale

The rationale for the project was based on four things. First, attention to routine problems in mathematics is important. Effective citizenship as a consumer, as a wage earner, as a taxpayer, requires an ability to solve a myriad of routine problems. Checking purchases, calculating interest costs, evaluating budgets, determining best buys, planning meals--all these are sample routine problems.

Second, unfortunately many students do not solve problems well. The availability of handheld calculators is of no value if a person does not know which buttons to press. It is well known that students are not usually fond of "story" problems, and the first National Assessment of Educational Progress (1975) offered evidence that people are not very proficient in solving routine problems. If existing research evidence suggests that certain procedures for teaching routine problem solving are promising, these should be identified and disseminated.

Third, at least a few such promising practices are identified in the literature but do not appear to be widely known. For example, VanderLinde (1964) found a positive effect on problem solving from spending time on developing meanings for symbols and on studying quantitative vocabulary.

Finally, directions for further research on routine problem solving in mathematics might be identified by an analysis and critique of the existing research.

Procedures

The investigators--Barnett, Vos, and Sowder--identified as many studies of routine problem solving in pre-college mathematics as they could, through searches of dissertation abstracts and ERIC files and through examination of journals deemed most likely to contain such studies. The studies were categorized with an adaptation of Kilpatrick's taxonomy of variables in problem solving research (1978). The most promising dissertations, reports, and articles were studied in full. On the basis of this work, manuscripts were prepared (see Products below). In addition, Dr. Edward Silver agreed to consult with the project and prepared a project paper on memory aspects of routine problem solving (see Appendix A).

Limitations. The project was necessarily limited in scope. Which journals should be concentrated on? How far afield from routine problems in mathematics should we explore? The homely when-do-we-stop-reading-and-start-writing question demanded an answer, dictated by manuscript deadlines in our case. Hence, we cannot claim to have accomplished a comprehensive search. For example, the information-processing approach to routine problem solving was slighted. Work along these lines is currently popular, perhaps too current for a dispassionate critique or for an even moderately thorough survey. Silver's project paper (Appendix A) does draw on work in information processing, however. Another attractive but unexplored body of work was in problem solving in fields other than mathematics--e.g., science, therapy, business. It may well be that important implications for mathematics education lie in studies in such domains.

Products

Serendipitously, the dissemination objective of the project was realized through the post-proposal appearance of plans for two works on problem solving--a monograph on "applied" problem solving (R. Lesh & D. Mierkiewicz, Eds.) and a National Council of Teachers of Mathematics yearbook on problem solving (S. Krulik, Ed.). Proposals and drafts of chapters for these two forthcoming works were prepared and accepted. In addition, Barnett prepared a chapter for a monograph on task variables in mathematical problem solving (G. Goldin & E. McClintock, Eds.), soon to appear. Citations for these publications are summarized in Appendix B. The intent to reach the teacher audience through the Arithmetic Teacher was abandoned on the appearance in the November, 1977, issue of an excellent problem-solving article along the lines planned (Suydam & Weaver); the yearbook chapter served as a teacher-oriented article.

Presentations based on the project have aided, or will aid, in the dissemination of the major findings: Barnett (state meeting of the Illinois Council of Teachers of Mathematics, October, 1978); Sowder (regional Illinois meeting, March, 1979; National Council of Teachers of Mathematics regional meeting, March, 1980); Vos (California Mathematics Council, Southern Section, November, 1979); Barnett, Vos, and Sowder (National Council of Teachers of Mathematics national meeting, April, 1980).

Finally, one product of the project was not planned in the original project but may be of great value to researchers in problem solving: the coded bibliography (see Appendix C). This bibliography will be made available to interested researchers through contacts in the Special Interest Group on Research in Mathematics Education of the American Educational Research Association, and through ERIC.

Selected research recommendations

The following condensed excerpts from the manuscript for the Lesh monograph represent the flavor of our recommendations for further research in routine problem solving in mathematics:

1. For studies of the processes involved in routine problem solving, test instruments that emphasize such process variables must be developed, as well as a protocol scoring-coding scheme that is both elegant and efficient.

2. Studies that attempt to determine the role of syntax and semantic variables in the decoding process in the first stage of problem solving are of particular importance.

3. Another area of needed research is that concerned with the improvement of instruction in reading and its relationship to improved problem solving ability.

4. Although the linear regression model has shown some promise as a research technique in the area of language variables and routine problem solving, it is clear that in its present form it falls short of being able to predict problem solving success. Improvements in the model might include different criteria of importance; it would be helpful for studies to provide data on several dependent measures used with several measures of importance.

5. The relative effects of different formats--words, pictures, objects--for problems should be investigated, particularly as they relate to learner characteristics.

6. What within-format variations make a difference?

7. Studies with positive results should be replicated--for example, Keil's 1964 study, in which student-generated and student-solved problems apparently led to improved problem solving.

8. Would concentrated attention to routine problems give the same striking results as in Bramhall's 1939 study (8 months growth in 2.5 months)?

9. Cooperation among researchers interested in routine problem solving must increase so that common problems, similar instruments, and shared data analysis can be more easily facilitated.

References

Bramhall, E. W. An experimental study of two types of arithmetic problems. The Journal of Experimental Education, 1939, 8, 36-38.

Goldin, G. A. & McClintock, C. E. (Eds.) Task variables in mathematical problem solving. Columbus, Ohio: ERIC/SMEAC, 1979 (in press).

Keil, G. E. Writing and solving original problems as a means of improving verbal arithmetic problem solving ability (Doctoral dissertation, Indiana University, 1964). Dissertation Abstracts, 1965, 25, 7109-7110. (University Microfilms No. 65-2376)

Kilpatrick, J. Variables and methodologies in research on problem solving. In L. Hatfield (Ed.), Mathematical problem solving. Columbus, Ohio: ERIC/SMEAC, 1978.

Krulik, S. Problem solving. Reston, Virginia: National Council of Teachers of Mathematics, in press.

Lesh, R., & Mierkiewicz, D. Applied problem solving. Columbus, Ohio: ERIC/SMEAC, 1979 (in press).

National Assessment of Educational Progress. Consumer math, selected results from the First National Assessment of Mathematics. Mathematics Report No. 04-MA-02. June, 1975.

Suydam, M. N., & Weaver, J. F. Research on problem solving: Implications for elementary school classrooms. Arithmetic Teacher, 1977, 25(2), 40-42.

VanderLinde, L. F. Does the study of quantitative vocabulary improve problem-solving? Elementary School Journal, 1964, 65, 143-152.

Appendix A

Project Paper

A Review of Selected Literature on the Role of Memory in Arithmetic and Algebra Word Problem Solving

by

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When I recently mentioned to a colleague that I was writing a paper on the role of memory in solving mathematics problems, she remarked, "Well, it certainly helps!" The fact is, however, that there are three distinct ways in which memory might interact with problem-solving performance. First, information from previous problems might not be available either because the solver has not encoded it or because it has been encoded in a fashion that makes it difficult or impossible to retrieve. In this case, memory would have little or no effect on problem-solving performance. The second way in which memory might interact with problem solving is to have a negative effect. Gestalt psychologists (e.g., Duncker, 1945; Luchins, 1942; Wertheimer, 1959) have examined extensively the instances in which past experience can negatively affect present problem-solving performance. The third way, of course, is the one to which my colleague was referring, in which information gained from previous problem-solving encounters is successfully recalled and used to solve a new problem.

Psychologists have studied the role of memory in general problem-solving activities, and the classical theories have differed greatly in the importance given to memory. The present review has been greatly influenced by the modern information-processing view of problem-solving (Newell & Simon, 1972). The reader who is unfamiliar with information processing psychology can find excellent discussions in Mayer (1977) or Norman (1976).

The human information-processing model can be divided into two general components: perception and memory. Memory is described in the literature in a variety of ways using various models and analogies. It is not possible in this paper to summarize the various models, but the reader will find an excellent summary of hypothesized memory structures and theories in Gagne and White (19.8) and a briefer, but highly readable, summary in Shavelson and Porton (Note 1).

In writing this paper, I have attempted not to duplicate the work of Greeno (1973), in which he applied the general information-processing view of problem solving in reviewing studies relating memory and problem solving. Therefore, this review has generally confined its attention to studies conducted since Greeno's excellent review and to studies that deal in some way with the concerns of mathematical word problem solving. While no claims are made for completeness of the review, it is hoped that the reader will become acquainted with the dominant theories, major results, and possible future directions for research on the role of memory in solving mathematics word problems.

Arithmetic Problem Solving

Although the arithmetic problem-solving competence of children has been of great interest to researchers, their primary focus has been the product (i.e. correct/incorrect answer) rather than the process. In their recent work, Jim Greeno, Joan Heller, and Mary Riley (e.g. Greeno, Note 3; Heller, Note 4; Heller & Greeno, Note 5; Riley, Note 6; Riley & Greeno, Note 7) have applied the information-processing viewpoint to arithmetic problem solving.

Heller and Greeno (Note 5) have developed a model of arithmetic word problem solving that emphasizes semantic processing as the primary component of problem understanding. Although the work of Tom Carpenter, Jim Moser, and their associates at the University of Wisconsin suggests that the Heller-Greeno model is both incomplete and partially incorrect (see Carpenter, Hiebert, & Moser, Note 8; Carpenter & Moser, Note 9), the model deserves careful consideration here since it points to the important role of memory in the solution of arithmetic word problems, especially by young children.

In the Heller-Greeno model, initial understanding of a problem is viewed as a process of constructing an integrated semantic representation of the general quantitative relations in the problem situation. Subsequent selection of the correct operation is based on a direct association between this semantic representation (corresponding to one of three fundamental schemata in the Heller-Greeno model) and the operators (available and associated with the given schema). Carpenter and Moser (Note 9) have suggested that there are more than three fundamental schemata and that children do not appear to reduce all problems to instances of a particular type and apply a single strategy. Nonetheless, their work suggests the fundamental importance of semantic processing in arithmetic word problem solving.

The Heller-Greeno characterization is especially interesting because it contrasts with the earlier information-processing model for word problem solving proposed by Bobrow (1968), in which the problem text is interpreted phrase-by-phrase, using syntactic function tagging, and directly transformed into an equation or system of several simultaneous equations representing the problem situation. Support for Heller & Greeno's emphasis on semantic processing may be found in studies that collectively suggest that the ability to represent a word problem in the form of an equation or a system of equations is not a necessary condition for successful solution of the problem. For example, several studies (Buckingham & Maclatchy, 1930; Carpenter, Hiebert, & Moser, Note 8) have found that young children can correctly solve some word problems before receiving any formal instruction in equation writing or the translation process. Furthermore, Riley and Greeno (Note 7) reported that second-grade children sometimes found it difficult or impossible to write equations for problems they had already solved. Additional support for the importance of semantic processing comes from reports of successful problem solvers and their characteristics (e.g. Larkin, Note 10; Paige & Simon, 1966; Simon & Simon, 1978); discussion of these reports is found later in this paper.

Therefore, the data suggest that the crucial understandings in the process of solving a problem are those involving "making sense" of the problem situation; i.e. applying to the problem at hand real world or technical domain-specific semantic knowledge that is stored in LTM. The typical instruction given to students who are learning to solve word problems usually encourages such semantic processing, but the usual emphasis is on syntactic procedural mechanisms.

For example, two reasonably well known procedures taught to children are the "Wanted-Given" approach and the "Action-Sequence" approach (Wilson, 1964). Both approaches emphasize a certain amount of semantic processing, in that students are trained to "look for" the wanted-given relationship or the imagined action-sequence embedded in a problem. Nevertheless, the major emphasis of instruction in either procedure is on the composition of an equation, often in a rather rote fashion that seems somewhat independent of the initial semantic processing that is presumed to occur.

Unfortunately, at this time, we know very little about how children "see" word problems. For example, what is it that suggests that a given problem is a subtraction problem, and how is that realization associated with the production of an appropriate equation or operational sequence?

One particularly fruitful line of research would appear to be the identification of the fundamental units of children's understanding of arithmetic concepts and problems. The work of Carpenter and his associates is noteworthy in this regard. Another approach is being taken by Alan Rudnitsky at Smith College. Rudnitsky has been interviewing children to determine the "primitives" (basic elements) of their arithmetic schemata. Such work can be seen as extending the seminal studies of Erlwanger (1975) and Ginsburg (1977) on children's understanding of arithmetic concepts and principles.

Algebra Problem Solving

If a competition were held to determine the most influential and popular memory construct in the area of algebra problem solving, there is no doubt that the current winner would be the notion of "schema" (taken here to be equivalent to notions such as "frame" or "script"). A memory schema, as it is typically conceptualized today, is a cluster of knowledge-concepts, procedures, and relations among these - that defines a more complex and frequently encountered concept or phenomenon.

Schemata have been variously defined and discussed in the current literature on memory models (e.g., Bobrow & Norman, 1975; Rumelhart & Ortony, 1977), but certain common properties are invariant across the different definitions. For example, a schema represents a prototypical abstraction of a complex concept, and the schema is derived from past experience with numerous exemplars of the complex concept. Furthermore, a schema can guide the organization of incoming information into clusters of knowledge that are "instantiations" of the schema (Thorndyke & Hayes-Roth, 1979). The notion of schema was first proposed in connection with algebra word problems by Hinsley, Hayes, and Simon (1977) and has been recently adopted by Bob Davis and his colleagues (Davis, Note 11; Davis, Jockusch, & McKnight, 1978) in discussing algebra problem solving in general.

Hinsley, et al. found that their subjects used two different procedures in solving algebra word problems. One approach involved a line-by-line direct translation procedure, such as the one proposed by Bobrow (1968) and discussed previously. The second approach involved reading the entire problem before formulating any equations or writing any relations among variables. This second approach - the "schema" approach - emphasized the fundamental importance of semantic knowledge and major decisions occurring early in the comprehension process. The data provided by Hinsley, et al. demonstrate that the "schema" approach is typically used by successful solvers and that the line-by-line procedure is a default process used only if the problem is not successfully matched to one of the solver's available problem category schemata.

Since the Hinsley, et al. study, further evidence of the existence of problem category schemata has been produced involving algebraically naive subjects (Silver, 1977; Silver, Note 12; Silver, Note 13), college students solving physics problems (Larkin, Note 10), and a wide variety of mathematical topics and students of various ages (Davis, Jockusch, & McKnight, 1978). The results of these studies suggest that problem schemata not only exist but are used by successful problem solvers in planning their approach to solving a given problem.

Larkin (Note 10) analyzed the protocols of college students solving rather complex physics problems. She found evidence that successful problem solvers performed an initial "qualitative analysis" before writing any equations. In the early stages of a problem solution, successful solvers constructed representations of the physical situation described in the problem, and they subsequently modified and elaborated the representation by including supplementary information required for a complete understanding of the problem situation but not given explicitly in the problem's written statement.

Larkin's protocols provide evidence that successful solvers retrieve from memory preliminary "chunks" or "schemata" of related physics concepts and principles and apply the "chunks" to some aspect of their problem representation. Problem features are elaborated further if necessary in relation to the "chunk" under consideration as the solver attempts to determine the applicability of the knowledge cluster to the problem representation or the solver exits from the problem solution episode. Upon finding a "chunk" that adequately "fits" the problem representation, the solver generates a solution procedure. The findings of Hinsley, et al. and Larkin suggest that problem schemata exist and may play a critical role in solving certain classes of problems, such as algebra word problems. Far less is known about the mechanisms of schema construction; i.e. how students form problem schemata.

Research conducted by Krutetskii (1976), Chartoff (1977), and Silver (1977) has suggested several dimensions along which students might form schemata. Silver asked eighth grade students to sort a set of word problems into groups of problems that were "mathematically related"; Chartoff asked students to rate problem pairs on a continuous scale, ranging from extremely dissimilar to extremely similar. The two investigators independently identified three similarity dimensions perceived by the students: mathematical structure, contextual (cover story) details, and the nature of the question asked. In addition, Chartoff found that students could recognize generalizations and specializations, and Silver identified a tendency to form clusters of problems on the basis of a common measurable quantity, such as age or weight.

The findings of Chartoff and of Silver, together with the observation by Krutetskii that good problem solvers tend to notice and recall a problem's structure, whereas poor solv s notice and recall only the details of a problem's statement, suggest that students apprehend the important aspects of a problem in different ways. This initial processing is clearly influenced by existing problem schemata, if any exist for the solver, and form the basis for construction of new schemata. Recent work by Silver (Note 12, Note 13) suggests that students cluster recall of problem information abound existing schemata, that they use information from previously solved problems when solving what they perceive to be related problems, and that good and poor problem solvers exhibit qualitatively different clustering and recall performances. These findings will be discussed in more detail in a later section of the paper.

Whereas the investigations cited above involved no direct schema-forming instruction, it is common for algebra word problem instruction to organize problems into "types"; such as "age" problems, "mixture" problems, and "work" problems. The emphasis on "types" may lead to the students' forming problem schemata on the basis of those categories. Hinsley, et al. found that their college subjects did organize algebra word problems into groups that conformed to the stereotypic groupings typically taught to first year algebra students. Nevertheless, it is evident that not all students who receive the same instruction form the same problem schemata.

Instruction involving problem "types" was prevalent in the Soviet Union in the 1930s and 1940s. The usual pedagogical style involved teaching students to identify problem "types", to recall "model" solutions and to ignore the influence of unfamiliar settings or extraneous data. Russian school psychologists thus had an opportunity to study the process by which a student forms the concept of a problem type. Although their paradigms differ from the modern information-processing viewpoint, their findings are germane.

Kalmykova (1947/1969) reported that the extensive use of model problems tends to reduce the act of problem solving to a choice of conditions of the problem. Menchinskaya (1946/1969) also expressed the view that typification leads students to search their memories for models to "fit" the given problem. She reported that such instruction led students to search their memories to reconstruct a previously encountered problem to serve as a model, rather than examine the problem's conditions effort to construct an appropriate solution.

It would appear that schemata are important especially in the formulation of problems in which the contextual details, the semantics of the cover story, match the underlying problem structure in an expected way. For these problems, if the necessary schema is available to the solver, then a solution may be obtained; otherwise, the line-by-line default procedure must be used.

The data of Chartoff (1977), Krutetskii (1976), and Silver (1977) suggest that schemata might be formed along inefficient dimensions; i.e. with respect to non-structural problem characteristics. The reports of Kalmykova (1947/1969) and Menchinskaya (1946/1969) suggest that, even if problem schemata are formed along the appropriate dimension of mathematical structure, they may not be useful in solving a problem when the solver fails to analyze carefully the conditions of the problem. Thus, we are reminded that the process of solving a typical algebra problem probably involves not only the recall of an appropriate schema but also the construction of an initial problem representation. The representation provides a framework to which the solver can apply the retrieved schema.

It is not at all uncommon to find first-year algebra students who can solve a problem when it matches exactly the "model" problem they have already solved but who cannot solve a similar problem that they perceive as different. One reasonable explanation for such behavior is the absence of semantic processing of problem information. In other words, the students may be searching his memory for a "model" problem to apply to the given situation and failing to find a "match". The failure may be due to the non-existence of an appropriate schema or the misdirection of the search due to the student's lack of problem representation to guide the search.

Construction of a meaningful problem representation involves the incorporation of semantic knowledge in the problem understanding process. The work of Larkin (Note 10) and Heller and Greeno (Note 5) discussed earlier suggest the critical importance of semantic processing in successful problem-solving performance. Further support for this view may be found in the work of Paige and Simon (1966) who reported that solvers who used a direct translation approach to solving problems containing containing contradictory information were able to obtain "impossible" solutions and not perceive the contradiction. They found that subjects who constructed "auxiliary representations" of the problem situation (e.g. drawings) or who relied on semantic, substantive information in the solution process were considerably more successful at recognizing the presence of incongruities in the problem's conditions. Krutetskii (1976) also reported similar findings in his work with highly capable mathematics students. The findings of the studies reported in this section strongly suggest that future research pay specific attention to the mechanisms of schema construction and problem representation formulation.

Another focus for further research might be the nature of schema composition; i.e. what knowledge is embedded in one's problem schema? It seems reasonable to expect that successful problem solvers may exhibit certain process similarities, such as those discussed by Larkin (Note 10), but that they may possess different knowledge structures. For example, two solvers may be quite successful in solving typical Distance/Rate/Time problems, yet they may have different schemata for such problems. One solver might view these problems as being similar to other typical algebra problems, such as "mixture" and "coin" problems, since they all involve the general structural notion:

Total = Rate Per Unit x Number of Units.

Another solver's schema might include specific details regarding the assumptions of such problems; for example, uniform rate of travel, smoothness of surface, diversity of path, and instantaneous "turn around". Another solver might not have these details explicitly stated, but may operate with "default" values that are equivalent to the necessary assumptions.

In addition to the few examples given above, it is clearly possible to propose other possible individual differences in schema composition. If such differences do exist, it may be fruitful for researchers to examine not only the expert-novice distinctions that have captured our attention for the past decade, but also expert-expert and novice-novice distinctions with respect to processes and with respect to schema composition. By pursuing this line of research, we may learn if there are necessary and sufficient components of problem schemata for various classes of problems, and this information could be useful in guiding instruction.

Of course, not all problem solving behavior can be neatly described in terms of schemata. When subjects have little or no experience in solving a class of problems, the usefulness of schemata is limited. When solving a new problem, a successful problem solver presumably uses information, procedures, and more general notions that have been obtained from previous experience and training. As noted earlier in this paper, Gestalt psychologists have demonstrated that prior experience may have a negative effect in problem solving performance. In recent years, attention has been focused in identifying the circumstances under which positive transfer occurs.

Most of the work in this area has dealt with "puzzle problems", such as the Tower of Hanoi or the Missionaries-Cannibals problem. The classic study by Reed, Ernst, and Banerji (1974) suggested that positive transfer occurred only when subjects were told of the relationship between the problems and only when they solved the more difficult problem of the pair first. Kulm and Days (1979) used an information-theoretic approach to study transfer between problems with related structures. They reported that the solution of related problems appeared to help subjects focus on relevant strategies, but that different problem contexts appeared to interfere with transfer.

Silver (Note 12) has suggested that the potential transfer to a new problem is greatly influenced by the solver's initial perception of the problem's relationships to previously solved problems; furthermore, the initial perception is largely a function of what aspects of a problem the solver views to be mathematically relevant to its solution. In other words, the solver must not only recognize that the new problem is related to previously encountered problems but also identify the important mathematical considerations that are relevant to the relationship with previous problems. Of course the solver must also have the necessary information stored in long term memory.

The question of what gets remembered after a problem solution episode has been dealt with at length by Reed and Johnsen (1977) and to a lesser extent by Jacoby (1978). Unfortunately, the literature on this subject is sketchy and largely based on non-mathematical problems. In the next section, we will discuss the few studies that have dealt specifically with long-term retention of mathematical problems.

Individual Differences in Memory and Problem Solving

In studying individual differences in technical problem solving, many researchers have examined the differential processing characteristics of novices and experts (e.g. Chi & Glaser, Note 14; Larkin, Note 10, Simon & Simon, 1978). The data from these studies generally suggest that experts are capable of deeply processing problem information very early in the solution process, thus facilitating solution plan formulation for complex problems and essentially solving "immediately" simple problems.

Since, as Miller, Galanter, and Pribram (1960) have noted, the major source of new plans is old plans, the process differences noted early in the solution are likely indicators of differences in the memories of experts and novices. In fact, the classic work of de Groot (1966) on the memories of skilled and unskilled chess players has stimulated much of the research into expert-novice distinctions. The data from de Groot's study and subsequent studies (Chase & Simon 1973a, 1973b; Frey & Adesman, 1976) demonstrated that skilled chess players were considerably more successful than weaker players at reproducing meaningful chess situations, and that the results were not attributable to superior memory or better guessing on the part of the experts.

Individual differences in memory associated with mathematical problem solving is a largely unexplored area. Krutetskii (1976) noted that skillful problem solvers were able to recall accurately the structure of a mathematics problem even after long periods of time; whereas, poor problem solvers tended to recall, if anything, only the details of the problem's statement.

Recently, Silver (1977, Note 12, Note 13) has reported data suggesting that good and poor problem solvers demonstrate qualitative differences in their recall of problem information and in their perception of problem relatedness. Regarding the latter, Silver (1977) had students sort a set of word problems into groups that were "mathematically related". The data indicated that good problem solvers tended to group the problems on the basis of mathematical structure, even when they lacked specific techniques designed to solve problems with the given structure. To examine differences in recall, Silver (Note 12, Note 13) asked students to reproduce all they could remember about a mathematical problem and its solution. Recall was examined on several occasions, both before and after presentation of problem solutions, and the data indicated superior structural recall by skillful problem solvers. Furthermore, the data indicated that skillful problem solvers were better able to transfer information from one problem solution to the solution of a structurally related problem (Silver, Note 12) and that skillful problem solvers tended to cluster related information from several problems in terms of problem structure, whereas, less skilled solvers tended not to cluster or to cluster in terms of problem details or cover story (Silver, Note 13).

Much more attention is neded to the issue of individual differences in mathematical problem-solving performance that may be related to memory. As Hunt (1978) has remarked, "Individual differences are undoubtedly due both to differences in peoples' mental machinery and to differences in how they program that machinery to bring it to bear upon the problems they face."

Solving Word Problems: A Final Word

Word problems have been the subject of much research activity by psychologists and mathematics educators. Since word problems require the solver to read and understand a written passage, to select and apply mathematical principles, algorithms or procedures in determining the value of one or more unknown quantities, and to interpret the mathematical solution with respect to the verbal information given in the problem, they represent a point of intersection of the concerns of those interested in mathematical competence and those interested in prose text comprehension. Thus it is fitting that some of the major conclusions of this review parallel results found in the literature on prose text comprehension.

For example, the influence and power of schemata in guiding encoding and retrieval of text information has been demonstrated by Anderson, Reynolds, Schallert, and Goetz (1977) and Mandler and Johnson (1977). Another parallel finding is the existence of differences between good and poor readers' recall of thematically relevant material (Smiley, Oakley, Worthen, Campione, & Brown, Note 2).

The major conclusions of this review are that the critical processes in mathematical word problem solving involve the solver in constructing an accurate representation of the problem and using that representation as a guide in recalling relevant and necessary information, often in the form of schemata, to solve the problem. We have seen that skilled and unskilled solvers demonstrate qualitative differences in the representations they construct and the structures from which they retrieve needed information. Nevertheless, we have also seen that our knowledge of how memory is involved in mathematical problem solving is very incomplete. Perhaps this review has sharpened a few questions for further study.

Reference Notes

1. Shavelson, R. J., & Porton, V. M. An information processing approach to research on mathematics learning and problem solving. Paper presented at the Modeling Mathematical Cognitive Development Conference, Athens, Georgia, May 1979.

2. Smiley, S. S., Oakley, D. D., Worthen, D., Campione, J. C., & Brown, A. L. Recall of thematically relevant material by adolsescent good and poor readers as a function of written versus oral presentation (Tech. Rep. No. 23). Center for the Study of Reading, University of Illinois at Urbana-Champaign, March 1977.

3. Greeno, J. G. Preliminary steps toward a cognitive model of learning primary arithmetic. Paper presented to the Workshop on Models of Learning Mathematics, Durham, New Hampshire, 1977.

4. Heller, J. I. Schemata in the solution of arithmetic word problems. Paper presented at the meeting of the American Educational Research Association, San Francisco, California, April 1979.

5. Heller, J. I., & Greeno, J. G. Information processing analysis of mathematical problem solving. Paper presented at the Applied Problem Solving Conference, Evanston, Illinois, January 1979.

6. Riley, M. S. The development of children's ability to solve arithmetic word problems. Paper presented at the meeting of the American Educational Research Association, San Francisco, California, April 1979.

7. Riley, M. S., & Greeno, J. G. Importance of semantic structure in the difficulty of arithmetic word problems. Paper presented at the meeting of the Midwestern Psychological Association, Chicago, Illinois, May 1978.

8. Carpenter, T. P., Hiebert, J., & Moser, J. The effect of problem structure on first-graders' initial solution processes for simple addition and subtraction problems. Paper presented at the meeting of the American Educational Research Association, San Francisco, California, April 1979.

9. Carpenter, T. P., & Moser, J. M. The development of addition and subtraction concepts in young children. Paper presented at the meeting of the International Group for Psychology and Mathematics Education, Warwick, England, August 1979.

10. Larkin, J. I. Skilled problem solving in physics: A hierarchical planning model. Unpublished manuscript, University of California at Berkeley, September 1977.

11. Davis, R. B. Conceptualizing the structures underlying cognitive behavior - The usefulness of "frames". Paper presented at the meeting of the American Educational Research Association, San Francisco, California, April 1979.

12. Silver, E. A. Problem-solving performance and memory for mathematical problems: Solving related problems. Paper presented at the meeting of the American Educational Research Association, San Francisco, California, April 1979.

13. Silver, E. A. Problem-solving performance and memory for mathematical problems: Cue salience and recall. Paper presented at the meeting of the National Council of Teachers of Mathematics, Boston, Massachusetts, April 1979.

14. Chi, M. T. H., & Glaser, R. Encoding process characteristics of experts and novices in physics. Paper presented at the meeting of the American Educational Research Association, San Francisco, California, April 1979.

References

Anderson, R. C., Reynolds, R. E., Schallert, D. L., & Goetz, E. T. Frameworks for comprehending discourse. American Educational Research Journal, 1977, 14, 367-381.

Bobrow, D. G. Natural language input for a computer problem-solving system. In M. Minsky (Ed.), Semantic information processing. Cambridge, Mass.: MIT Press, 1968.

Bobrow, D. G., & Norman, D. A. Some principles of memory schemata. In D. G. Bobrow & A. Collins (Eds.), Representation and understanding. New York: Academic Press, 1975.

Buckingham, B. R., & Maclatchy, J. The number abilities of children when they enter grade one. In 29th Yearbook of the National Society for the Study of Education. Bloomington, Ind.: Public School Publishing Company, 1930.

Chartoff, B. T. An exploratory investigation utilizing a multidimensional scaling procedure to discover classification criteria for algebra word problems used by students in grades 7-13 (Doctoral dissertation, Northwestern University, 1976). Dissertation Abstracts International, 1977, 37, 7006A.

Chase, W. G., & Simon, H. A. The mind's eye in chess. In W. G. Chase (Ed.), Visual information processing. New York: Academic Press, 1973. (a)

Chase, W. G., & Simon, H. A. Perception in chess. Cognitive Psychology, 1973, 4, 55-81. (b)

Davis, R. B., Jockusch, E., & McKnight, C. Cognitive processes in learning algebra. The Journal of Children's Mathematical Behavior, 1978, 2, 10-320.

de Groot, A. D. Perception and memory versus thought: Some old ideas and recent findings. In B. Kleinmentz (Ed.), Problem solving: Research, method, and theory. New York: Wiley, 1966.

Duncker, K. On problem solving. Psychological Monographs, 1945, 58 (5, Whole No. 270).

Erlwanger, S. H. Case studies of childrens' conceptions of mathematics-Part I. The Journal of Children's Mathematical Behavior, 1975, 1, 1957-283.

Frey, P. W., & Adesman, P. Recall memory for visually presented chess positions. Memory & Cognition, 1976, 4, 541-547.

Gagne, R. M., & White, R. T. Memory structures and learning outcomes. Review of Educational Research, 1978, 48, 187-222.

Ginsburg, H. Children's arithmetic: The learning process. New York: van Nostrand, 1977.

Greeno, J. G., The structure of memory and the process of solving problems. In R. L. Solso (Ed.), Contemporary issues in cognitive psychology: The Loyola symposium. Washington, D. C.: Winston, 1973.

Hinsley, D. A. Hayes, J. R. & Simon, H. A. From words to equations - meaning and representation in algebra word problems. In M. Just and P. Carpenter (Eds.), Cognitive processes in comprehension. Hillsdale, N.J.: Erlbaum, 1977.

Hunt, E. Qualitative sources of individual differences in complex problem solving. In J. M. Scandura & C. J. Brainerd (Eds.), Structural/Process models of complex human behavior. Alphen aan den Rijn, The Netherlands: Sijthoff & Noordhoff, 1978.

Jacoby, L. L. On interpreting the effects of repetition: Solving a problem versus remembering a solution. Journal of Verbal Learning and Verbal Behavior, 1978, 17, 647-667.

Kalmykova, Z. I. Psychological analysis of the formation of a concept of a problem type (Originally published in 1947). In J. Kilpatrick and I. Wirszup (Eds.), Soviet studies in the psychology of learning and teaching mathematics (Vol. 6). Stanford: School of Mathematics Study Group, 1969.

Krutetskii, V. A. The psychology of mathematical abilities in schoolchildren, J. Kilpatrick and I. Wirszup (Eds.). Chicago: University of Chicago Press, 1976.

Kulm, G., & Days, H. Information transfer in solving problems. Journal for Research in Mathematics Education, 1979, 10, 94-102.

Luchins, A. S. Mechanization in problem solving. Psychological Monographs, 1942, 54 (6, Whole No. 248).

Mandler, J. M. & Johnson, N. S. Remembrance of things parsed: Story structure and recall. Cognitive Psychology, 1977, 9, 111-151.

Mayer, R. E. Information processing variables in learning to solve problems. Review of Educational Research, 1975, 45, 525-541.

Menchinskaya, N. A. Intellectual activity in solving arithmetic problems (Originally published, 1946). In J. Kilpatrick and I. Wirszup (Eds.), Soviet studies in the psychology of learning and teaching mathematics (Vol. 3). Stanford: School Mathematics Study Group, 1969.

Miller, G., Galanter, E., & Pribram, K. Plans and the structure of behavior. New York: Holt, 1960.

Newell, A., & Simon, H. A. Human problem solving. Englewood Cliffs, N. J.: Prentice-Hall; 1972.

Norman, D. A. Memory and attention: An introduction to human information processing (2nd ed.). New York: Wiley, 1976.

Paige, J. M., & Simon, J. A. Cognitive processes in solving algebra word problems. In B. Kleinmentz (Ed.), Problem solving: Research, method, and theory. New York: Wiley, 1966.

Reed, S. K., Ernst, F. W., & Banerji, R. The role of analogy in transfer between similar problem states. Cognitive Psychology, 1974, 6, 436-450.

Reed, S. K., & Johnsen, J. A. Memory for problem solutions. In G. H. Bower (Ed.), Psychology of learning and motivation (Vol. 11). New York: Academic Press, 1977.

Rumelhart, D. E., & Ortony, A. The representation of knowledge in memory. In R. C. Anderson, R. J. Spiro, & W. E. Montague (Eds.), Schooling and the acquisition of knowledge. Hillsdale, N.J.: Erlbaum, 1977.

Silver, E. A. Student perceptions of relatedness among mathematical verbal problems. Journal for Research in Mathematics Education, 1979, 10, 195-210.

Simon, D. P., & Simon, H. A. Individual differences in solving physics problems. In R. Siegler (Ed.), Childrens' thinking: What develops? Hillsdale, N. J.: Erlbaum, 1978.

Thorndyke, P. W., & Hayes-Roth, B. The use of schemata in the acquisition and transfer of knowledge. Cognitive Psychology, 1979, 11, 82-106.

Wertheimer, M. Productive thinking. New York: Harper & Row, 1959.

Wilson, J. W. The role of structure in verbal problem-solving in arithmetic: An analytical and experimental comparison of three problem-solving programs. Unpublished doctoral dissertation, Syracuse University, 1964.

Appendix B

Publications Based on the Project

Barnett, J. C. The study of syntax variables. In G. Goldin & C. E. McClintock (Eds.), *Task variables in mathematical problem solving*. Columbus, Ohio: ERIC/SMEAC, 1979 (in press).

Barnett, J. C.: Sowder, L.; & Vos, K.E. A review of selected literature in applied problem solving research. In R. Lesh & D. Mierkiewicz (Eds.), *Applied problem solving*. Columbus, Ohio: ERIC/SMEAC, 1979 (in press).

Barnett, J. C.: Sowder, L.; & Vos, K.E. Teaching ideas for textbook problems. In S. Krulik (Ed.), *Problem Solving*. Reston, Virginia: National Council of Teachers of Mathematics, in press.

Appendix C

Bibliography

Bibliography with Coding for Selected Studies

Column numbers are labelled following the coding explanation.

Columns 1-5 Grade level of subjects. P(=Primary), I(Intermediate), J(7-9), S(Secondary), A(Adult), T(Teacher)

- 6 Organismic variables (sex, race, SES,...)
- 7 Trait (e.g., self-concept, cognitive factors, perseveration,...)
- 8 Instructional history (includes pre-test on dependent variable; 0 for covarying on other pretest unless mention coef)
- 11 Context
- 12 Structure (math: equation, relationships,...)
- 13 Format (oral, concrete, pictorial, words)
- 14-16 Math content (A=algebra, G=geometry, R=arithmetic, T=trig, C=coordinate geometry, L=logic)
- 17 Syntax
- 18 Semantic
- 19 Barnett's category (what operation, # steps, # digits,...)
- 22 Method
- 23 Delivery system
- 24 Class organization
- 25 Classroom interaction
- 26 Teacher variables
- 27 Situational variables (psychological, physical)
- 28 Clinical (C) or survey/status (S) study
- 31-33 Dependent variables
- 31 Concomitant variables (trait, inst. history,...)
- 32 Product
- 33 Process (forward, looking back also)

Non-letter codes: 0=not studied, 1=studied

The next two lines identify the columns referred to above.

Reference	1 2 3 12345678901234567890123456789012345	Author	Year
Adams, Jack A. Multiple versus single problem training in human problem solving. Journal of Experimental Psychology, January, 1954, 48(1), 15-18.	A000 000L 000 000000C 010	Adams	1954
Aiken, Lewis R., Jr. Verbal factors and mathematics learning: a review of research. Journal for Research in Mathematics Education, Nov., 1971, 2(4), 304-313.	aReview	Aiken	1971
Aiken, Lewis R., Jr. Language Factors in Learning Mathematics. Columbus, Ohio: ERIC Information Analysis Center for Science, Mathematics, and Environmental Education, Oct., 1972. (ERIC Document Reproduction Service No. ED 068 340)	Review	Aiken	1972
Akers, Bettie B. S. The relationship of given answers to persistence and achievement when attempting solutions to mathematical problems (Doctoral dissertation, Memphis State University, 1975). Dissertation Abstracts International, 1975, 36, 2698A. (University Microfilms No.75-26, 030)	J 100 000A 000 100001 110	Akers	1975
Alexander, Vincent E. The relationship of selected factors to the ability to solve problems in arithmetic (Doctoral dissertation, University of Southern California, 1959). Dissertation Abstracts, 1959, 20; 1221. (University Microfilms No. 59-2057)	J 101 000R 000 000000S 110	Alexander	1959
Alexander, Vincent E. Sex differences in seventh grade problem solving. School Science and Mathematics, Jan., 1962, 62(1), 47-50.	J 100 000R 000 000000S 010	Alexander	1962
Alexander, Vincent E. Seventh graders' ability to solve problems. School Science and Mathematics, Nov., 1960, 60(7), 603-606.	J 100 000R 000 000000S 010	Alexander	1960
Allen, Layman E.; Allen, Robert W.; & Miller, James C.	JS 000 000A 000 100000 010	ALLEN	1966

Programed games and the learning of problem-solving skills: The Wff 'n Proof example. Journal of Educational Research, September, 1966, 60(1), 22-25.								
Allen, Layman E., & Ross, Joan. Improving skill in applying mathematical ideas: A preliminary report on the instructional gaming program at Pelham Middle School in Detroit. Pittsburgh, Pa.: Annual Symposium of the National Gaming Council, Oct., 1974. (ERIC Document Reproduction Service No. ED 113 163)	J	001	010R	000	100000	010	Allen & Ross	1974
Allen, Layman E., & Ross, Joan. Instructional gaming as a means to achieve skill in selecting ideas relevant for solving a problem. 1974. (ERIC Document Reproduction Service No. ED 113 158)	J	T000	010R	000	100000	010	Allen & Ross	1974
Ammon, Richard I., Jr. An analysis of oral and written responses in developing mathematical problems through pictorial and written stimuli (Doctoral dissertation, Pennsylvania State University, 1972). Dissertation Abstracts International, 1973, 34, 1056A-1057A. (University Microfilms No. 73-21, 256)	I	101	001R	000	110000	111	Ammon	1972
Anderson, Lorin W. A measure of student involvement in learning: time-on-task. 1975. (ERIC Document Reproduction Service No. ED 110 504)	J	000	000AR	000	000100	010	Anderson	1975
Anderson, Richard C. Can first graders learn an advanced problem-solving skill? Journal of Educational Psychology, Dec., 1965, 56(6), 283-294.	P	000	000L	000	C00000C	011	Anderson	1965
Anthony, W. S. Working backward and working forward in problem solving. British Journal of Psychology, 1966, 57(1/2), 53-59.	A	000	000L	000	100000C	010	Anthony	1966
Arnold, William R. Knowledge of vocabulary, ability to formulate equations, and ability to solve verbal problems: an investigation of relationships (Doctoral dissertation, University of Oregon, 1968). Dissertation Abstracts International, 1969, 29, 2031A-2032A. (University Microfilms No. 69-1)	I	000	000R	010	000000S	010	ARNOLD	1969
Arter, Judith A., & Clinton, LeRoy. Time and error consequences of irrelevant data and question placement in arithmetic word problems II: fourth-graders. Journal of Educational Research, Sept., 1974, 68(1), 28-31.	I	000	000R	100	000000S	010	Arter & Clinton	1974
Ashby, Steven J. The development of the ability to combine responses in problem solving (Doctoral dissertation, University of Connecticut, 1976). Dissertation Abstracts International, 1977, 38, 331B. (University Microfilms No. 77-14, 445)	P	000	000L	000	000000S	010	ASHBY	1977
Ashton, Sister Madeleine R. Heuristic methods in problem solving in ninth grade algebra (Doctoral dissertation, Stanford University, 1962). Dissertation Abstracts, June, 1962, 22, 4269. (University Microfilms No. 62-2320)	J	001	000A	000	110000	010	Ashton	1962
Atkinson, Richard C. Methods for maximizing the learning process: a theoretical and experimental analysis. Aug., 1971. (ERIC Document Reproduction Service No. ED 063 267)	Group of studies						Atkinson	1971
Balow, Irving H. Reading and computation ability as determinants of problem solving. Arithmetic Teacher, Jan., 1964, 11(1), 18-22.	I	100	000R	110	000000S	010	Balow	1964
Bana, J., & Nelson, D. Distractors in nonverbal mathematical problems. Journal for Research in Mathematics Education, 1978, 9, 55-61.								
Barnett, Jeffrey C. Toward a theory of sequencing: study 3-7: an investigation of the relationships of structural vari-	A	001	000R	111	100000	010	Barnett	1974

ables, instruction, and difficulty in verbal, arithmetic problem solving (Doctoral dissertation, Pennsylvania State University, 1974). Dissertation Abstracts International, July, 1975, 36, 99A-100A. (University Microfilms No. 75-15, 787)

Bassler, Otto C., Beers, Morris I., & Richardson, Lloyd I. Comparison of two instructional strategies for teaching the solution of verbal problems. Journal for Research in Mathematics Education, May, 1975, 6(3), 170-178. J 000 000A 000 100000 010 Bassler, et al.1975

Beardslee, E., & Jerman, M. Linguistic variables in verbal arithmetic problems, Columbus, Ohio, 1973a. (ERIC Document Reproduction Service No. ED 073 926)

Beardslee, E., & Jerman, M. Syntactic variables in word problems solved by students in grades 4-8. Paper presented at the Annual Meeting at the National Council of Teachers of Mathematics, Houston, Texas, 1973b.

Beardslee, E., & Jerman, M. Structural, linguistic and topic variables in verbal and computational problems in elementary mathematics. Paper presented at the Annual Meeting of the American Educational Research Association, Chicago, Illinois, 1974.

Bechtold, Charles A. The use of extraneous material in developing problem-solving ability of pupils in Algebra I (Doctoral dissertation, Columbia University, 1965). Dissertation Abstracts, Dec., 1965, 26, 3105. (University Microfilms No. 65-9149) J 101 110A 000 100000 110 Bechtold 1965

Berglund-Gray, Gunborg. Difficulty of the arithmetic processes. Elementary School Journal, Nov., 1939, 40(3), 198-203. IJ 000 010R 000 C00000S 011 Berglund-Gray 1939

Berglund-Gray, Gunborg, & Young, Robert V. The effect of process sequence on the interpretation of two-step problems in arithmetic. Journal of Educational Research, Sept., 1940, 34(1), 21-29. IJ 000 010R 000 CC0000S 011 Berglund-Gray &1940

Bernstein, Barbara E. Individual differences in thought processes and their relevance to teaching mathematics. High School Journal, February, 1975, 58(5), 195-200. Review

Bessant, Helen P. The effects of semantic familiarity and information load on the arithmetic verbal problem solving performance of children in special classes for the educable mentally retarded (Doctoral dissertation, University of Connecticut, 1972). Dissertation Abstracts International, Dec., 1972, 33, 2787A. (University Microfilms No. 72-32, 201) J 001 000A 110 000000C 010 Bessant 1972

Biegen, David A. The effects of irrelevant and immaterial data on problem difficulty (Doctoral dissertation, University of Cincinnati, 1971). Dissertation Abstracts International, Jan., 1972, 32, 3774A. (University Microfilms No. 72-4399) J 001 000R 100 000000S 010 Biegen 1971

Blake, Rick N. The effect of problem context upon the problem solving processes used by field dependent and independent students: a clinical study (Doctoral dissertation, University of British Columbia, 1976). Dissertation Abstracts International, Jan., 1977, 37, 4191A-4192A. (University Microfilms No. none) S 011 100A 000 CC0000C 011 Blake 1977

Blankship, Coleen S., & Lovitt, Thomas C. Story problems: merely confusing or downright befuddling? Journal for Research in Mathematics Education, Nov., 1976, 7(5), 290-298. I 000 000R 111 000000C 010 Blankship & Lov1976

Blomstedt, Robert K. The effects of consensus on verbal problem I 011 000R 000 100000 110 Blomstedt 1974 solving in middle school mathematics (Doctoral dissertation, University of Texas at Austin, 1974). Dissertation Abstracts International, Nov., 1974, 35, 2523A-2524A. (University Microfilms No. 74-24, 830)

Boersig, Teresa M. The effects of instruction in the enactive mode of representation on multivariable verbal problems encountered in elementary algebra (Doctoral dissertation, Purdue University, 1973). Dissertation Abstracts International, Dec., 1973, 34, 3230A. (University Microfilms No. 73-28, 047)	JS	001	001A	000	110000	010	Boersig	1973
Bowers, Joan E. Procedure to strengthen ability to solve arithmetical problems. School Science and Mathematics, June, 1957, 57(6), 485-493.	General						Bowers	1957
Bowman, Herbert L. Reported preference and performance in problem solving according to intelligence groups. Journal of Educational Research, April/May, 1932, 25(4/5), 295-299.	J	001	100RL	000	000000S	010	Bowman	1932
Bowman, Herbert L. The relation of reported preference to performance in problem solving. Journal of Educational Psychology, April, 1932, 23(4), 266-276.	J	001	100RL	000	000000S	010	Bowman	1932
Boyd, Flora M. The effect of extraneous and nonextraneous information in direct and indirect type problems on the arithmetic verbal problem solving performance of the educable mentally retarded (Doctoral dissertation, University of Connecticut, 1975). Dissertation Abstracts International, May, 1975, 35, 7151A. (University Microfilms No. 75-10,609)	J	001	000R	100	000000S	010	Boyd	1975
Boyden, Joanne A. Construction of a diagnostic test in verbal arithmetic problem solving at the fifth grade level (Doctoral dissertation, University of Miami, 1970). Dissertation Abstracts International, Oct., 1970, 31, 1504A. (University Microfilms No. 70-18, 161)	I	101	000R	001	C00000S	011	Boyden	1970
Bramhall, Edwin W. An experimental study of two types of arithmetic problems. Journal of Experimental Education, September, 1939, 8(1), 36-38.	I	000	100R	000	100000	010	BRAMHALL	1939
Brian, Richard B. Processes of mathematics: a definitional development and an experimental investigation of their relationship to mathematical problem solving behavior (Doctoral dissertation, University of Maryland, 1966). Dissertation Abstracts International, Oct., 1967, 28, 1202A. (University Microfilms No. 67-11, 815)	A	001	000TCL	000	100000	011	Brian	1966
Brown, Gerald W. Improving instruction in problem solving in ninth grade general mathematics. School Science and Mathematics, May, 1964, 64(5), 341-346.	J	000	000AR	000	000000S	010	Brown	1964
Bunch, Martha A. A study of the effects on retention and on the problem-solving ability of students when geometry is used as an aid in teaching factoring of second-degree polynomials (Doctoral dissertation, University of Missouri-Kansas City, 1972). Dissertation Abstracts International, Sept., 1973, 34, 1057A-1058A. (University Microfilms No. 73-19, 718)	J	001	011AG	000	100000	010	Bunch	1973
Burch, Robert L. Formal analysis as a problem-solving procedure. Journal of Education, Nov., 1953, 136(2), 44-47, 64.	I	000	000R	000	C00000S	011	Burch	1953
Burns, Paul C., & Yonally, James L. Does the order of presentation of numerical data in multi-steps arithmetic problems affect their difficulty? School Science and Mathematics, April, 1964, 64(4), 267-270.	I	000	000R	001	000000S	010	Burns & Yonally	1964
Burrus, William B. Validation of a CAI-based learning hierarchy for a problem-solving task in mathematics (Doctoral dissertation, University of Kansas, 1974). Dissertation Abstracts International, March, 1975, 35, 5770A-5771A. (University	J	000	000A	000	100000	010	Burrus	1975

Microfilms No. 76-6161)								
Butler, Charles C. A study of the relation between children's understanding of computational skills and their ability to solve verbal problems in arithmetic (Doctoral dissertation, Boston University, 1956). Dissertation Abstracts, Dec., 1956, 16, 2400. (University Microfilms No. 56-3814)	J	001	000R	000	C00000S	010	Butler	1956
Caldwell, Janet H. The effects of abstract and hypothetical factors on word problem difficulty in school mathematics (Doctoral dissertation, University of Pennsylvania, 1977). Dissertation Abstracts International, 1978, 38, 4637A. (University Microfilms No. 77-30178)	IJS	000	100AR	000	C00000S	010	CALDWELL	1978
Campbell, Patricia F. The role of pictures in first grade children's perception of mathematical relationships (Doctoral dissertation, Florida State University, 1976). Dissertation Abstracts International, 1977, 37, 6323A. (University Microfilms No. 77-8574)	P	000	001R	000	000000S	011	CAMPBELL	1977
Campbell, Patricia F. The influence of selected artistic variables on children's perception of mathematical pictures. Paper presented at the meeting of the National Council of Teachers of Mathematics, San Diego, April 1978.								
Campbell, Patricia, & Virgin, Albert. A survey of elementary school teachers' and principals' attitudes to mathematics and utilizing mini-calculators. Toronto: Ontario Department of Education, July, 1976. (ERIC Document Reproduction Service No. ED 137 121)	T	000	000	000	000000S	000	Campbell & Virg	1976
Campbell, Patricia, & Virgin, Albert. An evaluation of elementary school mathematics programs utilizing the mini-calculator. Toronto: Ontario Department of Education, July, 1976. (ERIC Document Reproduction Service No. ED 137 120)	I	011	001R	000	110000	110	Campbell & Virg	1976
Carpenter, Thomas P., Coburn, Terrence G., Reys, Robert E., & Wilson, James W. Notes from national assessment: word problems. Arithmetic Teacher, May, 1976, 23(5), 389-393.	IJ	000	000R	000	000000S	011	Carpenter et al	1976
Carter, William L. A new basis of organization for the junior high school mathematics program (Doctoral dissertation, Ohio State University, 1952). Dissertation Abstracts, Nov., 1957, 17, 2521-2524. (University Microfilms No. 57-4057)	J	000	000AR	000	100100	111	Carter	1957
Cathcart, W. George, & Liedtke, Werner. Reflectiveness/impulsiveness and mathematics achievement. Arithmetic Teacher, Nov., 1969, 16(7), 563-567.	P	010	000R	000	000000S	110	Cathcart & Lied	1969
Chartoff, Barton T. An exploratory investigation utilizing a multidimensional scaling procedure to discover classification criteria for algebra word problems used by students in grades 7-13 (Doctoral dissertation, Northwestern University, 1976). Dissertation Abstracts International, 1977, 37, 7006A. (University Microfilms No. 77-10,012)	JSA	000	100A	000	000000S	011	Chartoff	1977
Chase, Clinton I. The position of certain variables in prediction of problem-solving in arithmetic. Journal of Educational Research, Sept., 1960, 54(1), 9-14.	I	000	000R	000	000000S	011	Chase	1960
Chen, Ta-Wei D. Analogical reasoning, learning, and problem solving with application to theorem proving and construction in plane geometry (Doctoral dissertation, State University of New York at Buffalo, 1976). Dissertation Abstracts International, Feb., 1977, 37, 4052A. (University Microfilms No. 77-3525)	Computer program						Chen	1977

Clark, Alan C. A creative versus a traditional approach to teaching story problems (Doctoral dissertation, University of Utah, 1967). Dissertation Abstracts International, Jan., 1968, 28, 2929B-2930B. (University Microfilms No. 67-17, 555)	J	011	000AR	000	111100	110	Clark	1968
Clark, John R. Should textbook problems be abolished? Education, Vol. 54, April, 1934, pp. 455-456.								
Clark, John R., & Vincent, E. Leona. A comparison of two methods of arithmetic problem analysis. Mathematics Teacher, April, 1925, 18(4), 226-233.	J	000	000R	000	100000	010	Clark & Vincent	1925
Clem, Orlie M., & Hendershot, Bertha A. Some difficulties involved in solving verbal problems in elementary algebra. Mathematics Teacher, March, 1930, 23(3), 141-147.	J	000	000A	000	000000S	011	Clem & Hendersh	1930
Clement, John J. Quantitative problem solving processes in children (Doctoral dissertation, University of Massachusetts, 1977). Dissertation Abstracts International, 1977, 38, 1952A-1953A. (University Microfilms No. 77-21, 992)	I	000	000R	000	000000C	011	CLEMENT	1977
Cohen, Martin P. Interest and its relationship to problem-solving ability among secondary school mathematics students (Doctoral dissertation, University of Texas, Austin, 1976). Dissertation Abstracts International, Feb., 1977, 37, 4929A. (University Microfilms No. 77-3880)	J	111	100R	000	000000S	010	Cohen	1976
Connor, William L., & Hawkins, Gertrude C. What materials are most useful to children in learning to solve problems? Educational Method, Oct., 1936, 16(1), 21-29.	PIJ	000	000R	000	000000S	010	Connor & Hawkin	1936
Conradi, Margaret S. Ordered word problems: a study of their effectiveness for elementary school students in solving word problems. (Doctoral dissertation, University of Cincinnati, 1975). Dissertation Abstracts International, Nov., 1975, 36, 2268B-2269B. (University Microfilms No. 75-25, 951)	PIJ	001	000R	100	100000	010	Conradi	1975
Consumer Math: Selected Results from the First National Assessment of Mathematics. Denver: Education Commission of the States, National Assessment of Educational Progress, June, 1975. (ERIC Document Reproduction Service No. ED 111 696)	IJSA	100	000R	000	000000S	010	NAEP	1975
Corle, Clyde G. Thought processes in grade six problems. Arithmetic Teacher, Oct., 1958, 5(6), 193-203.	I	000	000R	000	000000S	011	Corle	1958
Cottrell, Raymond S. A study of selected language factors associated with arithmetic achievement of third grade students (Doctoral dissertation, Syracuse University, 1967). Dissertation Abstracts International, 1967, 28, 4193B-4194B. (University Microfilms No. 68-5505)	I	000	000R	000	000000S	010	COTTRELL	1967
Covington, Martin V., & Crutchfield, Richard S. Facilitation of creative problem solving. Programmed Instruction, 1965, 4(4), 3-5; 10.	I	000	000RL	000	100000	010	Covington & Cru	1965
Crowe, Kenneth R. The relative effectiveness of two methods for translating worded problems in algebra into open sentences (Doctoral dissertation, University of Illinois at Urbana-Champaign, 1975). Dissertation Abstracts International, Nov., 1975, 36, 2732A. (University Microfilms No. 75-24, 288)	J	001	010A	000	100000	010	Crowe	1975
Cruickshank, William M. Arithmetic ability of mentally retarded children: I. Ability to differentiate extraneous materials from needed arithmetic facts. Journal of Educational Research, Nov., 1948, 42(3), 161-170.	IJ	100	000R	001	000000S	010	Cruickshank	1948
Cruickshank, William M. Arithmetic ability of mentally retarded	IJ	100	000R	000	000000S	011	Cruickshank	1948

children: II. Understanding arithmetic processes. Journal of Educational Research, Dec., 1948, 42(4), 279-288.

Cunningham, John D. Rigidity in children's problem solving. School Science and Mathematics. April, 1966, 66(4), 377-389. — Review — Cunningham 1966

Dahmus, Maurice E. How to teach verbal problems. School Science and Mathematics, Feb., 1970, 70(2), 121-138. — General — Dahmus 1970

Dalton, Roy M. Thinking patterns in solving certain word problems by ninth grade general mathematics students: an exploratory study in problem solving (Doctoral dissertation, University of Tennessee, 1974). Dissertation Abstracts International, May, 1975, 35, 5526B. (University Microfilms No. 75-11, 155) — J 000 000AR 000 100000C 011 Dalton 1974

Damarin, Suzanne K. Problem solving: Polya's heuristic applied to psychological research. 1976. (ERIC Document Reproduction Service No. ED 129 631) — Review — Damarin 1976

Davis, Gary A. Current status of research and theory in human problem solving. Psychological Bulletin, July, 1966, 66(1), 36-54. — Review — Davis, G. 1966

Davis, James H. The solution of simple and compound word problems. Behavioral Science, Oct., 1964, 9(4), 359-370. — A000 000L 000 000000S 010 Davis, J. 1964

Davis, James H., & Restle, Frank. The analysis of problems and prediction of group problem solving. Journal of Abnormal and Social Psychology, Feb., 1963, 66(2), 103-116. — A000 000L 000 001000 010 Davis & Restle 1963

Davis, Lawrence H. A study of two methods of teaching problem solving in eighth grade mathematics (Doctoral dissertation, Louisiana State University and A and M College, 1976). Dissertation Abstracts International, Dec., 1976, 37, 3373A. (University Microfilms No. 76-28, 797) — J 001 000A 000 100000 010 Davis 1976

Deep, Ronald. The relative effects of translating from mathematics to English and from English to mathematics on verbal problem solving in Algebra 2 (Doctoral dissertation, Florida State University, 1976). Dissertation Abstracts International, 1977, 37, 6323A-6324A. (University Microfilms No. 77-8578) — S 000 000A 000 100000 010 DEEP 1977

DeLong, G. Inquiry into pre- and early-adolescent interests. Adolescence, 1975, 10, 187-190.

Denmark, Ewell T., Jr. A comparative study of two methods of teaching elementary algebra students to use the algebraic technique to solve verbal problems (Doctoral dissertation, Florida State University, 1965). Dissertation Abstracts, March, 1965, 25, 5295-5296. (University Microfilms No. 65-297) — J 001 000A 000 100000 011 Denmark 1965

DeVard, Alma J. C. Oral reading of arithmetical problems by educable mentally retarded children (Doctoral dissertation, University of Connecticut, 1973). Dissertation Abstracts International, March, 1974, 34, 5752A. (University Microfilms No. 74-7115) — IJS 101 000R 110 100000 011 DeVard 1974

Dodson, Joseph W. Characteristics of successful insightful problem solvers (Doctoral dissertation, University of Georgia, 1970). Dissertation Abstracts International, May, 1971, 31, 5928A. (University Microfilms No. 71-13, 048) — IJS 111 000AGR000 000010S 010 Dodson 1970

Donahue, Robert T. An investigation of the factor pattern involved in arithmetic problem solving of eighth grade girls (Doctoral dissertation, Catholic University of America, 1969). Dissertation Abstracts International, Dec., 1969, 30, 2372A. (University Microfilms No. 69-19, 720) — J 101 000R 001 000000S 010 Donahue 1969

Dresher, R. Training in mathematics vocabulary.

Educational Research Bulletin, 1934, 13, 201-204.

Duncan, Carl P. Recent research on human problem solving. Psychological Bulletin, Nov., 1959, 56(6), 397-429.	Review	Duncan	1959
Duncan, Carl P. Effect of instructions and information on problem solving. Journal of Experimental Psychology, April, 1963, 65(4), 321-327.	A000 000L 000 100000 010	Duncan	1963
Dunn, J. A. Discovery, creativity and school mathematics: a review of research. Educational Review, Feb., 1976, 28(2), 102-117.	Review	Dunn	1976
Dweck, Carol S. The role of expectations and attributions in the alleviation of learned helplessness in a problem-solving situation (Doctoral dissertation, Yale University, 1972). Dissertation Abstracts International, Nov., 1972, 33, 2317B-2318B. (University Microfilms No. 72-29, 536)	IJ 111 000R 000 100000 110	Dweck	1972
Early, Joseph F. A study of children's performance on verbally stated arithmetic problems with and without word clues (Doctoral dissertation, University of Alabama, 1967). Dissertation Abstracts International, Feb., 1968, 28, 2889A. (University Microfilms No. 68-1037)	I 001 000R 110 000000S 011	Early	1967
Earp, N. Wesley. Procedures for teaching reading in mathematics. Arithmetic Teacher, November, 1970, 17(7), 575-579.	GEN ARTICLE	EARP	1970
Edwards, Leo, Jr. The effects of a problem solving model as an alternative in the general mathematics curriculum (Doctoral dissertation, Utah State University, 1976). Dissertation Abstracts International, April, 1977, 37, 6239A. (University Microfilms No. 77-8468)	J 111 000R 000 100000 110	Edwards	1977
Engelhart, Max D. The relative contribution of certain factors to individual differences in arithmetic problem solving ability. Journal of Experimental Education, September, 1932, 1(1), 19-27.	I 000 000R 000 000000S 010	ENGELHART	1932
An evaluation of the corrective mathematics services for disadvantaged pupils in non-public schools. ESEA Title I program. New York: New York University Center for Field Research and School Services, Aug., 1972. (ERIC Document Reproduction Service No. ED 087 835)	PIJ 111 000R 000 100000 110		1972
Evans, Edward W. Measuring the ability of students to respond in creative mathematical situations at the late elementary and early junior high school level (Doctoral dissertation, University of Michigan, 1964). Dissertation Abstracts, June, 1965, 25, 7107-7108. (University Microfilms No. 65-5302)	IJ 101 000L 000 000000S 111	Evans	1965
Everest, M. Inez. Community college students' academic achievement in mathematics and attitudinal change as a function of instructional methodology. 1975. (ERIC Document Reproduction Service No. ED 123 166)	A001 000A 000 110000 110	Everest	1975
Fafard, Mary-Beth. The effects of instructions on verbal problem solving in learning disabled children (Doctoral dissertation, University of Oregon, 1976). Dissertation Abstracts International, March, 1977, 37, 5741A-5742A. (University Microfilms No. 77-4713)	PI 010 000R 100 100000 011	Fafard	1977
Faulk, Charles J., & Landry, Thomas R. An approach to problem-solving. Arithmetic Teacher, April, 1961, 8(4), 157-160.	I 000 000R 000 100000 010	FAULK & Landry	1961
Finley, Carmen J. Arithmetic achievement in mentally retarded children: the effects of presenting the problem in different contexts (Doctoral dissertation, Columbia University, 1962). Dissertation Abstracts International, 1962, 23, 922. (University Microfilms	P 000 101R 000 000000S 010	FINLEY	1962

No. 62-3693)

Finley, Carmen J. Arithmetic achievement in mentally retarded children: the effects of presenting the problem in different contexts. American Journal of Mental Deficiency, September, 1962, 67(9), 281-286.	IJ 100	101R	000	000000S	010	FINLEY	1962
Fisher, Nancy C. Mathematical problem-solving's mathelation component related to achievement, attitude, critical thinking in prospective elementary teachers (Doctoral dissertation, Indiana University, 1972). Dissertation Abstracts International, May, 1973, 33, 5965A-5966A. (University Microfilms No. 73-10, 814)	A011	000AG	000	000000C	011	Fisher	1973
Flaherty, E. G. The thinking aloud technique and problem solving ability. Journal of Educational Research, February, 1975, 68(6), 223-225.	S 000	000A	000	000100C	011	FLAHERTY	1975
Flaherty, Eileen G. Cognitive processes used in solving mathematical problems (Doctoral dissertation, Boston University, 1973). Dissertation Abstracts International, Oct., 1973, 34, 1767A. (University Microfilms No. 73-23, 562)	S 001	000A	000	110000	111	Flaherty	1973
Flake, Janice L. The use of interactive computer simulations for sensitizing mathematics methods students to questioning behaviors (Doctoral dissertation, University of Illinois, 1973). Dissertation Abstracts International, June, 1974, 34, 7623A. (University Microfilms No. 74-12, 015)	A000	001	010	010010C	101	Flake	1974
Foster, Thomas E. The effects of computer programming experiences on student problem solving behaviors in eighth grade mathematics (Doctoral dissertation, University of Wisconsin, 1972). Dissertation Abstracts International, Feb., 1973, 33, 4239A-4240A. (University Microfilms No. 72-31, 527)	J 001	001R	000	110000	011	Foster	1973
Frandsen, Arden N., & Holder, James R. Spatial visualization in solving complex verbal problems. Journal of Psychology, November, 1969, 73(2), 229-233.	A001	000RL	000	100000	010	FRANDSEN, & HOLD	1969
Gallo, Dennis P. Problem solving: a test of two aspects (Doctoral dissertation, State University of New York at Stony Brook, 1974). Dissertation Abstracts International, March, 1975, 35, 4649B-4650B. (University Microfilms No. 75-5373)	I 000	000C	000	100000C	010	Gallo	1975
Gangler, Joseph M., Jr. An experimental study of the effects of participation and motivation on the problem solving ability of college freshmen (Doctoral dissertation, Columbia University, 1967). Dissertation Abstracts International, Nov., 1967, 28, 2157B. (University Microfilms No. 67-14, 046)	A001	000L	000	100001	111	Gangler	1967
Gawronski, Jane D. Inductive and deductive learning styles in junior high school mathematics: an exploratory study. Journal for Research in Mathematics Education, November, 1972, 3(4), 239-247.	J 001	000G	000	100000	010	Gawronski	1972
Gawronski, Jane D. An investigation of the effect of selected learning styles on achievement in eighth grade mathematics (Doctoral dissertation, University of Minnesota, 1971). Dissertation Abstracts International, Dec., 1972, 32, 3151A-3152A. (University Microfilms No. 72-351)	J 111	100C	000	100000	010	Gawronski	1972
Geisert, Paul G. A study of the hierarchical competencies underlying the problem solving use of proportion (Doctoral dissertation, Florida State University, 1971). Dissertation Abstracts International, March, 1972, 32, 5103A-5104A. (University Microfilms No. 72-10, 021)	I 001	010R	010	100000	010	Geisert	1972

Gilmary, Sister. Training effects of reading remediation to arithmetic computation when intelligence is controlled and all other school

factors are eliminated. Arithmetic Teacher, 1967, 14, 17-20.

Gimmestad, Beverly J. An exploratory study of the processes used by community college students in mathematical problem solving (Doctoral dissertation, University of Colorado at Boulder, 1976). Dissertation Abstracts International, 1977, 37, 7590A. (University Microfilms No. 77-11, 300)
A 001 000A 000 000000C 011 GIMMESTAD 1977

Godgart, Martin D. The arithmetic problem-solving ability of teachers as related to their effectiveness in teaching problem-solving (Doctoral dissertation, University of Connecticut, 1964). Dissertation Abstracts, Aug., 1965, 26, 793-794. (University Microfilms No. 65-2711)
A011 000R 000 000010S 11 Godgart 1965

Goldberg, Dorothy J. The effects of training in heuristic methods on the ability to write proofs in number theory (Doctoral dissertation, Columbia University, 1974). Dissertation Abstracts International, April, 1975, 35, 4989B. (University Microfilms No. 75-7836)
A001 000L 000 100000 110 Goldberg 1975

Goodnow, Jacqueline J., & Pettigrew, Thomas F. Some sources of difficulty in solving simple problems. Journal of Experimental Psychology, June, 1956, 51(6), 385-392.
A000 000L 000 100000 011 Goodnow, & Petti1956

Goodstein, H. A.; Bessant, Helen; Thibodeau, Gerard; Vitello, Stan; & Vlahakos, Irene. The effect of three variables on the verbal problem solving of educable mentally handicapped. American Journal of Mental Deficiency, 1972, 76(6), 703-709.
IJ 100 001R 000 000000S 010 Goodstein et al1972

Goodstein, H.A.; Cawley, J. F.; Gordon, S.; & Helfgott, J. Verbal problem solving among educable mentally retarded children. American Journal of Mental Deficiency, 1971, 76(2), 238-241.
I 100 000R 100 000000S 010 Goodstein et al1971

Gorman, Charles J. A critical analysis of research on written problems in elementary school mathematics (Doctoral dissertation, University of Pittsburgh, 1967). Dissertation Abstracts International, June, 1968, 28, 4818A-4819A. (University Microfilms No. 68-7509)
Review Gorman 1967

Grady, Merle B. Problem solving in algebra as related to Piagetian levels of thought (Doctoral dissertation, University of Texas at Austin, 1975). Dissertation Abstracts International, April, 1976, 36, 6587A. (University Microfilms No. 76-8034)
J 011 000A 000 000000C 011 Grady 1976

Graf, Richard G., & Riddell, Jeanne C. Sex differences in problem solving as a function of problem context. Journal of Educational Research, July-August, 1972, 65(10), 451-452.
A100 100R 000 000000S 110 Graf & Riddell 1972

Gray, Theresa H. A field study of mathematics laboratory development in Youngstown, Ohio (Doctoral dissertation, University of Pittsburgh, 1973). Dissertation Abstracts International, Sept., 1973, 34, 1184B-1185B. (University Microfilms No. 73-21, 242)
PI 001 001RG 000 010000S 010 Gray 1973

Greene, Harry A. Directed drill in the comprehension of verbal problems in arithmetic. Journal of Educational Research, January, 1925, 11(1), 33-40.
I 000 000R 000 100000C 011 Greene 1925

Hafner, A. Jack. Influence of verbalization on problem solving. Psychological Reports, 1957, 3, 360.
I 000 000G 000 000100 010 Hafner 1957

Haley, K. B. Operational research education for practitioners and managers. International Journal of Mathematical Education in Science and Technology,
Gen inf Haley 1972

October-December, 1972, 3(4), 343-347.								
Hall, Thomas R. A study of situational problem solving by gifted high school mathematics students (Doctoral dissertation, Georgia State University, 1976). Dissertation Abstracts International, Aug., 1976, 37, 906A-907A. (University Microfilms No. 76-16, 964)	JS	001	000AGR000		100000	011	Hall, T.	1976
Hall, William D. A study of the relationship between estimation and mathematical problem solving among fifth grade students (Doctoral dissertation, University of Illinois, 1976). Dissertation Abstracts International, April, 1977, 37, 6324A-6325A. (University Microfilms No. 77-9014)	I	001	000R	000	100000	010	Hall, W.	1977
Handler, Janet R. An exploratory study of the spatial visualization abilities and problem solving processes exhibited by high school mathematics students while solving a set of geometric problems (Doctoral dissertation, University of Tennessee, 1976). Dissertation Abstracts International, May, 1977, 37, 7003A. (University Microfilms No. 77-10, 770)	S	001	011G	000	000000C	111	Handler	1977
Hanna, Paul R. Methods of arithmetic problem solving. Mathematics Teacher, November, 1930, 23(7), 442-450.	IJ	000	000R	000	100000	010	Hanna	1930
Hansen, Carl W. Factors associated with successful achievement in problem solving in sixth-grade arithmetic. Journal of Educational Research, October, 1944, 38(2), 111-118.	I	000	000R	000	000000S	010	Hansen	1944
Harmon, Adelaide T. Problem solving in contemporary mathematics: the relative merits of two methods of teaching problem solving in the elementary school (Doctoral dissertation, New York University, 1969). Dissertation Abstracts International, Feb., 1970, 30, 3748B. (University Microfilms No. 69-21, 189)	I	001	000R	000	100000	011	Harmon	1970
Harvin, V. R., & Gilchrist, M. A. Mathematics teacher a reading teacher? Columbus, Ohio, 1970. (ERIC Document Reproduction Service No. ED 041 702).								
Hater, M. A. & Kane, R. B. The cloze procedure as a measure of the reading comprehensibility and difficulty of mathematical English. Columbus, Ohio, 1970. (ERIC Document Reproduction Service No. ED 040 881)								
Hatfield, Larry L. Computer-assisted mathematics: an investigation of the effectiveness of the computer used as a tool to learn mathematics (Doctoral dissertation, University of Minnesota, 1969). Dissertation Abstracts International, April, 1970, 30, 4329A-4330A. (University Microfilms No. 70-5569)	J	001	000R	000	110000	010	Hatfield	1970
Hatfield, Larry L. (Ed.) Mathematical problem solving. Columbus, Ohio: ERIC/SMEAC, 1978.							Hatfield	1978
Hatfield, Larry L., & Kieren, Thomas E. Computer-assisted problem solving in school mathematics. Journal for Research in Mathematics Education, March, 1972, 3(2), 99-112.	JS	000	000ART000		100000	010	Hatfield & Kier	1972
Hawkins, George E. Teaching verbal problems in first year algebra. School Science and Mathematics, June, 1932, 32(6), 655-660.	J	000	000A	000	100000	010	Hawkins	1932
Hayes, John R. Problem topology and the solution process. Journal of Verbal Learning and Verbal Behavior, June, 1965, 4(3), 371-379.	A	000	010L	000	000000S	011	Hayes	1965
Heine, Beatrice. An investigation of the effect of teaching selected topics in elementary mathematical logic on problem-solving ability of fifth grade students (Doctoral dissertation, Temple University, 1972). Dissertation	I	101	000L	111	100000	010	Heine	1972

Reference							Author	Year
Abstracts International, Oct., 1972, 33, 1587A. (University Microfilms No. 72-27, 196)								
Henney, Maribeth A. The relative impact of mathematics reading skills instruction and supervised study upon fourth graders' ability to solve verbal problems in mathematics (Doctoral dissertation, Kent State University, 1968). Dissertation Abstracts International, June, 1969, 29, 4377A. (University Microfilms No. 69-9556)	I	101	000R	110	110000	110	Henney	1969
Henney, Maribeth. Improving mathematics verbal problem-solving ability through reading instruction. Arithmetic Teacher, April, 1971, 18(4), 223-229.	Gen Inf						Henney	1971
Hensell, Kenneth C. Children's interests and the content of problems of arithmetic (Doctoral dissertation, Stanford University, 1956). Dissertation Abstracts International, 1956, 16, 1857. (University Microfilms No. 56-2946)	TEXT ANALYSIS						HENSELL	1956
Hesemann, John P. A spatial model for the cognitive representation of verbal algebra problems (Doctoral dissertation, Indiana University, 1976). Dissertation Abstracts International, Oct., 1976, 37, 2037A. (University Microfilms No. 76-21, 538)	S	001	001A	000	100000	110	Hesemann	1976
Hoerbelt, Bernard G. The role of beliefs, doubts and conflicts in the teaching and learning of mathematical problems (Doctoral dissertation, State University of New York at Buffalo, 1976). Dissertation Abstracts International, March, 1977, 37, 5564A-5565A. (University Microfilms No. 77-6138)	Theory						Hoerbelt	1977
Hoffman, Carl B. The relationship of immediate recall, delayed recall, and incidental memory to problem-solving ability (Doctoral dissertation, University of Pennsylvania, 1960). Dissertation Abstracts, Oct., 1960, 21, 813-814. (University Microfilms No. 60-3659)	J	001	000	000	000000S	100	Hoffman	1960
Hoffman, L. Richard, & Maier, Norman R. F. Sex differences, sex composition, and group problem solving. Journal of Abnormal and Social Psychology, February, 1961, 63(2), 453-456.	A	100	000R	000	001000	010	Hoffman & Maier	1961
Hoffman, L. Richard, & Maier, Norman R. F. Social factors influencing problem solving in women. Journal of Personality and Social Psychology, October, 1966, 4(4), 382-390.	A	100	100R	000	C00001	010	Hoffman & Maier	1966
Holden, Alistair D. C. The simulation of human methods of solving mathematical problems using digital computer programs with the capacity to learn (Doctoral dissertation, University of Washington, 1964). Dissertation Abstracts, June, 1965, 25, 7155. (University Microfilms No. 65-5425)		000	010T	000	000000	000	Holden	1965
Hollander, Sheila K. Strategies of selected sixth graders reading and working verbal arithmetic problems (Doctoral dissertation, Hofstra University, 1973). Dissertation Abstracts International, April, 1974, 34, 6258A-6259A. (University Microfilms No. 74-7896)	I	001	000R	110	000000C	111	Hollander	1974
Hollander, Sheila K. The effect of questioning on the solution of verbal arithmetic problems. School Science and Mathematics, December, 1977, 77(8), 659-661.	I	000	000R	000	000000C	011	Hollander	1977
Hollowell, Kathleen A. A flow chart model of cognitive processes in mathematical problem solving (Doctoral dissertation, Boston University School of Education,	S	000	000AGL	000	000000C	011	HOLLOWELL	1977

1977). Dissertation Abstracts International, 1977, 37, 7666A-7667A. (University Microfilms No. 77-11, 363)

Holtan, Boyd. Motivation and general mathematics students. The Mathematics Teacher, January, 1964, pp. 20-25.

Holtan, Boyd, & Knifong, J. Dan. A search for reading difficulties among erred word problems. Journal for Research in Mathematics Education, May, 1977, 8(3), 227-230. I 000 000R 000 000000C 011 Holtan & Knifon1977

Houtz, John C. Problem-solving ability of advantaged and disadvantaged elementary school children with concrete and abstract item representations (Doctoral dissertation, Purdue University, 1973). Dissertation Abstracts International, March, 1974, 34, 5717A. (University Microfilms No. 74-4981) PI 100 001R 000 110000 010 Houtz 1974

Hudgins, Bryce B. Effects of group experience on individual problem solving. Journal of Educational Psychology, February, 1960, 51(1), 37-42. I 001 000R 000 101000 010 Hudgins 1960

Hudgins, Bryce B., & Smith, Louis M. Group structure and productivity in problem solving. Journal of Educational Psychology, October, 1966, 57(5), 287-296. IJ 001 000R 000 001100 010 Hudgins & Smith1966

Hutcherson, Lyndal R. Errors in problem solving in sixth-grade mathematics (Doctoral dissertation, University of Texas at Austin, 1975). Dissertation Abstracts International, April, 1976, 36, 6459A-6460A. (University Microfilms No. 76-8047) I 001 000R 000 000000S 101 Hutcherson 1976

Hydle, L., & Clapp, Frank L. Elements of difficulty in the interpretation of concrete problems in arithmetic. University of Wisconsin, Bureau of Educational Research, Bulletin No. 9, 1927.

Irish, Elizabeth H. Improving problem solving by improving verbal generalization. Arithmetic Teacher, March, 1964, 11(3), 169-175. I 000 000R 000 100000 010 Irish 1964

James, Jim B. A comparison of performance of sixth-grade children in three arithmetic tasks: typical textbook verbal problems; revised verbal problems including irrelevant data; and computational exercises (Doctoral dissertation, University of Alabama, 1967). Dissertation Abstracts International, Nov., 1967, 28, 2030B. (University Microfilms No. 67-13, 241) I 001 100R 000 000000S 010 James 1967

Jansson, Lars C. The development of an instrument to assess critical thinking ability in mathematics (Doctoral dissertation, Temple University, 1970). Dissertation Abstracts International, Sept., 1971, 32, 1383A. (University Microfilms No. 71-10, 816) SA011 000AG 000 000000S 110 Jansson 1971

Jerman, M. Instruction in problem solving and an analysis of structural variables that contribute to problem-solving difficulty. Technical Report No. 180, Psychology Series, Stanford, California: Institute for Mathematical Studies in the Social Sciences, Stanford University, March, 1971.

Jerman, M. Structural variables in arithmetic problems. Mimeographed paper, The Pennsylvania State University, 1972.

Jerman, Max E. Problem solving in arithmetic as transfer from a productive thinking program (Doctoral dissertation, Stanford University, 1971). Dissertation Abstracts International, April, 1972, 32, 5671A. (University Microfilms No. 72- I 101 000R 000 100000 011 Jerman 1972

11, 576)

Jerman, Max. Individualized instruction in problem solving in elementary school mathematics. Journal for Research in Mathematics Education, January, 1973, 4(1), 6-19.
I 101 000R 000 100000 010 Jerman 1973

Jerman, Max, & Mirman, Sanford. Linguistic and computational variables in problem solving in elementary mathematics. Educational Studies in Mathematics, April, 1974, 5(3), 317-362.
IJA 000 000R 111 000000S 011 Jerman & Mirman1974

Jerman, Max, & Rees, Raymond. Predicting the relative difficulty of verbal arithmetic problems. Educational Studies in Mathematics, April, 1972, 4(3), 306-323.
IJ 000 000R 111 000000 010 Jerman & Rees 1972

John, Lenore. Difficulties in solving problems in arithmetic. Elementary School Journal, November, 1930, 31(3), 202-215.
I 000 000R 000 000000 011 John 1930

Johnson, Donald M. A modern account of problem solving. Psychological Bulletin, April, 1944, 41(4), 201-229.
Review Johnson 1944

Johnson, Donald M., & Hall, E. R. Organization of relevant and irrelevant words in the solution of verbal problems. Journal of Psychology, July, 1961, 52(1), 99-104.
A000 000R 010 000000 010 Johnson & Hall 1961

Johnson, Donald M., & Jennings, Joseph W. Serial analysis of three problem-solving processes. Journal of Psychology, July, 1963, 56(1), 43-52.
not math Johnson & Jenni1963

Johnson, Harry C. Problem-solving in arithmetic: a review of the literature. I. Elementary School Journal, March, 1944, 44(7), 396-403.
Review Johnson 1944

Johnson, Harry C. Problem-solving in arithmetic: a review of the literature. II. Elementary School Journal, April, 1944, 44(8), 476-82.
Review Johnson 1944

Johnson, Harry C. The effect of instruction in mathematical vocabulary upon problem solving in arithmetic. Journal of Educational Research, October, 1944, 38(2), 97-110.
J 001 000R 010 100000 010 Johnson 1944

Johnson, John T. On the nature of problem-solving in arithmetic. Journal of Educational Research, October, 1949, 43(2), 110-115.
Review Johnson 1949

Jonsson, Harold A. Interaction of test anxiety and test difficulty in mathematics problem-solving performance (Doctoral dissertation, University of California, Berkeley, 1965). Dissertation Abstracts, Jan., 1966, 26, 3757-3758. (University Microfilms No. 65-13, 514)
I 111 000R 000 000001S 010 Jonsson 1966

Kamins, Martin P. An exploratory study of the effect of familiar language on the ability of black children to achieve success with the solving of word problems (Doctoral dissertation, Wayne State University, 1971). Dissertation Abstracts International, Nov., 1971, 32, 2402A. (University Microfilms No. 71-29, 754)
I 100 001R 111 000000C 110 Kamins 1971

Kane, R. B. The readability of mathematical English. Journal of Research in Science Teaching, 1968, 5, 296-298.

Kane, R. B. The readability of mathematics textbooks revisited. Mathematics Teacher, 1970, 63, 579-581.

Kantowski, Eleanore L. Processes involved in mathematical problem solving (Doctoral dissertation, University of Georgia,
J 001 000G 000 100000C 111 Kantowski 1975

1974). Dissertation Abstracts International, Nov., 1975, 36, 2734A. (University Microfilms No. 75-23, 764)

Kantowski, Mary G. Processes involved in mathematical problem solving. Journal for Research in Mathematics Education, May, 1977, 8(3), 163-180.
J 001 000A 000 100000C 011 Kantowski 1977

Keil, Gloria E. Writing and solving original problems as a means of improving verbal arithmetic problem solving ability (Doctoral dissertation, Indiana University, 1964). Dissertation Abstracts, June, 1965, 25, 7109-7110. (University Microfilms No. 65-2376)
I 101 101R 111 100000 010 Keil 1964

Keislar, Evan R., & Stern, Carolyn. Differentiated instruction in problem solving for children of different mental ability levels. Journal of Educational Psychology, December, 1970, 61(6), 445-450.
P 010 000L 000 100000 011 Keislar & Stern1970

Kellar, Wylma R. The relative contribution of certain factors to individual differences in algebraic problem solving ability. Journal of Experimental Education, September, 1939, 8(1), 26-35.
J 000 000AR 000 000000S 010 Kellar 1939

Kellerhouse, Kenneth D., Jr. The effects of two variables on the problem solving abilities of first grade and second grade children (Doctoral dissertation, Indiana University, 1974). Dissertation Abstracts International, March, 1975, 35, 5781A. (University Microfilms No. 75-5564)
P 000 101R 110 100000 010 Kellerhouse 1975

Kellogg, Theodore E. The relative effects of variations in pure and physical approaches to the teaching of Euclidean geometry on pupils' problem solving ability (Doctoral dissertation, University of Minnesota, 1956). Dissertation Abstracts, Dec., 1956, 16, 2404-2405. (University Microfilms No. 56-3820)
S 001 001G 000 100000 110 Kellogg 1956

Kelly, Theresa L. S. An evaluation of textbook and real-life problems in arithmetic (unpublished doctoral dissertation, Fordham University, 1962). Dissertation Abstracts, Vol. 23, May, 1963, pp. 4261-4262.

Kendler, Howard H., & Kendler, Tracy S. Vertical and horizontal processes in problem solving. Psychological Review, January, 1962, 69(1), 1-16.
Review Kendler & Kendl1962

Kennedy, George; Eliot, John; & Krulee, Gilbert. Error patterns in problem solving formulations. Psychology in the Schools, January, 1970, 7(1), 93-99.
S 000 000A 000 000000C 011 Kennedy et al 1970

Keogh, Andrew J. An examination of the effects of research utilizing problem solving training on the verbal interaction of teachers in the classroom (Doctoral dissertation, Washington State University, 1976). Dissertation Abstracts International, Dec., 1976, 37, 3377A. (University Microfilms No. 76-27, 739)
A111 000 000 000110 100 Keogh 1976

Kilpatrick, Jeremy. Analyzing the solution of word problems in mathematics: an exploratory study (Doctoral dissertation, Stanford University, 1967). Dissertation Abstracts International, May, 1968, 28, 4380A. (University Microfilms No. 68-6442)
J 101 000AGR000 100000C 011 Kilpatrick 1968

Klausmeier, Herbert J., & Loughlin, Leo J., Behaviors during problem solving among children of low, average, and high intelligence. Journal of Educational Psychology, June, 1961, 52(3), 148-152.
I 100 000R 000 000000C 011 Klausmeier & Lo1961

Klugman, Samuel F. Cooperative versus individual efficiency in problem-solving. Journal of
I 100 000R 000 001000 011 Klugman 1944

Educational Psychology, February, 1944, 35(2), 91-100.								
Knifong, J. Dan., & Holtan, Boyd. An analysis of children's written solutions to word problems. Journal for Research in Mathematics Education, March, 1976, 7(2), 106-112.	I	000	000R	000	000000S	011	Knifong & Holta	1976
Koopman, Norbert E. Evaluations by superior high school students of their problem solving performances (Doctoral dissertation, University of Wisconsin, 1964). Dissertation Abstracts, Dec., 1964, 25, 3398. (University Microfilms No. 64-13, 899)	JS	100	000R	000	000000C	011	Koopman	1964
Kostick, Max M. A study of transfer: sex differences in the reasoning process. Journal of Educational Psychology, December, 1954, 45(8), 449-458.	Not math						Kostick	1954
Kove, Lila E. Deductive reasoning and problem solving (Doctoral dissertation, University of Connecticut, 1973). Dissertation Abstracts International, Oct., 1973, 34, 1487A. (University Microfilms No. 73-24, 410)	J	001	000L	000	100000	010	Kove	1973
Kratkiewicz, Robert F. The relationship between student variables and achievement in a high school computer science course where problem-solving is done on a terminal connected to a remote time-shared computer (Doctoral dissertation, Wayne State University, 1973). Dissertation Abstracts International, May, 1974, 34, 6946A. (University Microfilms No. 74-11, 119)	S	001	001AGR	000	000000S	110	Kratkiewicz	1974
Krushinski, J. An analysis of linguistic structural variables that contribute to problem solving difficulty. Master's paper, The Pennsylvania State University, March, 1973.							Krushinski	1973
Krutetskii, V. A. The psychology of mathematical abilities in schoolchildren (J. Kilpatrick & I. Wirszup, Eds.; J. Teller, trans.). Chicago: University of Chicago Press, 1976.							Krutetskii	1976
Kulm, Gerald; Lewis, Joan F.; Omari, Issa; & Cook, Harold. The effectiveness of textbook, student-generated, and pictorial versions of presenting mathematical problems in ninth-grade algebra. Journal for Research in Mathematics Education, January, 1974, 5(1), 28-35.	J	000	001A	000	000000S	011	Kulm et al	1974
Lamanna, Joseph B. The effect of teacher verbal behavior on pupil achievement in problem solving in sixth grade mathematics (Doctoral dissertation, St. John's University, 1968). Dissertation Abstracts International, March, 1969, 29, 3042A-3043A. (University Microfilms No. 69-4114)	I	000	000R	000	000110C	010	Lamanna	1969
Laudato, Nicholas C., Jr. The design and development of a computer assisted instructional program in word problem solving for the elementary school (Doctoral dissertation, University of Pittsburgh, 1975). Dissertation Abstracts International, March, 1976, 36, 5777A-5778A. (University Microfilms No. 76-5456)	I	000	001R	000	110000	010	Laudato	1976
Leder, Gilah C. Sex differences in mathematics problem appeal as a function of problem context. Journal of Educational Research, April, 1974, 67(8), 351-353.	S	100	100AG	000	000000	010	Leder	1974
Leder, Gilah. Contextual setting and mathematical performance. The Australian Mathematics Teacher, 1976, 32, 119-127.								
Lee, Kil S. An exploratory study of fourth graders' heuristic problem solving behavior (Doctoral dissertation, University of Georgia, 1977). Dissertation Abstracts International, 1978, 38,	I	000	000R	000	100000C	011	LEE	1978

Reference								
4004A. (University Microfilms No. 77-29, 779)								
Leggette, Earl C. The effect of a structured problem-solving process on the problem-solving ability of capable but poorly prepared college freshmen in mathematics (Doctoral dissertation, Rutgers University, 1973). Dissertation Abstracts International, Jan., 1973, 34, 3838A. (University Microfilms No. 73-32, 223)	A	011	000A	000	100000	110	Leggette	1973
Leno, Richard S. Children's methods of problem solving in arithmetic (Doctoral dissertation, Stanford University, 1958). Dissertation Abstracts, April, 1959, 19, 2549. (University Microfilms No. 59-242)	PI	101	000R	000	100000	010	Leno	1959
Lerch, Harold H., & Hamilton, Helen. A comparison of a structural-equation approach to problem solving with a traditional approach. School Science and Mathematics, March, 1966, 66(3), 241-246.	I	001	010R	000	100000	011	Lerch & Hamilto	1966
Lester, Frank K., Jr. Developmental aspects of human problem solving in a simple mathematical system via computer assisted instruction (Doctoral dissertation, Ohio State University, 1972). Dissertation Abstracts International, Feb., 1973, 33, 4178A. (University Microfilms No. 73-2047)	PIJS	100	000L	000	010000C	011	Lester	1973
Lincoln, Eugene A., Briscoe, Lloyd W., & Williams, Dorothy K. Parents make a difference in teaching in urban schools. Arithmetic Teacher, October, 1975, 22(6), 460-463.	I	001	000R	000	000000C	010	Lincoln et al	1975
Linville, William J. The effects of syntax and vocabulary upon the difficulty of verbal arithmetic problems with fourth grade students (Doctoral dissertation, Indiana University, 1969). Dissertation Abstracts International, April, 1970, 30, 4310A. (University Microfilms No. 70-7957)	I	101	000R	110	000000S	010	Linville	1969
Linville, William J. Syntax, vocabulary, and the verbal arithmetic problem. School Science and Mathematics, February, 1976, 76(2), 152-158.	I	001	000R	110	000000S	010	Linville	1976
Lipson, Stanley H. The effects of teaching heuristics to student teachers in mathematics (Doctoral dissertation, Columbia University, 1972). Dissertation Abstracts International, Nov., 1972, 33, 2221A-2222A. (University Microfilms No. 73-30, 334)	A	001	000ART000		100110	011	Lipson	1972
Loftus, Elizabeth J. F. An analysis of the structural variables that determine problem-solving difficulty on a computer-based teletype (Doctoral dissertation, Stanford University, 1970). Dissertation Abstracts International, May, 1971, 31, 5853A. (University Microfilms No. 71-12, 942)	J	100	000R	111	000000C	010	Loftus	1971
Loftus, Elizabeth F., & Suppes, Patrick. Structural variables that determine problem-solving difficulty in computer-assisted instruction. Journal of Educational Psychology, December, 1972, 63(6), 531-542.	I	100	000R	001	000000C	010	Loftus & Suppes	1972
Logiudice, Joseph F. The relationship of self-esteem, test anxiety and sixth grade students' arithmetical problem solving efficiency under variant test instructions (Doctoral dissertation, St. John's University, 1970). Dissertation Abstracts International, Nov., 1970, 31, 2995B-2996B. (University Microfilms No. 70-23, 263)	I	111	000R	000	000001S	010	Logiudice	1970
Logothetti, David E. Development and implementation of the Poincare-Hadamard conception of mathematical problem solving (Doctoral dissertation, University of California, Los Angeles, 1972). Dissertation Abstracts International, April, 1973, 33, 5475A. (University Microfilms No. 73-	A	000	000A	000	100000	000	Logothetti	1973

10, 45)

Loree, M. Ray. Problem-solving techniques of children in grades four through nine. Cooperative Research Project No. 2608, OE, USDHEW, 1965.

Lueck, William R. An experiment in writing algebraic equations. Journal of Educational Research, October, 1948, 42(2), 132-137.
J 001 010A 000 100000 001 Lueck 1948

Luger, George F. The use of "artificial intelligence" techniques for the study of problem solving behavior (Doctoral dissertation, University of Pennsylvania, 1973). Dissertation Abstracts International, Feb., 1974, 34, 4571A. (University Microfilms No. 74-2430)
A000 010L 000 000000C 011 Luger 1974

Lyda, Wesley J. Direct, practical experiences in mathematics and success in solving realistic verbal "reasoning" problems in arithmetic. Mathematics Teacher, April, 1947, 40(4), 166-167.
J 000 100R 000 C00000S 010 Lyda 1947

Lyda, Wesley J., & Church, Ruby S. Direct, practical arithmetical experiences and success in solving realistic verbal "reasoning" problems in arithmetic. Journal of Educational Research, July-August, 1964, 57(10), 530-533.
I 000 100R 000 000000S 010 Lyda & Church 1964

Lyda, Wesley J., & Duncan, Frances M. Quantitative vocabulary and problem solving. Arithmetic Teacher, April, 1967, 14(4), 289-291.
P 001 000R 010 000000C 010 Lyda & Duncan 1967

Lyda, Wesley J., & Franzen, Carl G. F. A study of grade placement of socially significant arithmetic problems in the high-school curriculum. Journal of Educational Research, December, 1945, 39(4), 292-295.
JS 000 100R 000 000000S 011 Lyda & Franzen 1945

Maier, Norman R. F., & Casselman, Gertrude G. Locating the difficulty in insight problems: individual and sex differences. Psychological Reports, 1970, 26, 103-117.
A000 001ARL000 C00000S 011 Maier & Casselm1970

Malouf, David B. The effect of color-cueing critical words in training EMR children to solve verbal arithmetic problems containing extraneous information (Doctoral dissertation, University of Oregon, 1976). Dissertation Abstracts International, March, 1977, 37, 5746A. (University Microfilms No. 77-4740)
IJ 101 001R 000 C00000 010 Malouf 1977

Mandelbaum, Joseph. A study of the effects, on achievement and attitude, of the use of the computer as a problem solving tool with low performing tenth grade students (Doctoral dissertation, Temple University, 1973). Dissertation Abstracts International, Jan., 1974, 34, 3700A. (University Microfilms No. 74-1809)
S 000 000R 000 010000 110 Mandelbaum 1974

Mangru, Matadial. A comparative study of the nature of verbal arithmetic problems, grades three through six, from four periods: the mid-30's, the mid-50's, the mid-60's, the early 70's (Doctoral dissertation, University of Iowa, 1976). Dissertation Abstracts International, June, 1977, 37, 7533A. (University Microfilms No. 77-13, 107)
S Mangru 1977

Martin, Mavis D. Reading comprehension, abstract verbal reasoning, and computation as factors in arithmetic problem solving (Doctoral dissertation, State University of Iowa, 1963). Dissertation Abstracts, May, 1964, 24, 4547-4548. (University Microfilms No. 64-3395)
IJ 000 000R 110 C00000S 010 Martin 1964

Mattson, Dale E. Three kinds of transfer in problem-solving task. Journal of Educational Psychology, April, 1965, 56(2), 73-80.
A000 000R 000 1000000 011 Mattson 1965

Maxwell, Ann A. An exploratory study of secondary school geometry students: problem solving related to convergent-divergent productivity (Doctoral dissertation, University of Tennessee, 1974). Dissertation Abstracts International, Feb., 1975, 35, 4987A. (University Microfilms No. 75-3626)	S	010	000G	000	000000C	011	Maxwell	1975
Mayer, Marie L. An investigation of the problem solving performance of EMR students with direct and indirect problems using an action sequence presentation of arithmetic verbal problems (Doctoral dissertation, University of Connecticut, 1974). Dissertation Abstracts International, May, 1975, 35, 7158A. (University Microfilms No. 75-10, 647)	JS	100	100R	000	000000S	010	Mayer	1975
Mayer, Richard E. Acquisition and resilience under test stress of structurally different problem solving procedures (Doctoral dissertation, University of Michigan, 1973). Dissertation Abstracts International, Feb., 1974, 34, 4091B-4092B. (University Microfilms No. 74-3688)	A	000	000A	000	100000	010	Mayer	1974
Mayer, Richard E. Acquisition processes and resilience under varying testing conditions for structurally different problem-solving procedures. Journal of Educational Psychology, October, 1974, 66(5), 644-656.	A	000	010A	000	110000	010	Mayer	1974
Meadow, Arnold, Parnes, Sidney J., & Reese, Hayne. Influence of brainstorming instructions and problem sequence on a creative problem solving test. Journal of Applied Psychology, December, 1959, 43(6), 413-416.	A	000	000L	000	110000C	011	Meadow et al	1959
Means, Gladys H., & Loree, M. Ray. The influence on problem-solving ability of following an efficient model. Journal of Educational Research, November, 1968, 62(3), 135-141.	I	000	000R	000	100000	011	Means & Loree	1968
Meconi, L. J. Concept learning and retention in mathematics. Journal of Experimental Education, Fall, 1967, 36(1), 51-57.	J	000	000AR	000	100000	011	Meconi	1967
Meyer, Ruth A. A study of the relationship of mathematical problem solving performance and intellectual abilities of fourth grade children (Doctoral dissertation, University of Wisconsin--Madison, 1975). Dissertation Abstracts International, July, 1976, 37, 123A-124A. (University Microfilms No. 76-8601)	I	000	000R	000	000000S	110	Meyer	1976
Miller, Herbert F. The combination of the guess-and-check and multi-equation methods for deriving the equations for verbal problems in elementary algebra (Doctoral dissertation, Ohio State University, 1959). Dissertation Abstracts, Dec., 1959, 20, 2180. (University Microfilms No. 59-5860)	J	000	010A	000	100000	010	Miller	1959
Milton, G. A. Sex differences in problem solving as a function of role appropriateness of the problem content. Psychological Reports, 1959, 5, 705-708.	A	100	100R	000	000000S	010	Milton	1959
Mitchell, Claude. Problem analysis and problem-solving in arithmetic. Elementary School Journal, February, 1932, 32(6), 464-466.	J	000	000R	000	000000S	010	Mitchell	1932
Monroe, Walter S., & Engelhart, Max D. The effectiveness of systematic instruction in reading verbal problems in arithmetic. Elementary School Journal, January, 1933, 33(5), 377-381.	I	000	000R	110	100000	010	Monroe & Engleh	1933
Morello, Vincent J.; Turner, Ralph R.; & Reed, Nedra E. Problem-solving strategies on a partial reinforcement task: effects of socioeconomic status and cognitive level. Journal of Experimental Child Psychology, 1977, 24, 74-85.	P	000	000L	000	000000S	011	Morello et al	1977
Morris, Lynn L. An information processing examination of skill	I	000	000R	000	000000C	011	Morris	1976

assembly in problem solving and development using Wertheimer's area of a parallelogram problem (Doctoral dissertation, University of Pittsburgh, 1975). Dissertation Abstracts International, June, 1976, 36, 7957A. (University Microfilms No. 76-14, 155)

Murray, John E. An analysis of geometric ability. Journal of Educational Psychology, 1949, 40, 118-124. — S 000 000G 000 00000S 010 Murray 1949

Myers, Garry C. The prevention and correction of errors in arithmetic. Chicago: Plymouth Press, c1925. — IJ T000 100R 000 00000S 010 Myers 1925

Neil, Marilyn S. A study of the performance of third grade children on two types of verbal arithmetic problems (Doctoral dissertation, University of Alabama, 1968). Dissertation Abstracts International, 1969, 29, 3337A. (University Microfilms No. 69-6559) — P 000 001R 000 C0000S 010 NEIL 1969

Neimark, Edith D. Information-gathering in diagnostic problem-solving: a preliminary report. Psychological Record, 1961, 11, 243-248. — Not math Neimark 1961

Neimark, Edith D., & Lewis, Nan. The development of logical problem-solving strategies. Child Development, March, 1967, 38(1), 107-117. — Not math Neimark & Lewis 1967

Nelson, Glenn T. The effects of diagram drawing and translation on pupils' mathematical problem-solving performance (Doctoral dissertation, University of Iowa, 1974). Dissertation Abstracts International, Jan., 1975, 35, 4149A. (University Microfilms No. 75-1234) — I 000 001R 000 100000 011 Nelson 1975

Nesher, Perla. Three determinants of difficulty in verbal arithmetic problems. Educational Studies in Mathematics, December, 1976, 7(4), 369-88. — J 000 000R 111 C0000S 010 Nesher 1976

Newcomb, R. S. Teaching pupils how to solve problems in arithmetic. Elementary School Journal, November, 1922, 23(3), 183-189. — J 000 000R 000 100000 011 Newcomb 1922

Newell, A., & Simon, H. A. Human problem solving. Englewood Cliffs, N.J.: Prentice-Hall, 1972. — Newell & Simon 1972

Newstat, Steven. A study of the relationships between sociocultural variables and geometric problem solving performances of disadvantaged children (Doctoral dissertation, Michigan State University, 1972). Dissertation Abstracts International, May, 1973, 33, 6069A. (University Microfilms No. 73-12, 783) — J 100 000G 000 C00000 110 Newstat 1973

Nickel, Anton P. A multi-experience approach to conceptualization for the purpose of improvement of verbal problem solving in arithmetic (Doctoral dissertation, University of Oregon, 1971). Dissertation Abstracts International, Dec., 1971, 32, 2917A-2918A. (University Microfilms No. 72-960) — I 000 001R 000 100000 010 Nickel 1971

Norman, Philip B. Relationships between problem-solving ability computational skill, intelligence, and amount of training in mathematics (Doctoral dissertation, Columbia University, 1950). Dissertation Abstracts, 1950, 10(4), 156-157. (University Microfilms No. 50-333) — SA000 100R 000 C0000S 010 Norman 1950

O'Flaherty, Helen T. The developmental significance of pictorial representation in problem solving (Doctoral dissertation, Fordham University, 1971). Dissertation Abstracts International, Oct., 1971, 32, 2382B. (University Microfilms No. 71-26, 989) — IJ 100 001R 000 C0000C 010 O'Flaherty 1971

Olion, LaDelle. The effects of selected variables on the arithmetical verbal problem solving performance of educable mentally retarded children (Doctoral dissertation, Univer- — IJ 100 100R 000 C0000S 111 Olion 1974

sity of Connecticut, 1973). Dissertation Abstracts International, March, 1974, 34, 5728A. (University Microfilms No. 74-7130)								
Olson, Gary M.; Miller, Leon K.; Hale, Gordon A.; & Stevenson, Harold W. Long-term correlates of children's learning and problem-solving behavior. Journal of Educational Psychology, August, 1968, 59(4), 227-232.	J	100	000L	000	000000S	010	Olson et al	1968
Pace, Angela. Understanding and the ability to solve problems. Arithmetic Teacher, May, 1961, 8(5), 226-233.	I	000	000R	000	100000	011	Pace	1961
Pack, Elbert C. The effect of mode of computer-operation on learning a computer language and on problem solving efficiency of college bound high school students (Doctoral dissertation, University of California, Los Angeles, 1970). Dissertation Abstracts International, June, 1971, 31, 6477A. (University Microfilms No. 71-16, 348)	S	000	000A	000	010000	110	Pack	1971
Paige, Jeffrey M., & Simon, Herbert A. Cognitive processes in solving algebra word problems. In B. Kleinmuntz (Ed.), Problem Solving: Research, Method, and Theory. New York: Wiley, 1966.							Paige & Simon	1966
Palzere, Donald [illegible]. An analysis of the effects of verbalization and nonverbalization in the learning of mathematics (Doctoral dissertation, University of Connecticut, 1967). Dissertation Abstracts International, Feb., 1968, 28, 3034A-3035A. (University Microfilms No. 68-1388)	S	000	000A	000	000000S	011	Palzere	1968
Papert, Seymour. Teaching children to be mathematicians versus teaching about mathematics. International Journal of Mathematical Education in Science and Technology, July-September, 1972, 3(3), 249-262.	Gen inf						Papert	1972
Parler, Jane B. Reading skills incorporated into mathematical instruction's effect on ability to solve mathematical word problems (Doctoral dissertation, University of South Carolina, 1974). Dissertation Abstracts International, April, 1975, 35, 6579A. (University Microfilms No. 75-8686)	I	100	000R	110	100000	110	Parler	1975
Parnes, Sidney J. Effects of extended effort in creative problem solving. Journal of Educational Psychology, June, 1961, 52(3), 117-122.	A	000	000L	000	000000S	001	Parnes	1961
Parnes, Sidney J., & Meadow, Arnold. Effects of "brainstorming" instructions on creative problem solving by trained and untrained subjects. Journal of Educational Psychology, August, 1959, 50(4), 171-176.	A	000	000L	000	100000	001	Parnes & Meadow	1959
Parnes, Sidney J., & Meadow, Arnold. Evaluation of persistence of effects produced by a creative problem-solving course. Psychological Reports, 1960, 7, 357-361.	A	000	000L	000	100000	011	Parnes & Meadow	1960
Paull, Duane R. The ability to estimate in mathematics (Doctoral dissertation, Columbia University, 1971). Dissertation Abstracts International, Jan., 1972, 32, 3567A. (University Microfilms No. 72-4178)	S	000	000A	000	000000S	011	Paull	1972
Penner, William J. Effect of cue word form class on the solving of arithmetic word problems by the mentally handicapped (Doctoral dissertation, University of Connecticut, 1973). Dissertation Abstracts International, Nov., 1973, 34, 2424A-2425A. (University Microfilms No. 73-26, 581)	I	100	000R	110	000000S	010	Penner	1973
Pennington, Barbara A. Behavioral and conceptual strategies as decision models for solving problems (Doctoral dissertation, University of California, Los Angeles, 1970). Dissertation	I	000	000R	000	100000	010	Pennington	1970

21

Abstracts International, Oct., 1970, 31, 1630A-1631A. (University Microfilms No. 70-19, 879)

Pereira-Mendoza, Lionel. The effect of teaching heuristics on the ability of grade ten students to solve novel mathematical problems (Doctoral dissertation, University of British Columbia, 1975). Dissertation Abstracts International, June, 1976, 36, 8014A. (University Microfilms No. none)
S 100 000AG 000 100000 011 Pereira-Mendoza 1976

Peterson, Margaret J., & Aller, Scuia. Arithmetic problem solving. Journal of Experimental Psychology, November, 1971, 91(1), 93-97.
A000 010AR 000 000000S 010 Peterson & Alle 1971

Petty, Olan. Non-pencil-and-paper solutions of problems. Arithmetic Teacher, December, 1956, 3(6), 229-235.
I 000 000R 000 110000 010 Petty 1956

Portis, Theodore R. An analysis of the performance of fourth, fifth and sixth grade students on problems involving proportions, three levels of aids and three I. Q. levels (Doctoral dissertation, Indiana University, 1972). Dissertation Abstracts International, 1973, 33, 5981A-5982A. (University Microfilms No. 73-10, 858)
I 000 001R 000 000000S 011 PORTIS 1973

Post, Richard. A study of certain factors affecting the understanding of verbal problems in arithmetic (Doctoral dissertation, Columbia University, 1958). Dissertation Abstracts, July, 1958, 19, 90-91. (University Microfilms No. 58-2242)
I 000 100R 001 C00000S 011 Post, R. 1958

Post, Thomas R. The effects of the presentation of a structure of the problem-solving process upon problem-solving ability in seventh grade mathematics (Doctoral dissertation, Indiana University, 1967). Dissertation Abstracts International, May, 1968, 28, 4545A. (University Microfilms No. 68-4746)
J 011 000R 000 100000 010 Post, T. 1967

Post, Thomas R., & Brennan, Michael L. An experimental study of the effectiveness of a formal versus an informal presentation of a general heuristic process on problem solving in tenth-grade geometry. Journal for Research in Mathematics Education, January, 1976, 7(1), 59-64.
S 000 000G 000 100000 010 Post & Brennan 1976

Priest, Robert F., & Hunsaker, Phillip L. Compensating for a female disadvantage in problem solving. Journal of Experimental Research in Personality, 1969, 4, 57-64.
A100 000L 000 000000S 011 Priest & Hunsac 1969

Pyle, W. H. An experimental study of the development of certain aspects of reasoning. Journal of Educational Psychology, October, 1935, 26(7), 539-546.
PIJS 000 000R 000 000000S 010 Pyle 1935

Pylyshyn, Zenon W. Search strategy and problem structure in heuristic problem-solving. Canadian Journal of Psychology, 1963, 17(3), 291-301.
Not math Pylyshyn 1963

Rankin, Joanne S. The development and testing of indigenous word problems for grades four-six in Liberia, West Africa (Doctoral dissertation, University of Michigan, 1977). Dissertation Abstracts International, 1977, 38, 1272A-1273A. (University Microfilms No. 77-18, 101)
I T 100 001R 000 100000 010 RANKIN 1977

Ray, Wilbert S. Complex tasks for use in human problem-solving research. Psychological Bulletin, March, 1955, 52(2), 134-149.
Review of gen prob tasks Ray 1955

Rebhun, Albert M. The reflective-impulsive dimension and mathematical performance in the elementary school (Doctoral dissertation, University of California, Los Angeles, 1973). Dissertation Abstracts International, Dec., 1973, 34, 3039A-
PI 010 000R 000 000000S 110 Rebhun 1973

3040A. (University Microfilms No. 73-28, 970)

Restle, Frank, & Davis, James H. Success and speed of problem solving by individuals and groups. Psychological Review, November, 1962, 69(6), 520-536.
Math model — Restle & Davis 1962

Riban, David M. An investigation of the relationship of Gagne's hierarchical sequence model in mathematics to the learning of high school physics (Doctoral dissertation, Purdue University, 1969). Dissertation Abstracts International, May, 1970, 30, 4845A. (University Microfilms No. 70-8957)
S 000 000A 000 100000 010 Riban 1970

Richardson, Lloyd I., Jr. Student achievement in solving verbal problems as related to teacher preparation (Doctoral dissertation, George Peabody College for Teachers, 1973). Dissertation Abstracts International, Feb., 1974, 34, 3927B. (University Microfilms No. 74-4628)
JST000 000R 000 100010 010 Richardson 1974

Richardson, Lloyd I. The role of strategies for teaching pupils to solve verbal problems. Arithmetic Teacher, May, 1975, 22(5), 414-421.
JST000 000AR 000 100000 011 Richardson 1975

Riedesel, Clark A. Procedures for improving verbal problem-solving ability in arithmetic (Doctoral dissertation, State University of Iowa, 1962). Dissertation Abstracts International, 1963, 23, 2819-2820. (University Microfilms No. 63-958)
I 000 000R 000 100000 011 RIEDESEL 1963

Riley, James D. An investigation of the effects of reading guides and a directed reading method upon word problem comprehension, problem solving ability, and attitude toward mathematics (Doctoral dissertation, Syracuse University, 1976). Dissertation Abstracts International, 1977, 37, 7587A. (University Microfilms No. 77-9897)
J 000 000R 000 100000 010 RILEY 1977

Rimoldi, H. J. A. A technique for the study of problem solving. Educational and Psychological Measurement, 1955, 15, 450-461.
Scoring technique — Rimoldi 1955

Rimoldi, H. J. A.; Aghi, M.; & Burger, G. Some effects of logical structure, language, and age in problem solving in children. Journal of Genetic Psychology, March, 1968, 112(1), 127-143.
PI 000 000L 110 000000S 011 Rimoldi et al 1968

Ripple, Richard E., & Dacey, John. The facilitation of problem solving and verbal creativity by exposure to programmed instruction. Psychology in the Schools, 1967, 4, 240-245.
J 000 000L 000 100000 011 Ripple & Dacey 1967

Robinson, Mary L. An investigation of problem solving behavior and cognitive and affective characteristics of good and poor problem solvers in sixth grade mathematics (Doctoral dissertation, State University of New York at Buffalo, 1973). Dissertation Abstracts International, April, 1973, 33, 5620A. (University Microfilms No. 73-9745)
I 000 000R 000 000000C 111 Robinson 1973

Rogers, Margaret Anne. A different look at word problems. Mathematics Teacher, April, 1975, 68(4), 285-288.
Textbook review — Rogers 1975

Rohr, Judith A. G. The relationship of the ability to conserve on Piagetian tasks to achievement in mathematics (Doctoral dissertation, University of Tennessee, 1973). Dissertation Abstracts International, Nov., 1973, 34, 2398A. (University Microfilms No. 73-27, 743)
P 010 000R 000 000000S 010 Rohr 1973

Rohwer, W. D., & Matz, R. D. Improving aural comprehension in white and in black children. Journal of Experimental Child Psychology, 1975, 19, 23-26.

Rosenthal, Daniel J., & Resnick, Lauren B. Children's solution processes in arithmetic word problems. Journal of Educational Psychology, December, 1974, 66(6), 817-825.	I	000	000R	110	CC0000S	010	Rosenthal & Res	1974
Roth, Bernard. The effects of overt verbalization on problem solving (Doctoral dissertation, New York University, 1965). Dissertation Abstracts International, Sept., 1966, 27, 957B. (University Microfilms No. 65-9321)		000	000	000	000000C	011	Roth	1966
Russell, David H., & Holmes, F. Melville. An experimental comparison of algebraic reading practice and the solving of additional verbal problems in tenth grade algebra. Mathematics Teacher, December, 1941, 34(8), 347-352.	S	000	000A	000	100000	010	Russell & Holme	1941
Safren, Miriam A. Associations, sets, and the solution of word problems. Journal of Experimental Psychology, January, 1962, 64(1), 40-45.	Not math word probs						Safren	1962
Sanders, Violet A. Arithmetic problem solving strategies of fourth grade children (Doctoral dissertation, Wayne State University, 1972). Dissertation Abstracts International, May, 1973, 33, 5983A-5984A. (University Microfilms No. 73-12, 590)	I	101	000R	000	CC0000C	111	Sanders	1973
Scandura, Joseph M. The teaching-learning process: an exploratory investigation of exposition and discovery modes of problem solving instruction (Doctoral dissertation, Syracuse University, 1962). Dissertation Abstracts, Feb., 1963, 23, 2798. (University Microfilms No. 63-2874)	I	000	000R	000	100000	011	Scandura	1963
Scandura, Joseph M. Abstract card tasks for use in problem solving research. Journal of Experimental Education, Winter, 1964, 33(2), 145-148.	Gen inf						Scandura	1964
Scandura, Joseph M. An analysis of exposition and discovery modes of problem solving instruction. Journal of Experimental Education, Winter, 1964, 33(2), 149-159.	I	000	000L	000	100000	011	Scandura	1964
Scandura, Joseph M. Mathematical problem solving. American Mathematical Monthly, March, 1974, 81(3), 273-280.	Gen exptl inf						Scandura	1974
Scandura, Joseph M. Problem solving. New York: Academic Press, 1977.							Scandura	1977
Schall, William E. Comparing mental arithmetic modes of presentation in elementary school mathematics. School Science and Mathematics, May, 1973, 73(5), 359-366.	I	000	000R	000	010000	010	Schall	1973
Schonberger, Ann K. The interrelationship of sex, visual spatial abilities, and mathematical problem solving ability in grade seven (Doctoral dissertation, University of Wisconsin--Madison, 1976). Dissertation Abstracts International, Dec., 1976, 37, 3536A. (University Microfilms No. 76-20, 132)	J	100	001G	000	000000S	010	Schonberger	1976
Schulz, Rudolph W. Problem solving behavior and transfer. Harvard Educational Review, Winter, 1960, 30(1), 61-77.	Review						Schulz	1960
Schwieger, Ruben D. A component analysis of mathematical problem solving (Doctoral dissertation, Purdue University, 1974). Dissertation Abstracts International, Dec., 1974, 35, 3308A-3309A. (University Microfilms No. 74-26, 777)	JSA	000	000AGR	000	000000C	11	Schwieger	1974
Scott, Ralph and Lighthall, Frederick, F. Relationship between content, sex, grade, and degree of disadvantage in arithmetic problem solving. Journal of School Psychology, Fall, 1967, 6(1), 61-67.	I	100	100R	000	CC0000S	010	Scott & Lightha	1967

Sedlak, Robert A. Performance of good and poor problem solvers on arithmetic word problems presented in a modified cloze format. Journal of Educational Research, July/August, 1974, 67(10), 467-471. I 010 000R 110 000000S 010 Sedlak 1974

Sedlak, Robert A. A comparison of good and poor EMH arithmetic problem solvers on modified cloze problems (Doctoral dissertation, Pennsylvania State University, 1973). Dissertation Abstracts International, Dec., 1974, 35, 3557A. (University Microfilms No. 74-28, 934) I 101 000R 100 000000C 11 Sedlak 1974

Segalla, A. Using structural variables to predict word-problem solving difficulty for junior college arithmetic students. Paper presented at the American Educational Research Association Annual Meeting, New Orleans, 1973.

Sekyra, Francis, III. The effects of taped instruction on problem-solving skills of seventh grade children (Doctoral dissertation, University of Alabama, 1968). Dissertation Abstracts International, April, 1969, 29, 3473A-3474A. (University Microfilms No. 69-6569) J 000 000R 000 010000 11 Sekyra 1969

Shann, Mary H. Evaluation of an interdisciplinary, problem solving curriculum in elementary science and mathematics. Science Education, Winter, 1977, 61(4), 491-502. PI 000 000RL 000 100000S 010 Shann 1977

Shaw, J. Reading problems in mathematics texts. Columbus, Ohio, 1967. (ERIC Document Reproduction Service No. ED 016 587)

Sheehan, T. Joseph. Patterns of sex differences in learning mathematical problem-solving. Journal of Experimental Education, Summer, 1968, 36(4), 84-87. J 100 000A 000 100000 010 Sheehan 1968

Sherard, Wade H., III. The effect of arithmetical operations on the difficulty levels of verbal problems (Doctoral dissertation, George Peabody College for Teachers, 1974). Dissertation Abstracts International, Dec., 1974, 35, 2895. (University Microfilms No. 74-29, 189) J 000 000R 111 C00000S 011 Sherard 1974

Sherrill, James M. The effects of differing presentations of mathematical word problems upon the achievement of tenth grade students (Doctoral dissertation, University of Texas at Austin, 1970). Dissertation Abstracts International, Jan., 1971, 31, 3427A. (University Microfilms No. 71-191) S000 001AG 00C 0C0000S 010 Sherrill 1971

Sherrill, James M. The effects of different presentations of mathematical word problems upon the achievement of tenth grade students. School Science and Mathematics, April, 1973, 73(4), 277-282. S 000 001AG 000 CC0000S 010 Sherrill 1973

Shields, Joseph J. The detection and identification of comprehensive problem solving strategies used by selected fourth grade students (Doctoral dissertation, Michigan State University, 1976). Dissertation Abstracts International, Dec., 1976, 37, 3481A-3482A. (University Microfilms No. 76-27, 149) I 000 000R 000 000000C 011 Shields 1976

Shoecraft, Paul J. The effects of provisions for imagery through materials and drawings on translating algebra word problems, grades seven and nine (Doctoral dissertation, University of Michigan, 1971). Dissertation Abstracts International, Jan., 1972, 32, 3874A-3875A. (University Microfilms No. 72-4976) J 000 001AR 000 100000 110 Shoecraft 1972

Silver, E. A. Student perceptions of relatedness among mathematical word problems (Doctoral dissertation,

25

Teachers College, Columbia University, 1977).							
Smith, Charlotte E. C. The structure of intellect protocol analysis system: a technique for the investigation and quantification of problem solving processes (Doctoral dissertation, University of Houston, 1971). Dissertation Abstracts International, Feb., 1972, 32, 4255A. (University Microfilms No. 72-7745)	A100	000A	000	000000C	011	Smith, C.	1972
Smith, Dan F. A study of the relationship of teacher sex to fifth grade boys' sex role preference, general self concept, and scholastic achievement in science and mathematics (Doctoral dissertation, University of Miami, 1970). Dissertation Abstracts International, March, 1971, 31, 4563A. (University Microfilms No. 71-4312)	I T110	000R	000	000000S	110	Smith, D.	1971
Smith, Frank. The readability of sixth grade word problems. School Science and Mathematics, June, 1971, 71(6), 559-562.	Textbook analysis					Smith	1971
Smith, James P. The effect of general versus specific heuristics in mathematical problem-solving tasks (Doctoral dissertation, Columbia University, 1973). Dissertation Abstracts International, Nov., 1973, 34, 2400A. (University Microfilms No. 73-26, 637)	A000	000AGL000		100000	011	Smith, J.	1973
Snethen, Charles C. Peer support in the teaching of verbal problem solving in arithmetic (Doctoral dissertation, University of Missouri--Columbia, 1975). Dissertation Abstracts International, Oct., 1976, 37, 1980A. (University Microfilms No. 76-21, 977)	PI 000	000R	000	001000	010	Snethen	1976
Sparks, Billie E. Pupil achievement in solving verbal problems in mathematics as related to teacher preparation and experience (Doctoral dissertation, George Peabody College for Teachers, 1976). Dissertation Abstracts International, 1977, 37, 5058A. (University Microfilms No. 77-3119)	I T 000	000R	000	100010	010	SPARKS	1977
Spencer, P., & Russell, D. Reading in arithmetic. National Council of Teachers of Mathematics Yearbook, 1960, 25, 202-223.							
Spitzer, Herbert F., & Flournoy, Francis. Developing facility in solving verbal problems. Arithmetic Teacher, November, 1956, 3(7), 177-182.	Textbook analysis, examples of ps					Spitzer & Flour	1956
Stanionis, Victor A. An examination of the relationship between the ability of students to solve applied problems in mathematics and certain characteristics of the students, their teachers, and schools (Doctoral dissertation, Columbia University, 1975). Dissertation Abstracts International, May, 1975, 36, 2512A-2513A. (University Microfilms No. 75-25, 725)	S000	000AGT000		000000S	110	Stanionis	1975
Stern, Carolyn. Acquisition of problem-solving strategies in young children and its relation to verbalization. Journal of Educational Psychology, August, 1967, 58(4), 245-252.	P 000	000L	000	100000	010	Stern	1967
Stern, Carolyn, & Keislar, Evan R. Acquisition of problem-solving strategies by young children, and its relation to mental age. American Educational Research Journal, January, 1967, 4(1), 1-12.	P 000	000L	000	100000	010	Stern & Keislar	1967
Stevens, B. A. Problem solving in arithmetic. Journal of Educational Research, April/May, 1932, 25(4/5), 253-260.	IJ 000	000R	000	000000S	010	Stevens	1932
Stevenson, P. R. Increasing the ability to solve arithmetic problems. Educational Research Bulletin, October, 1924, 3, 267-270.	I 000	000R	000	100000	011	Stevenson	1924
Stilwell, Merle E. The development and analysis of a category	ST000	000G	000	000110S	011	Stilwell	1968

system for systematic observation of teacher-pupil interaction during geometry problem-solving activity (Doctoral dissertation, Cornell University, 1967). Dissertation Abstracts International, Feb., 1968, 28, 3083A. (University Microfilms No. 68-893)

Stright, Isaac L. The relation of reading comprehension and efficient methods of study to skill in solving algebraic problems. Mathematics Teacher, December, 1938, 31(8), 368-372.
J 000 000A 000 100000 010 Stright 1938

Stuart, Alvin J. Effects upon pupil performance in arithmetic of instructional programs differing in amounts of emphasis upon computational structure and verbal problem solving (Doctoral dissertation, Ohio University, 1965). Dissertation Abstracts International, June, 1967, 27, 4058A. (University Microfilms No. 66-4335)
I 000 000R 000 100000 010 Stuart 1967

Stull, Lorren L. Auditory assistance of reading as a factor in intermediate-grade pupils' interpretation of verbal arithmetic problems (Doctoral dissertation, Pennsylvania State University, 1964). Dissertation Abstracts, June, 1965, 25, 7113. (University Microfilms No. 65-4424)
I 000 001R 100 010000 010 Stull 1965

Sumagaysay, Lourdes S. The effects of varying practice exercises and relating methods of solution in mathematics problem solving (Doctoral dissertation, University of Toronto, 1970). Dissertation Abstracts International, June, 1972, 32, 6751A. (Microfilm National Library of Canada at Ottawa)
000 100R 000 100000 010 Sumagaysay 1970

Suppes, P., Hyman, L., & Jerman, M. Linear models for response and latency performance in arithmetic. Technical Report No. 100, Psychology Series. Stanford, California: Institute for Mathematical Studies in the Social Sciences, Stanford University, 1966.

Suppes, P., Jerman, M., & Brian, D. Computer-Assisted Instruction: The 1965-66 Stanford Arithmetic Program. New York: Academic Press, 1968.

Suppes, Patrick, Loftus, Elizabeth & Jerman, Max. Problem-solving on a computer-based teletype. Educational Studies in Mathematics, 1969, 2(1), 1-15.
I 000 000R 111 000000S 011 Suppes et al 1969

Swart, William L. A comparative study of the effects of high- and low-structure approaches to developing problem-solving ability in fourth grade children (Doctoral dissertation, University of Michigan, 1969). Dissertation Abstracts International, Aug., 1970, 31, 669A. (University Microfilms No. 70-14, 451)
I 000 010RG 000 100000 010 Swart 1970

Talton, Carolyn F. An investigation of selected mental, mathematical, reading, and personality assessments as predictors of high achievers in sixth grade mathematical verbal problem solving (Doctoral dissertation, Northwestern State University of Louisiana, 1973). Dissertation Abstracts International, Sept., 1973, 34, 1008A-1009A. (University Microfilms No. 73-21, 255)
I 000 000R 000 000000S 011 Talton 1973

Taschow, H. G. Reading improvement in mathematics. Reading Improvement, 1969, 6, 63-67.

Tate, Merle W., & Stanier, Barbara. Errors in judgment of good and poor problem solvers. Journal of Experimental Education, Summer, 1964, 32(4), 371-376.
J 000 000R 000 000000S 011 Tate & Stanier 1964

Thibodeau, Gerard P. Manipulation of numerical presentation in verbal problems and its effect on verbal problem among EMH children. Education and Training of the
I 001R 000 100000 010 Thibodeau 1974

27

Mentally Retarded, 1974, 9, 9-14.

Thompson, Elton N. Readability and accessory remarks: factors in problem solving in arithmetic (Doctoral dissertation, Stanford University, 1967). Dissertation Abstracts International, Jan., 1968, 28, 2464A-2465A. (University Microfilms No. 67-17, 547)
I 000 000R 110 000000S 010 Thompson 1968

Travers, Kenneth J. D. Forced-choice preference for problem-solving situations in mathematics (Doctoral dissertation, University of Illinois, 1965). Dissertation Abstracts, June, 1966, 26, 7161-7162. (University Microfilms No. 66-4310)
J 000 100R 000 000000S 110 Travers 1966

Travers, Kenneth J. A test of pupil preference for problem-solving situations in junior high school mathematics. Journal of Experimental Education, Summer, 1967, 35(4), 9-18.
J 010 100R 000 000000S 011 Travers 1967

Treacy, John P. The relationship of reading skills to the ability to solve arithmetic problems. Journal of Educational Research, October, 1944, 38(2), 86-96.
J 000 000R 000 000000S 010 Treacy 1944

Treffinger, Donald J. The effects of programmed instruction in productive thinking on verbal creativity and problem solving among pupils in grades four, five, six, and seven (Doctoral dissertation, Cornell University, 1969). Dissertation Abstracts International, Sept., 1969, 30, 1031A. (University Microfilms No. 69-10, 473)
IJ 000 000R 000 100000 011 Treffinger 1969

Tucker, Benny F. A correlation study of three primary skills which contribute to arithmetic problem-solving ability among fourth-grade students (Doctoral dissertation, University of Illinois at Urbana-Champaign, 1975). Dissertation Abstracts International, Nov., 1975, 36, 2620A. (University Microfilms No. 75-24, 416)
I 000 000R 000 000000S 010 Tucker 1975

Tupesis, Janis A. Mathematical learning as a consequence of the learner's involvement in interactive problem-solving tasks (Doctoral dissertation, University of Wisconsin, 1972). Dissertation Abstracts International, July, 1973, 34, 126A-127A. (University Microfilms No. 73-9295)
S000 000G 000 100000 010 Tupesis 1973

Underwood, Jacqueline M. An exploratory study of the problem-solving procedures used by selected college freshmen on certain basic consumer mathematics problems (Doctoral dissertation, University of Tennessee, 1976). Dissertation Abstracts International, Feb., 1977, 37, 4909A-4910A. (University Microfilms No. 77-3694)
A000 000R 000 C00000S 011 Underwood 1977

Van Wie, Joseph L. The development and appraisal of a unit on problem solving for engineering technology students (Doctoral dissertation, University of Northern Colorado, 1976). Dissertation Abstracts International, Jan., 1977, 37, 4196A. (University Microfilms No. 76-29, 789)
A000 000A 000 100000C 011 Van Wie 1977

Vander Linde, Louis F. Does the study of quantitative vocabulary improve problem-solving? Elementary School Journal, December, 1964, 65(3), 143-152.
I 000 000R 000 100000 010 Vander Linde 1964

Velez-Serra, Damian. Effects of extraneous information on the solving of arithmetic word problems by the Spanish-speaking mentally handicapped (Doctoral dissertation, University of Connecticut, 1975). Dissertation Abstracts International, Aug., 1975, 36, 822A. (University Microfilms No. 75-16, 525)
J 100 000R 110 C00000S 010 Velez-Serra 1975

Vernon, Magdalen D. The value of pictoral illustration, British Journal of Educational Psychology, Vol. 23, 1953, p. 180-187.

Vitello, Stanley J. The effect of three variables on the solution of verbal problems requiring quantitative class inclusions among educable mentally retarded children (Doctoral dissertation, University of Connecticut, 1972). Dissertation Abstracts International, Dec., 1972, 33, 2795A. (University Microfilms No. 72-32, 194)	I 100	101R	000	000000S	010	Vitello	1972
Vos, Kenneth E. A comparison study of the effects of three instructional strategies on problem solving behaviors (Doctoral dissertation, University of Minnesota, 1973). Dissertation Abstracts International, Nov., 1973, 34, 2283A. (University Microfilms No. 73-25, 688)	S 000	000AR	000	100000	011	Vos	1973
Vos, Kenneth E. The effects of three instructional strategies on problem-solving behaviors in secondary school mathematics. Journal for Research in Mathematics Education, November, 1976, 7(5), 264-275.	S 000	000AR	000	100000	011	Vos	1976
Walek, Bruce P. A study of the relationship between conceptual tempo and problem-solving abilities of fourth-grade children (Doctoral dissertation, University of Florida, 1972). Dissertation Abstracts International, July, 1973, 34, 215A-216A. (University Microfilms No. 73-15, 550)	I 011	000R	000	000000S	011	Walek	1973
Washburne, Carleton W. Comparison of two methods of teaching pupils to apply the mechanics of arithmetic to the solution of problems. Elementary School Journal, June, 1927, 27(10), 758-767.	PI 000	000R	000	100000	011	Washburne	1927
Washburne, Carleton W., & Morphett, Mabel V. Unfamiliar situations as a difficulty in solving arithmetic problems. Journal of Educational Research, October, 1928, 18(3), 220-224.	I 000	100R	000	000000S	010	Washburne & Mor	1928
Washburne, Carleton W., & Osborne, Raymond. Solving arithmetic problems I. Elementary School Journal, November, 1926, 27(3), 219-226.	PIJ 000	000R	000	100000	011	Washburne & Osb	1926
Washburne, Carleton W., & Osborne, Raymond. Solving arithmetic problems II. Elementary School Journal, December, 1926, 27(4), 296-304.	PIJ 000	000R	000	100000	011	Washburne & Osb	1926
Wearne, Diana C. Development of a test of mathematical problem solving which yields a comprehension, application, and problem solving score (Doctoral dissertation, University of Wisconsin, 1976). Dissertation Abstracts International, April, 1977, 37, 6328A-6329A. (University Microfilms No. 76-29, 945)	Test					Wearne	1977
Webb, Leland F., & Sherrill, James M. The effects of differing presentations of mathematical word problems upon the achievement of preservice elementary teachers. School Science and Mathematics, November, 1974, 74(7), 559-565.	A000	001G	000	000000S	010	Webb & Sherrill	1974
Webb, Norman L. An exploration of mathematical problem-solving processes (Doctoral dissertation, Stanford University, 1975). Dissertation Abstracts International, Nov., 1975, 36, 2689A-2690A. (University Microfilms No. 75-25, 625)	S 110	000A	000	000000C	011	Webb	1975
Weir, Morton W. Developmental changes in problem-solving strategies. Psychological Review, November, 1964, 71(6), 473-490.	PIJSA000	000L	000	000000S	011	Weir	1964
Welch, Ronald C. The relative merits of two types of arithmetic problems. Unpublished master's thesis, University of Iowa, 1950.							
Welker, Latney C., Jr. A study of interrelationships in arithmetical problem solving (Doctoral dissertation, University of Southern Mississippi, 1962). Dissertation Abstracts,	J 000	010R	000	000000S	010	Welker	1963

92

April, 1963, 23, 3750-3751. (University Microfilms No. 63-1780)

Westmoreland, John S. First grade entrants' arithmetic problem-solving behavior as influenced by language variation and sex (Doctoral dissertation, Indiana University, 1974). Dissertation Abstracts International, March, 1975, 35, 5796A. (University Microfilms No. 75-5562) — P 110 000R 010 000000S 010 Westmoreland 1975

Wheat, Harry G. The relative merits of conventional and imaginative types of problems in arithmetic. Contributions to Education, No. 359. New York: Teachers College, 1929. — IJ 010 100R 000 C00000S 010 Wheat 1929

Wheatley, Grayson H., Frankland, Robert L., Mitchell, R., & Kraft, Rosemarie. Hemispheric specialization and cognitive development: implications for mathematics education. Journal for Research in Mathematics Education, 1978, 9, 20-32.

Whitaker, Donald R. A study of the relationships between selected noncognitive factors and the problem solving performance of fourth grade children (Doctoral dissertation, University of Wisconsin, 1976). Dissertation Abstracts International, April, 1977, 37, 6329A. (University Microfilms No. 76-29, 947) — I T000 000R 000 010000 110 Whitaker 1977

White, Helen M. Does experience in the situation involved affect the solving of a problem? Education, April, 1934, 54(8), 451-455. — I 000 100R 000 000000S 11 White 1934

Whitlock, Prentice E. An investigation of selected factors that affect ability to solve verbal mathematical problems at the primary level (Doctoral dissertation, Fordham University, 1974). Dissertation Abstracts International, Sept., 1974, 35, 1437A. (University Microfilms No. 74-19, 713) — P 000 100R 001 000000S 010 Whitlock 1974

Williams, Ann W. Teaching mathematical verbal problems to "middle ability" sixth grade readers with an inquiry method (Doctoral dissertation, Pennsylvania State University, 1972). Dissertation Abstracts International, Sept., 1973, 34, 1144A. (University Microfilms No. 73-21, 281) — I T000 000R 000 100110 010 Williams 1973

Wills, Herbert, III. Transfer of problem solving ability gained through learning by discovery (Doctoral dissertation, University of Illinois, 1967). Dissertation Abstracts International, Oct., 1967, 28, 1319A-1320A. (University Microfilms No. 67-11, 937) — S 000 000A 000 100000 010 Wills 1967

Wilson, Estaline. Improving the ability to read arithmetic problems. Elementary School Journal, January, 1922, 22(5), 380-386. — Review Wilson 1922

Wilson, James W. Generality of heuristics as an instructional variable (Doctoral dissertation, Stanford University, 1967). Dissertation Abstracts International, Jan., 1968, 28, 2575A. (University Microfilms No. 67-17, 526) — S 000 000A 000 100000 011 Wilson, James 1968

Wilson, John W. The role of structure in verbal problem solving in arithmetic: an analytical and experimental comparison of three problem-solving programs (Doctoral dissertation, Syracuse University, 1964). Dissertation Abstracts International, May, 1965, 25, 6442-6443. (University Microfilms No. 65-3445) — I 000 000R 000 100000 011 Wilson, John 1965

Wilson, John W. The role of structure in verbal problem solving. Arithmetic Teacher, October, 1967, 14(6), 486-497. — I 000 000R 000 100000 011 Wilson 1967

Wittrock, M. C. Replacement and nonreplacement strategies in children's problem solving. Journal of Educational — P 000 000L 000 100000 010 Wittrock 1967

Psychology, April, 1967, 58(2), 69-74.

Woody, Clifford. Some investigations resulting from the testing program in arithmetic: an investigation to determine the influence of specialized drill in reading upon the solution of verbal problems. Indiana University School of Education Bulletin, April, 1930, 6(4), 30-39. IJ 000 000R 000 100000 010 Woody 1930

Wright, Jone P. A study of children's performance on verbally stated problems containing word clues and omitting them (Doctoral dissertation, University of Alabama, 1968). Dissertation Abstracts International, November, 1968, 29, 1770B. (University Microfilms No. 68-15,518) I 010 000R 010 000000S 011 Wright 1968

Young, Robert V., & McIsaac, John S. The sequence of processes affects the pupil's interpretation of verbal problems in arithmetic. Education, April, 1941, 61(8), 488-491. Review Young & McIsaac 1941

Zalewski, Donald L. An exploratory study to compare two performance measures: an interview-coding scheme of mathematical problem solving and a written test (Doctoral dissertation, University of Wisconsin, 1974). Dissertation Abstracts International, March, 1975, 35, 5797A-5798A. (University Microfilms No. 74-27, 771) J 000 000R 000 000000C 011 Zalewski 1975

APPENDIX D

NATIONAL SCIENCE FOUNDATION Washington, D.C. 20550	FINAL PROJECT REPORT NSF FORM 98A	

PLEASE READ INSTRUCTIONS ON REVERSE BEFORE COMPLETING

PART I—PROJECT IDENTIFICATION INFORMATION

1. Institution and Address	2. NSF Program	3. NSF Award Number
Northern Illinois University DeKalb, IL 60115	RISE	SED 77-19157
	4. Award Period From 9/1/77 To 10/31/79	5. Cumulative Award Amount $35,000

6. Project Title

A Review of Research on Solving Routine Problems in Pre-College Mathematics

PART II—SUMMARY OF COMPLETED PROJECT *(FOR PUBLIC USE)*

This project reviewed the research on routine problem solving (e.g., the typical "story" problem) with an aim toward (a) identifying and disseminating promising practices for teaching routine problem solving and (b) suggesting directions for further research in the area.

Practices which might improve the teaching of routine problem solving include these:

1. Give attention to <u>processes</u> involved in solving routine problems (e.g., write an equation, make a chart).
2. Devote time to developing the meaning of mathematical vocabulary and symbols.
3. Teach that reading of a mathematical problem is different from reading less technical prose, and requires multiple readings with attention to vocabulary and relationships among variables.
4. Have the learners make up, and solve, their own word problems.

Areas in which further research and development seem warranted include these:

5. Instrumentation is needed for process-analysis studies, both for protocol coding and process measurement.
6. Studies that examine the role of language variables (both syntactic and semantic) in the "decoding" phase of solving a routine problem should contribute to our knowledge of teaching problem solving.
7. Whether different ways of presenting problems--objects, pictures, words--help children of different ages and mental characteristics needs examination.

PART III—TECHNICAL INFORMATION *(FOR PROGRAM MANAGEMENT USES)*

1. ITEM *(Check appropriate blocks)*	NONE	ATTACHED	PREVIOUSLY FURNISHED	TO BE FURNISHED SEPARATELY TO PROGRAM: Check (✓)	Approx. Date
a. Abstracts of Theses	X				
b. Publication Citations		X			
c. Data on Scientific Collaborators		X (App. D)			
d. Information on Inventions	X				
e. Technical Description of Project and Results		X			
f. Other *(specify)*					

2. Principal Investigator/Project Director Name *(Typed)*	3. Principal Investigator/Project Director Signature	4. Date
Larry Sowder	Larry Sowder	Dec 14, 1979

NSF Form 98A (5-78) Supersedes All Previous Editions — Form Approved OMB No. [illegible]

Appendix D

Project Collaborators

Co-investigators

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Larry K. Sowder, Associate Professor, Northern Illinois University, DeKalb, Illinois

Kenneth E. Vos, Associate Professor, College of St. Catherine, St. Paul, Minnesota

Consultant

Edward A. Silver, Assistant Professor, San Diego State University, San Diego, California

ERIC Accession Number Ranges

(By Year)

Resources in Education (RIE)

PRE-1966	ED	001 001	-	003 960
1966	ED	010 000	-	010 093
1967	ED	010 094	-	012 348
1968	ED	012 349	-	021 151
1969	ED	021 152	-	031 604
1970	ED	031 605	-	042 060
1971	ED	042 061	-	054 390
1972	ED	054 391	-	066 620
1973	ED	066 621	-	080 787
1974	ED	080 788	-	095 253
1975	ED	095 254	-	110 594
1976	ED	110 595	-	127 413
1977	ED	127 414	-	142 684
1978	ED	142 685	-	157 987
1979	ED	157 988	-	174 743
1980	ED	174 744	-	

Current Index to Journals in Education (CIJE)

1969	EJ	000 001	-	011 707
1970	EJ	011 708	-	027 599
1971	EJ	027 600	-	045 271
1972	EJ	045 272	-	062 751
1973	EJ	062 752	-	082 164
1974	EJ	082 165	-	101 872
1975	EJ	101 873	-	121 926
1976	EJ	121 927	-	142 252
1977	EJ	142 253	-	163 351
1978	EJ	163 352	-	186 217
1979	EJ	186 218	-	207 484
1980	EJ	207 485	-	