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## An Investigation of Two Methods for Improving Problem Solving Performance of Fifth Grade Students

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AN INVESTIGATION OF TWO METHODS FOR IMPROVING PROBLEM  
SOLVING PERFORMANCE OF FIFTH GRADE STUDENTS

by  
Leah Melnik

A Dissertation Submitted to the Faculty of the Graduate School  
of Loyola University of Chicago in Partial Fulfillment of Requirements  
for the Degree of Doctor of Philosophy

January

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## VITA

The author, Leah Melnik, is the daughter of David Melnik and Zelda (Golden) Melnik. She was born on April 4, 1939.

Her elementary and secondary education was obtained in the White Plains, New York public school system.

In September, 1957, she entered the Pennsylvania State University, University Park, Pennsylvania. In January, 1961, she received the degree of Bachelor of Science with a major in Elementary Education. In January, 1961, she enrolled at Teachers College, Columbia University, New York City, and in August, 1964, was awarded the Master of Arts degree, with a major in Language Arts.

Since September, 1961, she has been involved in the teaching profession. She taught in the Rye Neck and Byram Hills School Districts in Westchester County, New York, prior to moving to Chicago in 1970. From 1970 to 1982, the author was a teacher of elementary grades for the Chicago Board of Education.

During the 1982-83 school year, she was awarded a sabbatical leave, during which she held a Graduate Assistantship in the Department of Curriculum and Instruction at Loyola University of Chicago. The author is currently the coordinator and teacher of a remedial mathematics computer laboratory for the Chicago Board of Education.

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## CHAPTER ONE

### NATURE OF THE PROBLEM

#### Introduction

Identification of successful problem solving strategies has long concerned psychologists and learning theorists. Recent technological advances have provided opportunities for computer scientists to study simulations of human problem solving in order to better understand the stages involved in the problem solving process. Strategies utilized by successful problem solvers have been identified which caused development of new curriculum designed to maximize the effects of these strategies within subject areas and in content-free problem solving courses. Microcomputer software programs as well as computer languages such as LOGO have been specifically designed or adapted to reinforce use of identified problem solving strategies.

Despite advances in research and practice, the American educational system is repeatedly indicted for its failure to teach critical thinking and problem solving with lower achievement results cited as support for the criticism. The primary rationale for current demands for problem solving skill development may be viewed as follows:

The most significant change in the curriculum of the next ten or twenty years will be to place great emphasis on realistic, non-routine problem solving. Most recently, the National Council of Teachers of Mathematics (1980) issued recommendations regarding the teaching of problem solving. A key feature of those recommendations is that the curriculum be organized around problem

solving with instruction in a broad range of strategies and processes. The movement toward the use of problem solving strategies and processes is not confined to any one discipline. In any discipline, the intellectual needs of our time, in light of our technological capabilities, mean developing problem solving skills.<sup>1</sup>

While problem solving strategies have been described and included in current elementary level mathematics textbooks, the role of direct instruction in improving mathematics problem solving achievement test performance is not evident. The current emphasis on problem solving skill development provides the rationale for this investigation of instructional methods designed specifically to reinforce problem solving skills of elementary level students, both with and without implementation of a specific problem solving strategy model.

#### Significance of Study

The purpose of this investigation is to determine whether or not directed practice and reinforcement in methods of problem solving can facilitate positive achievement results in math word problem solving performance. This study was designed to focus on five specific objectives:

1. Improvement of math word problem solving performance through specific teacher directed worksheet practice.
2. Evaluation of the effectiveness of content-free problem solving software as an instructional tool.
3. Evidence of transfer from treatment method to math problem solving performance.
4. Development of a general problem solving strategy model which can be effectively implemented with elementary level students.

5. Evaluative data concerning the potential role of microcomputers in improving student problem solving performance.

#### Problem Solving

Attention to higher level cognitive skill development is essential if students are to develop into lifelong learners and adequate problem solvers. Higher order cognitive skills are defined as: skills that involve reasoning and application in a functional context, as contrasted with skills and subskills reflecting mostly memorization and rote learning.<sup>2</sup>

The need for developing higher level thinking skills has been well documented in recent reports which have indicted the American educational system for its continued focus on minimum competency, lower level skill training. Schools are being charged with failure to adequately prepare students for tackling the job of solving the myriad problems of life in an increasingly complex society.

The release of the report of the National Commission on Excellence in Education, A Nation at Risk, has focused on the lack of attention to higher level skills, expressing concern that students will lack the ability to use previously learned information in new, more challenging situations. The emphasis placed on these problem solving skills is evident:

Some worry that schools may emphasize such rudiments as reading and computation at the expense of other essential skills such as comprehension, analysis, solving problems and drawing conclusions.<sup>3</sup>

Glaser has stated that although evidence indicates improvement in teaching of basics, this has not been accompanied by attention to thinking and mindfulness.<sup>4</sup> Individuals must acquire not only

knowledge, but the ability to think and reason.<sup>5</sup> Houtz and Denmark, in citing finds from several national study groups, including the Commission on Excellence, the Carnegie Report (Boyer, 1983), the report of the Twentieth Century Fund Task Force (Making the Grade, 1983) and the Task Force on Education for Economic Growth (1983) suggest that there is evidence not only of lower achievement results, but, more importantly, of lack of attention to teaching of creative thinking and problem solving.<sup>6</sup> Results from the National Assessment of Educational Progress (NAEP) have indicated that while performance in basic skills has improved, students show uniformly poor performance at the application or problem solving level.<sup>7</sup> The Education Commission of the States (1982) indicates that in the four learning areas tested by NAEP, reading, writing, mathematics and science, results indicate that students may have acquired very few skills for examining ideas. Many are capable of preliminary interpretations but few are taught to move on to extended comprehensive and evaluative skills.<sup>8</sup>

In a 1977 position paper on basic mathematics skills, the National Council of Supervisors of Mathematics claimed problem solving to be the number one basic skill, while the National Council of Teachers of Mathematics in Agenda for Action (1980) suggested that problem solving be the focus of the curriculum for the 1980's.<sup>9</sup>

According to Charles and Lester:

research in that elusive area of mathematical activity, "problem solving", has become increasingly popular in recent years. Unfortunately, despite the attention, very little is known about how to teach students to be better problem solvers.<sup>10</sup>

While problem solving instruction has most often been approached through instruction in mathematics, the growing interest in the quality of education provided by the public schools has led to numerous programs specifically designed to improve students' thinking skills through direct instruction in problem solving strategies. The theoretical support pillar for many current programs appears to be the model initially developed for mathematical problem solving by George Polya. The 1945 model developed by Polya has served as a foundation upon which theorists have developed mathematical and general problem solving curricula. In How to Solve It, Polya defines four steps in problem solving. His four steps include:

1. Understanding the problem
2. Devising a plan for solving the problem
3. Carrying out the plan
4. Looking back or evaluating the solution<sup>11</sup>

Initial interest in the present investigation of problem solving was strengthened by evidence of the generalizability of Polya's model to curriculum areas other than math. Programs of content-free problem solving strategy training, using this model as a guide, have been developed from the elementary through university and adult training levels. Support for the use of Polya's model as a theoretical base for this investigation, as well as an historical perspective of problem solving theory, will be discussed in the next chapter.

### Strategy Training

Much of the current work on problem solving today explores the various methods, or strategies, used by expert problem solvers, and



how these strategies differ from the methods or strategies employed by novices. The Mathematics Problem Solving program (MPS) compared the problem solving performance of students who received direct instruction in problem solving strategies with that of students whose only exposure to problem solving was provided by the regular textbook.<sup>12</sup> Suydam suggests that children be taught a variety of strategies that they can apply in different problem solving situations, plus an overall plan for how to go about problem solving.<sup>13</sup> Dytman and Wang have used the LOGO authoring language as a tool to examine the nature of children's problem solving processes. Efforts to improve instruction aimed at developing problem solving expertise have been aided by descriptive information on: 1. strategies children use to solve problems, and 2. the relationship between strategy use and solution paths. Such data increase the understanding of how to improve instruction aimed at developing problem solving expertise.<sup>14</sup>

### Transfer

Strategy training models have been developed in problem solving, with modest gains in students' abilities to learn, remember, and solve problems. However, because no lasting increases in performance have been found, it is suggested that thinking skills must be developed gradually as by-products of practice and expertise.<sup>15</sup> Gagne, in discussing the learnable aspects of problem solving, cites the importance placed on the role of cognitive strategies in problem solving, while questioning whether general strategies can be directly taught, or must result from problem solving experience and reflective thought.<sup>16</sup>

The area of transfer, or generalizability, is a key issue in problem solving research and a major focus of the present investigation. Sternberg contends that transfer is the major issue to be addressed in any problem solving or thinking skill development program, and he raises the issue of whether training should be designed as a separate course, or as a topic infused within a specific curriculum area.<sup>17</sup> Current literature poses the dilemma between an instructional emphasis on general domain-independent or domain-specific skill development. A central question concerning transfer of acquired knowledge and skill to other domains remains an unresolved issue.<sup>18</sup>

#### Microcomputer-Assisted Problem Solving

The microcomputer is rapidly finding its way into the elementary schools, in learning centers, specifically designed laboratory configurations, and individual classrooms. Although there has been a rapid proliferation of research assessing its role in education, cognitive effects of microcomputers, including potential for improving problem solving skills, are only beginning to be systematically investigated. Much of this research has focused on the cognitive effects of learning a programming language, including prerequisite skills observed in successful programmers. Questions concerning cognitive prerequisites for programming as well as children's use of strategies have been addressed through studies of children's learning of BASIC (Beginner's All-Purpose Symbolic Instructional Code) and LOGO, a highly interactive authoring language.

Use of the computer as a teaching tool has generated great

interest in the quality, quantity and type of available educational software. Drill and practice, tutorial, and simulation programs have been utilized for several years. Problem solving issues are more recently being addressed through commercially prepared software programs which fit all subject areas, while not being subject specific. Increasingly proficient programming technology has produced well designed, colorful, highly interactive programs, in which increasingly complex problem solving tasks are being incorporated. In these programs, students must use problem solving strategies to find solutions to puzzles, mazes, and other problem situations.

Research involving use of software to effect positive growth in problem solving performance can proceed only as quickly as appropriate material is developed. For example, Sunburst Communications has developed several highly interactive programs which appear to reflect cognitive skill strategies inherent to the process of problem solving. In their documentation, Sunburst advocates an integrated approach to problem solving, one in which certain skills are introduced by the teacher and reinforced through use of the computer programs. Problem solving strategies attended to in the Sunburst materials appear to correlate strongly with those considered effective in more traditional approaches to problem solving. The question of whether or not computerized problem solving programs can be effective in improving problem solving performance has not yet been answered, although it is currently being addressed in several studies, including school-based research in Rochester, Minnesota and Hinsdale, Illinois.

### Limitations of Study

1. Lack of randomization for assignment to treatment groups.
2. Lack of control over home use of computers.
3. Limited range of content area for evidence of transfer. Math was chosen as experimental treatment subject because of ease of generalizability of this subject to all potential sixth grade experimental subjects.

### Assumptions

1. Teachers followed intervention instructions consistently and accurately.
2. All children in the computer group are normally distributed.
3. Children in the non-computerized group are not informed that other students in the study are using computers.

### Summary

The purpose of this investigation is to determine the effectiveness of teacher directed problem solving worksheet practice (WORDS) and problem solving computer software programs (COMPS). A strategy model at the elementary level has been built into the experimental design to evaluate its effect on problem solving performance. Society has deemed problem solving to be a major educational concern, and demands for a more effective instructional delivery system have created new questions concerning the role of microcomputers in problem solving skill development. As new products are designed, cognitive psychologists and curriculum specialists, in cooperation with computer software companies, universities, and school systems, are beginning the evaluative phase of determining the

effectiveness of current software. The potential use of content-free problem solving software as vehicles for introducing and reinforcing problem solving strategies must be explored.

### Research Questions

In the present study, the following research questions will be addressed:

1. Will problem solving worksheet practice (WORDS) facilitate higher performance on a math problem solving achievement test?
2. Will problem solving software (COMPS) practice facilitate higher performance on a math problem solving achievement test?
3. Will introduction of a problem solving strategy model facilitate higher performance on a math problem solving achievement test?
4. Will introduction of a strategy model facilitate a change in student attitude toward self in terms of solving problems.

## CHAPTER I FOOTNOTES

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- <sup>5</sup>Ibid., p. 103.
- <sup>6</sup>John C. Houtz and Robert M. Denmark, "Student Perceptions of Cognitive Classroom Structure and Development of Creative Thinking and Problem Solving Skills," Educational Research Quarterly 8 (1983) p. 20.
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- <sup>8</sup>Larry Picus, Thomas Sachser, and Ronald Smith, Teaching Problem Solving: A Research Synthesis. Portland Oregon:Northwest Regional Educational Laboratory. ERIC Document Reproduction Service, ED 238 875, (June, 1983), p. 2.
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- <sup>10</sup>Randall Charles and Frank Lester, "An Evaluation of a Process-Oriented Instructional Program in Mathematics Problem Solving in Grades 5 and 7," Journal for Research in Mathematics Education 15 (1984):15.
- <sup>11</sup>George Polya, How to Solve It, (Garden City, New York: Doubleday Anchor, 1957), p. 128.
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<sup>14</sup>Joan Dytman and Margaret Wang, "Elementary School Children's Accuracy and Strategy Use in Problem Solving," paper presented at the annual meeting of the American Educational Research Association, New Orleans, April, 1984, p. 2.

<sup>15</sup>Sharon Derry, "Strategy Training: An Incidental Learning Model for CAI," paper presented at the annual meeting of the American Educational Research Association, New Orleans, April, 1984, p. 2.

<sup>16</sup>Robert Gagne, "Learning Aspects of Problem Solving," Educational Psychologist 15 (1980):90.

<sup>17</sup>Robert Sternberg, "Training Intellectual Skills," taped presentation for ASCD National Curriculum Institute, titled Developing and Evaluating Thinking Skills Programs, (October 20-21, 1983.

<sup>18</sup>Robert Glaser, "Education and Thinking: The Role of Knowledge," American Psychologist 39 (February 1984):102.

## CHAPTER TWO

### REVIEW OF THE LITERATURE

#### Introduction

The present research study investigates the relationship of 1) treatment method, 2) strategy model, and 3) microcomputer software to the development of improved problem solving skills. The development of a strategy model was the result of examination of various theoretical models, culminating in a synthesis based on comparable theoretical components. The four phase model suggested by Polya served as a conceptual framework upon which other theories of problem solving were examined.

Review of current mathematics textbooks revealed instructional models which suggested stages in sequential instruction paralleling the problem solving phases described by Polya. This four phase model, which is adaptable to widely varied instructional levels, consists of understanding, planning, executing, and checking of the problem. The role of the teacher is to design various questions which facilitate student exploration, through a variety of strategy techniques, toward a correct solution path. It is the use of problem solving strategies, rather than an algorithmic set of defined rules, which is the focus of Polya's theory.

Current regeneration of interest in fostering problem solving skills has led to inquiry regarding the role of the microcomputer in



this endeavor. Software designed to reinforce problem solving strategies has been developed as a result of this interest, with the individualized, interactive nature of this content free software serving as justification for its consideration as an instructional tool.

### Problem Solving Theory

Early work on problem solving distinguished, on the basis of specific skills, differences between good and poor problem solvers. Bloom and Broder determined that the study of individual problem solving processes, rather than the observed product, would reveal distinct variations in problem solving behavior characteristics.

Variations were categorized under the major headings:

1. Understanding the nature of the problem
2. Understanding of the ideas contained in the problem
3. General approach to the solution of problems
4. Attitude toward the solution of problems.<sup>19</sup>

It was determined that good problem solvers were able to extract key ideas from the problem, reorganizing, simplifying, or breaking it into subproblems. Poor problem solvers proceeded with no apparent plan, attacking the problem as a whole, reading the directions, problem statement and alternatives repeatedly, exhibiting difficulty in deciding how to determine the relevant information or misinterpreting the problems, through incomplete, superficial reading of directions. Successful problem solvers were careful and systematic in their method of attack on the problem.<sup>20</sup>

Defining the term "problem" is a starting point in understanding

the complexity of the actual problem solving process. Mayer presents the view that a problem consists of certain characteristics, including givens, goals, and obstacles, and that any definition of "problem" should include the following three ideas:

1. the problem is present in some state, but
2. it is desired that it be in another state, and
3. there is no direct, obvious way to accomplish the change.<sup>21</sup>

Problem solving, as defined by Mayer, is the process or series of mental operations used in moving from the present situation to the desired goal.<sup>22</sup>

Wickelgren clarifies a distinction between formal problems, which include all mathematical problems of a "to find" or "to prove" character through a description of those problems which are not considered formal due to an inability to restrict thinking to a specified set of givens, operations, or goals.<sup>23</sup> This concept of "problem" is described in a discussion distinguishing between these and formal problems:

Problems such as what you should eat for breakfast, whether you should marry x or y, whether you should drop out of school, or how can you get yourself to spend more time studying are not formal problems. These problems are virtually impossible at the present time to turn into formal problems because we have no good ways of restricting our thinking to a specified set of given information and operations (courses of action we might take), or do we often even know how to specify precisely what our goals are in solving these problems.<sup>24</sup>

### Summary of Models

Through descriptions of observed problem solving approaches, theorists have established descriptive criteria for a general

framework of stages, from which the process of problem solving may be viewed. Numerous systems for describing the processes, steps, or stages in problem solving have been suggested.

In 1909, Dewey postulated five steps in the problem solving process:

1. A felt difficulty
2. Its location and definition
3. Suggestion of possible solution
4. Development by reasoning of the bearings of the suggestion
5. Further observation and experiment leading to its acceptance or rejection, that is, the conclusion of belief or disbelief.<sup>25</sup>

Dewey believed that an educated mind could estimate the potential value of time spent on each process. He argued that a student, in developing sensitivity to solving problems through constant inquiry within the classroom, would gain the ability to deal with problems, to develop and verify hypotheses, and eventually to develop his own style of thought. Dewey distinguished reflective thought from other operations included in the definition of thought by citing the stages of searching, hunting, inquiring to find material to resolve the doubt, and settle and dispose of the perplexity.<sup>26</sup> Dewey, therefore, attributes the origin of thinking to perplexity, confusion, or doubt.<sup>27</sup>

When a situation arises containing a difficulty or perplexity, the person who finds himself in it may take one of a number of courses. He may dodge it, dropping the activity that brought it about, turning to something else. He may indulge in a flight of fancy, imagining himself powerful or wealthy, or in some other way in possession of the means that would enable him to deal with the difficulty. Or, finally, he may face the situation. In this case, he begins to reflect.<sup>28</sup>

Dewey's five phases of reflective thought appear to be the model from which subsequent problem solving models were derived.

Merwin suggests that the sophisticated skills of problem solving will not be developed without opportunity for students to engage in thinking at higher levels. The ability to use questioning, as a critical phase of the problem solving process is developed and emphasized as a component of the following model from which Merwin suggests a simplified view based on the work of Dewey. Merwin describes the procedures for problem solving as:

1. Defining the problem
2. Developing an Hypothesis
3. Testing the Hypothesis
4. Deriving a Conclusion
5. Formulating a Generalization.<sup>29</sup>

Merwin developed three models, the first derived from the work of Dewey and two others based on the work of Taba and Bloom, respectively. While each model suggests a definite sequence of steps for problem solving, Merwin argues for a flexible approach, one which incorporates components of various models. Merwin's recommendation is that students be taught more than one model with teachers providing questions and experiences appropriate for learners at different stages of development. It appears that Merwin has developed sequential models as his interpretation of various theoretical viewpoints, but that his own view of the problem solving process is best reflected in the model based on the work of Dewey.

Beyer describes the problem solving process as one containing

five major steps:

1. identifying and clarifying a problem
2. hypothesizing solutions to the problem
3. testing the various alternative solutions
4. choosing the "best" solution
5. applying the solution.<sup>31</sup>

A distinction is made between what Beyer describes as broad thinking processes, those integral to the problem solving process, and more discrete, microthinking operations inventoried by Bloom. Beyer does not view Bloom's taxonomy as inclusive stages in the problem solving process, but rather operations employed in the more complex problem solving process.

A simplified version, identified and described by Mason as problem solving stages from the perspective of the student:

1. getting started
2. getting involved
3. mulling
4. keep going
5. insight
6. checking
7. looking back.<sup>32</sup>

This model, as described above, was implemented in the Lane County Mathematics Project, which will be discussed in a later section of this chapter.

The model developed by Feldhusen, Houtz and Ringebach is included in this discussion as an example of a more detailed description of

stages. The synthesis developed for this investigation included components of this model, which further reflects the four phase model of stages developed by Polya.

1. sensing that a problem exists
2. defining the problem
3. clarifying the goal
4. asking questions
5. guessing causes
6. judging if more information is needed
7. noticing relevant details
8. using familiar objects in unfamiliar ways
9. seeking implications
10. solving single-solution problems
11. solving multiple-solution problems
12. verifying solutions<sup>33</sup>

Hayes' approach to problem solving describes a characteristic sequence of actions performed by the problem solver as follows:

1. finding the problem
2. representing the problem
3. planning the solution
4. carrying out the plan
5. evaluating the solution
6. consolidating gains<sup>34</sup>

Hayes directs attention toward improving the problem solving performance of adult learners by converting problem solving stages to directed actions, designed through complex questioning strategies, to guide the learner toward solution processes. While reflecting other theorists, Hayes appears to have taken as further step by incorporating directed strategy instruction in his model.

It appears that theorists as early as Dewey and as contemporary as Hayes have subscribed to a description of problem solving stages which are similar to those proposed by Polya. Justification for the focus on Polya's four-step model in the present investigation may be found by it being widely cited in current literature. Picus, in a 1983 research synthesis, stated that "Polya's four steps appear to be the most generally applicable and most frequently used in defining the major processes involved in problem solving."<sup>35</sup> The 1980 NCTM Yearbook, Problem Solving in School Mathematics placed such high value on Polya's model that full page reproductions are prominently displayed on both the front and back inside covers. The following editor's note, prefacing the lead article in the Yearbook, "On Solving Mathematical Problems in High School" by Polya, expresses the continuing importance placed on Polya's work:

EDITOR'S NOTE: This lead article by Polya, although originally presented in the November 1948 issue of the California Mathematics Council Bulletin (vol. 7, no. 2), offers some thoughts about problem solving that are as current today as they must have been avant-garde then. It should be read by all teachers of mathematics, not just those who are teaching high school mathematics. 36

Any model of problem solving stages, in the form of a general blueprint, provides the framework upon which the problem solving

curriculum may be built. This framework may be developed in the form of heuristics or generalized suggestions of strategies for problem solving.

### Heuristic

Polya supports his recommendations for teaching of general problem solving methods by encouraging the modern interpretation of heuristic. Through explicit attention to heuristics, or process, Polya has delineated a checklist of questions that do not generate correct answers but, rather, elicit general strategies toward possible solutions.

Polya's definitions for "heuristics", "heuristic reasoning", and "modern heuristics" are presented here as an introduction to the focus on heuristics in current studies of problem solving.

Heuristic: the name of a certain branch of study, not very clearly circumscribed, belonging to logic, or to philosophy, or to psychology, often outlined, seldom presented in detail, and as good as forgotten today. The aim of heuristic is to study the methods and rules of discovery and invention.<sup>37</sup>

Heuristic reasoning: reasoning not regarded as final and strict, but as provisional and plausible only, whose purpose is to discover the solution of the present problem.<sup>38</sup>

Modern heuristic: endeavors to understand the process of solving problems, especially the mental operations typically useful in this process.<sup>39</sup>

Heuristics are described by Mayer as one of three related pieces of information used in problem solving. The three are listed as:

1. facts: which are immediately available to the subject
2. algorithms: sets of rules that automatically generate the correct answers
3. heuristics: rules of thumb or general plans of action.<sup>40</sup>



Cyert has expressed concern that current research has not provided any theorems or laws related to heuristics which are easily applicable to curriculum development by educators. His lament concludes that any results to date have been drawn in the form of heuristics, which he views as unrelated to the specific content area, with no general theory to guide the student as to the order in which these heuristics relate to particular problems.<sup>41</sup>

Krulik and Rudnick present a set of heuristics useful for students at various levels.<sup>42</sup> Their model incorporates the problem solving stages along with suggestions to follow at each step.

1. Read

- a. Note key words.
- b. Get to know the problem setting.
- c. What is being asked for?
- d. Restate the problem in your own words.

2. Explore

- a. Draw diagram, or construct a model.
- b. Make a chart. Record the data.
- c. Look for patterns.

3. Select a strategy.

- a. Experiment.
- b. Look for a simpler problem.
- c. Conjecture/guess.
- d. Form a tentative hypothesis.
- e. Assume a solution.

4. Solve.

5. Review and Extend.

- a. Verify your answer.
- b. Look for interesting variations on original problem.

Krulik and Rudnick view heuristics as a set of suggestions, which can be used as guidelines for problem solution.<sup>43</sup> Heuristics can give students and teachers a starting point from which to view the problem solving process. It appears that a strategy model, derived by Polya, is a current and viable model for problem solving skill development.

#### Mathematical Word Problem Solving

Improved thinking and improved problem solving skills are projected as desired outcomes of instruction for the 1980's. Because these goals are not being achieved satisfactorily by our schools, attention to the specific area of math word problem solving affords a focal point for addressing the wider issue of general problem solving strategies.

Word problems, as presented in traditional textbooks, are frequently grouped by mathematical operation. The word problem is utilized as a vehicle for reinforcing the specific operation, rather than as a skill in itself to be developed. Students may attempt solutions by extracting numerical data, performing an operation, and accepting a solution without reasoning or evidence of use of the problem solving process. Textbook word problems frequently require much reading that frequently interferes with both process and solution efforts. Verbal comprehension deficiencies encountered in the first phase of understanding the problem may discourage student from further efforts to engage in problem solving.

The amount of unequivocal knowledge we have about mathematical problem solving instruction is small by comparison with its importance (Begle, 1979; Lester, 1978, 1980). This seems to be particularly true of problem solving instruction at the elementary and middle school grades. Indeed, although problem

importance (Begle, 1979; Lester, 1978, 1980). This seems to be particularly true of problem solving instruction at the elementary and middle school grades. Indeed, although problem solving instruction has been a popular area of inquiry in recent years, relatively little of this research has focused on Grades 1-8.<sup>44</sup>

Hutcherson, in a 1975 replication of a study initiated by Lenore John in 1927, concluded that there had been no significant change in the pattern of errors in solving routine two-step word problems over the 48 year interval between the two studies.<sup>45</sup> Implications from the Third National Mathematics Assessment revealed that non-routine problem solving performance had changed little from the Second Assessment, and that more effort and time is needed to effect substantial change in the problem solving ability of school age children.<sup>46</sup> The challenge of improving math problem solving performance has not been met.

The strength of Polya's model lies in its applicability to the solution of a wide variety of problem types. At the elementary level it should be applied to strengthening students' abilities at solving non-routine problems usually found not only in mathematics but in puzzle books. These type problems are too often regarded as merely extra credit, enrichment, or brain teaser material.<sup>47</sup> A critical prerequisite for teaching problem solving, in order to maintain students' interest, should lie in creating or selecting the problems for students to solve, with problems which have variety and relevance to the learner. Prerequisite skill development in solution techniques should be introduced as a component of formal problem solving instruction. Polya's model presents a vehicle for an effective skill development instructional system, applicable throughout the elementary grades.

Suydam and Weaver report research principles concerning difficulty levels of word problems. These findings are pertinent to the discussion of problem selection:

1. Problems which are (or can be) represented visually are easier to solve.

2. The inclusion of irrelevant data makes problems more difficult.

3. Problems requiring multiple, small steps are easier than single step problems, where the step is large and undifferentiated.

4. Problem difficulty increases with the readability level of the passage.<sup>48</sup>

Charles and Lester report on a process oriented problem solving program, Mathematics Problem Solving (MPS), a research and development project conducted through the West Virginia Department of Education under Title IV-C. This program compared problem solving performance of students in the program to that of students whose only exposure to problem solving was that provided by the math textbook.<sup>49</sup>

Two types of problems were selected for inclusion in West Virginia study:

1. Translation, simple one step, or complex, multiple step were chosen. Computational skills needed to find solutions had been taught at least two months prior to intervention.

2. Process problems, those which cannot be solved by simple translation to number sentences exemplified need for practice in understanding problems, in developing and carrying out solution strategies, and in evaluating solutions.<sup>50</sup>

This program also provided a problem solving strategy guide, which focused on the following:

1. each phase of Polya's four phase model
2. extensive experience with process problems
3. development of students' abilities to select and use a variety of strategies
4. incorporation of a specific teaching strategy for problem solving.<sup>51</sup>

The problem solving guide used as part of the teaching strategy consists of the following components:<sup>52</sup>

#### PROBLEM SOLVING

1. UNDERSTANDING THE PROBLEM
  - a. Read the problem again.
  - b. Write what you know.
  - c. Look for key phrases.
  - d. Find the important information.
  - e. Tell it in your own words.
  - f. Tell what you are trying to find.
2. SOLVING THE PROBLEM
  - a. TRY THIS
    - Look for a pattern
    - Guess and check
    - Write an equation
    - Use reasoning
  - b. WOULD THIS HELP?
    - Draw a picture
    - Make a list or table
    - Use objects and act out a problem
    - Simplify the problem
    - Work backwards
3. ANSWERING THE PROBLEM
  - a. Have you used all the important information?
  - b. Have you checked your work?
  - c. Have you decided if the answer makes sense?
  - d. Have you written the answer in a complete sentence?

Conclusions of this study included the following:

1. The program did promote improvement of students' problem solving performance for two types of problems, translation and process, but proved more effective with process than complex translation problems. Significance of this appears to lie in the fact that the additional practice did not improve students' abilities to obtain correct results on translation problems. However, two measures of problem solving performance, understanding and planning, appeared to be improved.

2. Students appeared more willing to engage in problem solving and gained confidence in their ability to succeed in the problem solving process.

Findings of this study concluded that while MPS did not greatly improve students' abilities to obtain correct results on complex translation problems, the ability to understand problems and to plan solution strategies did improve.

Donahue compared the problem solving behavior of second and fourth grade children in strategies exhibited as routine (simple) and non-routine (translation and complex) problems were solved. Demonstration of effective strategies engaged in by the students, but not taught in the elementary school, led to the conclusion that formal presentation of problem solving techniques could be effectively introduced as early as the second grade level.<sup>53</sup>

In a study of students in grades 7, 9, and 11, processes involved in solving non-routine mathematics problems were evaluated in terms of demonstrated competence in Polya's four phases. Singh determined that

7th grade subjects with no formal instruction in problem solving strategies demonstrated use of the following skills: guess, check and refine, diagramming, listing, working backwards, and looking for similar problems and patterns. More emphasis must be placed upon Polya's concluding phase, Looking Back, which, according to Singh, would markedly improve the students' ability to obtain the correct solution.<sup>54</sup> Further implications of Singh's study include the following recommendations, which were implemented in the design of the present investigation:

1. Exploration of problem solving skill development, with and without direct emphasis on teaching problem solving skills.
2. A study in which similar type problems are not put together in one problem set, but rather in random order.
3. A study conducted with average ability students at a lower level.<sup>55</sup>

Evidence of the presence of strategy use, as reported by Singh, Donahue and Brewer has implication for problem solving instructional design. In observing strategy use by children who have not received formal instruction in use of specific strategies, evidence has been documented that effective strategies are in use. It therefore behooves curricula planners to consider implementation of strategy instruction within the mathematics curriculum.

Changes in problem solving behavior of 32 average fifth grade students receiving instruction in mathematics word problems, based on Polya's model, were evaluated in a study by Brewer,<sup>56</sup> who employed an

an interview and pre-post test design with a control group. These students were randomly selected and given instruction on an individual basis. A difference in the interview situation was indicated, while scores on the written evaluation were significantly higher than those of the control group on only one criterion, Devising a Plan.

Recommendations for further study include:

1. replication with a larger number of students.
2. an intervention of longer than a six week time period.<sup>57</sup>

Discussion of heuristics and their applicability to mathematics problem solving instruction at the elementary grades are tied together in studies such as conducted by Charles and Lester, and in evidence provided through studies discussed in this chapter. The methods for providing instruction in strategy use as well as questions concerning the value of specific training in strategy use must be addressed.

### Strategy Training

Issues of direct instruction in problem solving strategies have been addressed by educators and cognitive scientists who appear in agreement concerning the desirability of such instruction. Thus far neither demonstrably better problem solvers nor data to support claims for generalizable skill performance have been produced.<sup>58</sup> Cognitive strategy, or capabilities that may control such processes as attention, perceived encoding, and retrieval of learned materials<sup>59</sup> are a major component of human capability involved in problem solving. Gagne describes executive strategies as governing strategies which include the ability to shift from one strategy to another, to consider several in rapid succession, and to abandon one in favor of another,



enabling problem solvers to weigh and choose the best strategies for a particular task.<sup>60</sup>

There are limited research reports concerning classroom implementation of strategy instruction. Owing to the limited number of studies, and to the lack of identified variables relating to unsuccessful implementation, problems which need to be addressed are themselves not clearly defined.<sup>61</sup> In urging classroom based cognitive strategy research, Peterson and Swing raise several questions in the belief that they will only be solved by research in an actual classroom situation. Among issues addressed, the following are particularly relevant to the concerns of this investigation:

1. Following cognitive strategy training, can strategy use be maintained and generalized to other similar tasks?
2. What cognitive strategies should be taught, and to whom?
3. How should cognitive strategy instruction be implemented in the classroom?
4. What individual differences in students need to be considered for cognitive strategy instruction to be implemented effectively?<sup>62</sup>

Peterson and Swing also suggest that a fruitful area for future research would be to investigate the feasibility and effectiveness of training teachers to implement strategy instruction.<sup>63</sup>

Recommendations of curriculum specialists, according to NAEP findings, are that students be taught problem solving techniques at the same time as they are mastering the basic skills.<sup>64</sup> This issue relates strongly to questions of transfer, which is discussed at greater length at a later point in this chapter.

### Microcomputer Research

Recent investigations concern the nature of children's problem solving processes within a variety of contexts. Microcomputer based research has provided insight into strategies applied by subjects learning a programming language. Dytman and Wang addressed the use of strategies and their relationship to problem solving accuracy through an analysis of steps taken by children, ages 7-12, while performing spatial construction tasks. The tasks involved construction of geometric figures on a monitor using the LOGO computer program. LOGO competence had been established as a prerequisite for participating subjects, with the focus of the investigation being an assessment of strategy use. LOGO served as the vehicle for the study. The investigation supported the theory that children, even at the earliest stages of schooling, have developed individualized strategic approaches to problem solving. Descriptions of two characteristic problem solving process patterns, visual approximation and analytic strategies, were identified. Those students who used the analytic strategy obtained a significant higher solution accuracy than those using the visual strategy approach. The visual strategy approach included:

1. larger number of steps to reach a solution
2. small sized steps
3. few planned behaviors

The analytic strategy, which led to more successful problem solutions, consisted of:

1. smaller number of steps to solution

2. larger sized steps

3. more planning behavior<sup>65</sup>

The lack of planning behavior attributed to subjects using the visual strategy corresponds to the findings of Bloom and Broder, wherein poor problem solvers proceeded with no apparent plan.

Webb, in another investigation designed to examine problem solving processes, focused on planning strategies used by students learning BASIC, specifically designating a hierarchy of strategies, from operational, least abstract, through intermediate, procedural planning, to the highest, most abstract design planning level.<sup>66</sup> Hierarchical planning, as described by Hayes-Roth, involves preplanning, while opportunistic planning, also referred to as planning-in-action by Pea and Kurland is done concurrent with the activity.<sup>67</sup> Students who engaged in opportunistic planning rarely engaged in abstract, higher level, design planning or coherent, integrated plans for the entire program were not developed.<sup>68</sup>

Dytman and Wang have determined, through observing elementary students engaged in LOGO tasks, that various strategies are applied in the way children approach tasks and how they move from the initial problem statement to the goal. It is contended that instructional intervention can be effective in developing problem solving expertise when strategy use is delineated. Findings of Webb, and of Dytman and Wang, concerning the lack of planning behavior attributed to subjects determined to be less successful problem solvers, correspond to the attributes described by Bloom and Broder, wherein poor problem solvers proceeded with no apparent plan. The implication to be derived is

that, in any investigation of problem solving strategy instruction, the role of planning, the second phase of Polya's model, appears to be significant.

#### Microcomputer Software Research

A three year program, funded through Title IV-C, entitled "Computer Assisted Problem Solving Practice" (CAPS) was initiated in 1981 in the Rochester, Minnesota School District #535. The primary need addressed by this program was:

To provide elementary school students with more frequent and more appropriate opportunities to practice the skills and strategies involved in problem solving in order to improve their concepts of themselves as problem solvers and to increase actual problem solving abilities.<sup>69</sup>

First year focus on acquisition and analysis of a conceptual and philosophical definition of problem solving produced a problem solving skill matrix which delineated strategies applied in the problem solving process. The focus for the following two years was on design development and testing of microcomputer software and classroom activities. The major focus in classroom activities was to develop instruction programs which correlated with the initial strand of the problem solving program, which was improving of memory. Software was developed mainly at the primary level.

The CAPS program supported the belief that providing many problem solving opportunities for students was the most important thing teachers could do and that in order to obtain greater efficiency and proficiency in problem solving, students must be allowed to find and use the proper strategy.<sup>70</sup> This view is supported by Brown:



Thinking and problem solving skills improve through instruction and practice. To learn to solve problems more effectively, students need opportunities to practice solving problems.<sup>71</sup>

Teacher directed activities and computer software designed for this phase stressed the memory and cognitive skills categories of the problem solving matrix, using computer programs designed in cooperation with Sunburst Communications. Software programs which specifically address the cognitive control strategy category of the matrix are being designed by Sunburst, and several are already in use in elementary classrooms. Two of the cognitive strategy programs, which will be implemented in the present investigation, are entitled: The Factory, and Code Quest.

A 1982 report, Microcomputer Use in Hinsdale District #181<sup>72</sup> recommended a systematic study of the effectiveness of computers in enhancing specific curriculum related skills. The area chosen for study was problem solving in math with skills in coordinate geometry evaluated through study of the effects of a software package, Bumble Games. This one week pilot project, which produced insignificant results due to its short length, led to recommendations for further study. This recommendation culminated in a 1984 investigation, which is described in a report by Bosma, entitled "The Effects of the Computer on Problem Solving".<sup>73</sup> This study, which was conducted in Hinsdale, Illinois District #181, in cooperation with The Institute for Educational Research, evaluated the effects of the computer on problem solving.

Two hundred (200) 5th grade students used selected problem

solving software in order to determine whether or not visual-spatial skills stressed in the computer activities would transfer to more general problem solving and reasoning skills. For the purpose of the Hinsdale study, problem solving was defined as skill in manipulating figures in 2-dimensional space. Instruments used in the evaluation design included: The New Jersey Test of Reasoning Skills, a 50 item paper and pencil test of elementary reasoning and inquiry skills, which focused on part-whole reasoning, discerning causal relationships and syllogistic reasoning, and the analogies subtest of the Test of Cognitive Skills, which focused on sequences, analogies, memory and verbal reasoning. A lack of a significant effect for the computer group led to the conclusion that there was little empirical evidence available for the claim that computers enhance problem solving skills.

Significance of the Bosma study appears to lie in questions raised concerning the appropriateness of the tests and teaching methods utilized. The testing instruments addressed general reasoning skills, while the software was designed to reinforce specific strategies. Bosma has stated that the major role of the teacher is to show students how to make the connections between strategies devised to solve a specific problem and more generalized problem solving and reasoning skills.<sup>74</sup> The focus recommended by Bosma has not been addressed in any follow up study, although the final report indicates planning for future studies.

### Transfer

A major issue in designing learning experiences for students concerns the degree and type of transfer of knowledge expected from

these learning experiences to tasks in subsequent courses and to other situations. Evidence of transfer has been a central goal of educational researchers. This issue is especially appropriate in the area of problem solving since all curriculum areas present problems which students are required to solve.

Research suggests that skills taught in isolation from subject matter are not likely to transfer easily to other situations where they can be used productively. Research suggests that skills taught in isolation from one another are not likely to become functional.<sup>75</sup>

Can basic, broadly transferable knowledge and skills be taught and learned, or is there limited human capability for transfer of knowledge and skill from specific situations to analogical but not identical situations? This central curriculum design question, as posed by Simon<sup>76</sup> exemplifies the domain specific vs. content-free dilemma discussed by Glaser, Sternberg and Greeno, and is evidenced by numerous current programs designed to address problem solving skill acquisition.

Programs designed to teach specific problem solving skills include the process oriented program designed by Whimbey and Lochhead, which subscribes to the premise that poor problem solving is the result of errors in planning, in failure to use relevant facts appropriately, and in lack of evaluative checking. While course descriptions address a high school and college age population, it appears that techniques proposed by Whimbey and Lochhead have possible applications at the middle school level.

In discussing recent curriculum programs designed to encourage

problem solving and thinking skills, Glaser has delineated four categories:

1. process-oriented
2. programs using familiar knowledge
3. problem solving heuristics
4. logical thinking in context of basic skill acquisition.<sup>78</sup>

Acknowledging the emphasis placed on the teaching of general processes, Glaser cautions that such programs, in using relatively knowledge-free problems, offer limited insight into learning and thinking requiring domain specific knowledge.<sup>79</sup> He further stresses the issue of transferability of acquired knowledge and skill, raising the question of human capability in transferring such general skills.

This dilemma is further exacerbated by the lower cognitive entry level of elementary students. Evaluations of problem solving programs at higher educational levels may proceed with a comparison of knowledge specific and content-free program outcome due to the knowledge specific requirements of courses at higher educational levels. Direct instruction in problem solving strategies at the elementary level may be considered secondary to instruction in basic skill acquisition. Although problem solving performance is considered a basic goal of education, acquisition of specific skill to enhance this performance continues to be viewed as a component of mathematics instruction, and not as a specific skill to be taught.

Evidence of positive transfer from instruction and practice in strategy games to problem solving ability is provided in a study by Fluck.<sup>80</sup> One hundred seventy one fifth grade students served as the



experimental and control groups in a study to test the effects of playing and analyzing computational strategy games. A pre and posttest form of the Krulik Problem Solving Test determined a significant gain in problem solving performance after a five week intervention, therefore supporting the belief that problem solving practice does make a difference.

### Summary

In the present investigation the strategy model is viewed as an essential component of the design. A number of models appropriate for investigating problem solving were examined, with the synthesis in Figure 1 developed for specific implementation at the elementary level. Review of the literature confirmed strategy use at the level of interest, while also revealing a paucity of classroom-based research at this level.

Current interest in the impact and potential of microcomputer implementation at the elementary and middle school levels provides justification for a study designed to evaluate problem solving skill development, a major concern of this investigation. It has not been determined whether general problem solving strategies, either through specific skill training, computer software programs, or a combination of both, can be utilized to improve problem solving performance.

## CHAPTER II FOOTNOTES

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<sup>24</sup>Ibid., p. 2.

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<sup>27</sup>Ibid., p. 15.

<sup>28</sup>Ibid., p. 102.

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<sup>30</sup>Ibid., p. 128.

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## CHAPTER THREE

### DESIGN AND METHODOLOGY

#### Hypotheses

The following null hypotheses will be tested:

There are no significant differences in performance among the treatment method groups on the achievement scale.

There are no significant differences in performance between the experimental (STRAT) group and the control (NOSTRAT) group on the achievement scale.

There are no significant differences in performance among the treatment method groups on the attitude scale.

There are no significant differences in performance between the experimental (STRAT) group and the control (NOSTRAT) group on the attitude scale.

#### Subjects

One hundred forty-four (144) fifth grade students, from six (6) fifth grade classrooms, served as subjects in this experiment. Lacking preexperimental sampling equivalence, the six classrooms (four experimental and two control), selected for inclusion in this study, constitute a nonequivalent control group design. The self-contained classroom configuration necessitates this quasi-experimental design, set up as a compromise before-after experimental-control group design. Quasi-experiments are defined by Cook and Campbell as experiments that have treatments, outcome measures, and experimental units, but do not use random assignment to create the comparisons from which treatment caused change is inferred.<sup>81</sup>

A major function of an effective research design is to control variance. The present investigation utilizes a research design which controls for variance through adherence to the maxmincon principle, defined by Kerlinger as follows:

The origin of this name is obvious: maximize the systematic variance under study: control extraneous systematic variance: and minimize error variance--with two of the syllables reversed for euphony.<sup>82</sup>

To maximize the variance under study, three distinctly different experimental treatment methods were designated. Because randomization was not possible, six self-contained classrooms at the same grade level and within the same school system were selected to control for extraneous systematic variance. An additional dependent variable, Attitude, has been built into the design to control for extraneous variance. If changes in attitude occurred as a result of treatment methods, the factorial design would allow analysis of its effect. Efforts to minimize error variance included selection of reliable dependent measures as well as control of the experimental conditions. Control of experimental conditions are more difficult in field than in laboratory research. Problems which occurred during the course of this investigation are discussed in Chapter 4. Adherence to the maxmincon principle addresses concerns of internal validity, which determine the confidence one can place on whether or not an experimental manipulation really made a significant difference. It was anticipated that the classroom instructional framework of the experimental setting would reduce threats to internal validity as much as possible, since the organizational structure of the experimental

procedure so closely parallels ongoing classroom instruction. The Hawthorne effect should be reduced for the reason stated.

Threats to external validity include generalizability, reactive effects of pretesting, and interactive effects of selection, setting and history. This research sample appeared to include a representative sample of fifth grade students, which would permit generalization to adjacent grade levels. The selected groups received instruction for a ten week period, sufficiently long to control for reactive effects of pretesting. In addition, utilization of the Mathematics Applications subtest of the Stanford Achievement Test (SAT) as the dependent measure permitted use of different forms for Pre/Post test measures. Due to the self contained classroom structure of experimental groups, this study may be replicated with different age and ability levels. Interactive effects of selection and treatment are difficult to control in non-randomized intact classroom research, as will be discussed in Chapter 4.

A total of nine teachers volunteered to participate in this investigation. The six classroom groups were selected after conferences with principals and volunteer teachers in each school. In order to assure inclusion of teachers possessing both willingness to participate and a self-reported confidence in teaching the subject of the investigation, interviews were conducted in which any negative attitudes toward mathematics or computers were discussed. In order to attain comparable groups, an attempt was made to consider the composition of the students within each experimental classroom. As a result of this process, two possible classrooms were removed due to



homogeneous grouping within those specific classrooms.

A large Chicago suburban school system participated in the present investigation. The socioeconomic status of those persons residing within the target school district range from lower to upper-middle class levels. According to data compiled in September, 1985 the ethnic composition is as follows: Non-Hispanic White 40%, Hispanic 27.3%, Asian/South Pacific 2.3%, Black 30%; American Indian 0.4%. The population of students is serviced in 15 elementary schools. Classes participating in this investigation appeared representative of the total school population.

#### Procedure

Selection of control and experimental groups was accomplished as follows:

1. Schools selected for participation utilized a heterogeneous classroom organization, which, according to the principal of each building, generally approximated the particular school population.
2. Teachers expressed willingness to participate in experimental groups.
3. Classrooms selected for participation had received comparable microcomputer instruction.

The two independent variables to be investigated in this study are:

1. treatment method (METHOD)
  - problem solving worksheets (WORDS)
  - microcomputer problem solving software (COMPS)
  - traditional (CONTROL)

2. strategy model (MODEL)

strategy (STRAT)

no strategy (NOSTRAT)

#### Description of Treatment Method

#### Independent Variable (IV) #1 (METHOD 1,3)

For a period of ten weeks, a total of six classrooms participated in this study. Two classrooms were assigned at random to each of three treatment methods. From among the three delivery methods, two classrooms received traditional classroom instruction (control), two experimental classrooms participated in one hour per week of specific problem solving worksheet practice (WORDS), utilizing math problem worksheets compiled by the investigator, and two experimental classrooms utilized microcomputer software (COMPS) for problem solving practice for a total of one hour per student per week.

#### Description of Math Problem Solving

#### Worksheet Practice (WORDS)

The following aspects of math word problem solving were considered in selection of problems for the ten worksheets, which are contained in Appendix A:

1. Reading level was determined to be one year below the grade level of participating students.
2. Three types of problems were selected:
  - a. simple translation problems
  - b. complex, multiple step transformation problems
  - c. process problems
3. Problems were organized so that each worksheet contained

problems of simple, complex and process nature, as well as sampling of the basic processes of addition, subtraction, multiplication, division, fractions, decimals and percents.

4. Problems were randomly selected from fifth and sixth grade textbooks of six (6) major textbook publishers.

5. Proportion of problem types represented in the worksheets was determined by examination of both Iowa Test of Basic Skills (ITBS) and Stanford Achievement Test (SAT) problem solving subtests, in order to reflect the evaluation instrument.

6. The level of difficulty of included problems was determined after a pilot study, in order to assure randomization of placement throughout the ten worksheets.

7. Word problem worksheets were field tested in three different school systems, with students in both fifth and sixth grade, in classroom groups ranging from remedial to gifted. Teacher input was solicited regarding specific problems of concern, and alterations or deletions of inappropriate problems were made when necessary.

Procedure for worksheet treatment method (WORDS) was organized as follows:

1. Teachers received ten (10) envelopes, each contained work materials (problem and answer sheets) for one problem set. (See Appendix A)

2. Teachers were instructed to designate a one (1) hour session, on Tuesday, Wednesday or Thursday, to be devoted to specific word problem solving practice. This allowed flexibility in their scheduling, and permitted the investigator the opportunity to collect,

analyze, and return corrected answer sheets by Monday of the following week.

3. The practice session was broken down into the following three segments:

- a. Fifteen (15) minutes to review returned, corrected problems.
- b. Fifteen (15) minutes to discuss new problem set and answer questions.
- c. Thirty (30) minutes work time, during which teacher would be available to offer assistance.
- d. Students were permitted to complete and submit problem set and answer sheet, on which all work was to be shown. All work was to be handed in by Thursday of each week.

#### Microcomputer Assisted

#### Problem Solving Practice (COMPS)

A schedule, assigning each participating student to one hour computer time per week, was followed. The software utilized in this study, developed by Sunburst Communications, is described as follows:

##### 1. THE FACTORY

The documented objectives of this program are stated as development of problem solving strategies, such as working backward, analyzing a process, determining sequence, applying creativity and inductive thinking, integrating visual discrimination, and spatial perception. The software does not provide strategy training but is designed to provide opportunities to reinforce listed strategies.

The program's main menu gives the choice of three activities, in

which students may: Test a Machine, Build a Factory, or Make a Product. In the initial five weeks of this intervention, students were to work independently at progressively more complex design configurations. During the last half of the intervention, an additional option, in which the teacher or another student may be challenged to reproduce the product, was used. This program requires little or no teacher instruction.

## 2. CODE QUEST

This program utilizes a format consisting of six types of codes which students must decipher in order to identify a "What Is It?" mystery object. Students received individual folders (Appendix B) which contained worksheets for use with this program. These worksheets were designed by the investigator in order to allow students to work independently in this program, which otherwise would have required additional teacher instruction in initial understanding of the different codes.

Code Quest allows students to save a problem in progress, and to enter their own clues and mystery objects. Problem solving skills addressed in Code Quest include:

1. discrimination of letters and symbols
2. pattern identification
3. analysis, breaking down a code into parts
4. classification, sorting and rearranging letters or symbols
5. sequencing
6. flexibility, openness to new ways of decoding
7. trial and error

The two programs selected for inclusion in this study contained characteristics addressing the primary interest of this investigation. Each selected program addressed several specific problem solving skills, with repetitive activities stressing skill development. Field testing of The Factory and Code Quest was conducted by Sunburst in several schools throughout the country over a period of two years. Analysis conducted by the investigator in order to determine appropriateness of selected software included testing of programs to determine ease of operation, clarity of directions, level of difficulty, and motivational appeal. Subsequent to selection of software, the investigator designed the following instructional sequence as 1. determination of student ease of software operation and 2. validation procedure to support the documentation objectives.

1. Ninety (90) sixth grade students being trained on the Apple IIe Microcomputer utilized the two Sunburst programs as training materials. Prior to this training, none of these students had used this particular computer, and only six had ever used a computer with a disk drive. Of the ninety students, only eight had previous experience with any microcomputer, while a total of only seventeen (17) displayed any knowledge of typing skills. The average reading level of the participating students was one year below grade level. After two (2) periods of forty minutes per period, all but five of the students were able to operate the system independently and to load and utilize each of the programs.

2. Validation of the software was accomplished through a workshop format consisting of two three hour sessions, preceded by a reading

assignment consisting of a short descriptive paper prepared by the investigator, in which basic problem solving definitions and theory were delineated. Participants in the workshop consisted of professional colleagues of the investigator including: an educational psychologist, two mathematics teachers, two elementary teachers, and an instructional media coordinator. The goals of the validation procedure included: 1. a review of problem solving strategies, 2. a determination of specific problem solving strategies utilized in the software and 3. a critique of the documentation and effectiveness of the software.

#### Description of Strategy Model

##### Independent Variable (IV) #2 (MODEL 1,2)

In order to investigate the effect of strategies for problem solving, a model, designed specifically for elementary level students, based on Polya's four phase model, was developed for this study by the investigator. This model (Figure 1) was prominently displayed in one control classroom, one worksheet (WORDS) classroom, and one microcomputer (COMPS) classroom, where it was implemented during specific problem solving practice. The worksheet (WORDS) teacher was instructed to refer to the problem solving model before, during, and upon completion of worksheet problem sets. The computer program (COMPS) and control teachers were instructed to refer to the problem solving model before and during regular mathematics instruction, and at any appropriate point during daily instruction. The period designation was not restricted to math period as the concept of problem solving strategies integrated within subject areas other than

# HOW TO SOLVE PROBLEMS

## UNDERSTAND!

## PLAN!

## DO!

## CHECK!

## IT!

### Understanding the Problem

What do you know?  
What do you need to know?  
What information is missing?  
What information is important?  
What are you trying to find?

### Devising a Plan

Do you know a related problem?  
Reread the problem.  
Simplify the problem.  
Break the problem into  
little parts (sub-goals).

### Carrying Out the Plan

Check each step.  
Draw a picture.  
Make a list, table,  
or diagram.  
Guess.

### Looking Back

Can you check the result?  
Does the result make sense?  
Can you repeat your steps?



mathematics was of interest in the present investigation.

### Strategy Model Practice

Students were encouraged to 1) both think through the four phases during attempts to solve problems, and 2) utilize strategies, such as seeking analogous situations, working backwards, making charts, diagrams and tables, scanning for erroneous information, and evaluating for sense of answers.

### Time Line

The time line for this investigation follows:

1. Experimental intervention totaled ten weeks instructional time, with pretesting conducted during the week prior to onset of the experiment and posttesting the week following the conclusion of instruction. Two additional weeks were built into the calendar which follows in order to allow for Spring vacation and inclement weather school closings.

2. The timetable for this investigation follows:

a. Pretesting:           Week of February 18, 1985

b. Intervention:        Week of February 25, 1985

                          through

                          Week of May 6, 1985

c. Posttesting:        Week of May 13, 1985

### Instrumentation

Two critical issues inherent in evaluating the effectiveness of a problem solving program are: 1) availability of an appropriate evaluation instrument, and 2) evidence of transfer of acquired skill.

Many tests for evaluating thinking skills are available, including:

Test of Cognitive Skills, (McGraw Hill), Ross Test of Higher Level Thinking (Academic Therapy Publications), Cognitive Abilities Test (Riverside Publishing Company), and the New Jersey Test of Reasoning Skills. However, no instrument appears to evaluate the issue of problem solving strategies which is addressed in both the strategy model and the computer software. The purpose of this investigation was to provide data to determine the effectiveness of both teacher directed math problem solving practice and of problem solving software. Transfer of acquired skills to demonstrated improvement on a math word problem test would be an observable outcome of an effective treatment. In order to address these issues, it was determined that a general word problem solving achievement test, the Stanford Achievement Test (SAT) would be a valid evaluative instrument.

In order to assess changes in student attitude, an instrument developed by Dr. Martin Covington, The Childhood Attitude to Problem Solving Inventory (CAPS), was selected. After survey of the literature, it became apparent that few instruments of this type have been developed. This instrument was selected for inclusion in the Rochester problem solving study, and appears to address the affective concerns of this investigation.

The first dependent variable, problem solving performance, was assessed utilizing the Mathematics Applications subtest (Intermediate 2 level) of the Stanford Achievement Test.

The Stanford Achievement Test (SAT): The 7th Edition of the Stanford Achievement Test (1983) by E.F. Gardner, H.C. Rudman, B. Karlsen, and J.C. Merwin is published by The Psychological

Corporation, a division of Harcourt Brace Jovanovich. There are six battery levels, ranging from grades 1.5 to 9.9. These levels provide extended grade coverage in order to make possible to use a particular battery at the higher or lower range than it is intended to be used. This is to allow flexibility of interpretation of scores unique to a specific class or an entire school system.

In order to obtain normative data descriptive of achievement in the nation's schools and to establish statistical reliability and validity of these tests, National Standardization Programs took place in Fall, Mid-year, and Spring, beginning in September, 1981 through May, 1982. Approximately 465,000 students from 300 school districts participated in the program. Validity and reliability of the test were dealt with in very general terms. Content validity can be evaluated through careful examination of the test content which is presented in the Stanford Index of Instructional Objectives. Reliability, the extent to which the test yields consistent results from one test administration to another, from one form to another, and from one item to another is known as internal consistency reliability, and is reported in Kuder-Richardson Formula #20 coefficients and standard errors of measurement in raw score units. An additional estimate of reliability is alternate-forms reliability, which were determined from the Equating of Forms phase of the standardization program.

Additional studies to equate scores on the forms of each level of the Stanford and to establish alternate-form reliability were conducted, to provide for comparison of scores from one form to another. The present investigation includes raw score data obtained

from alternate forms (E and F) of the Mathematics Applications subtest.

Equating of levels was accomplished through administration of subtests at adjacent levels to approximately 20,000 students in grades 1-8 and 10. This program was essential in order to develop a continuous score scale for interpretation of scores across levels of the test.

The Intermediate 2 standardization sample produced the following data for the Mathematics Applications subtest:

1. Internal consistency reliability analysis (K-R 20) coefficient of .90 for both Forms E and F.

2. Alternate-Forms Reliability analysis produced an obtained score of .88 for Form E and 8.7 for Form F.

A second dependent variable was included in this investigation, in order to assess the student's attitude toward self as a problem solver. The Childhood Attitude To Problem Solving Inventory, written by Dr. Martin Covington, was implemented, utilizing a Likert-type scale, which is defined by Kerlinger as:

a summated rating scale, a set of attitude items, all of which are considered of approximately equal "attitude value", and to each of which subjects respond with degrees of agreement or disagreement. Scores are summed, or summed and averaged, to yield an individual's attitude score.<sup>83</sup>

The Inventory (CAPS), which consisted of thirty (30) scaled responses, ranging from Strongly Agree-(5) to Strongly Disagree-(1), was, in fact and in terms of analysis, six separate subscales, evaluating responses to the following components of problem solving attitude:

1. Self-Confidence
2. Willingness
3. Persistence
4. Risk-taking
5. Efficiency Myth
6. Fixed Ability Myth

Reliability of each subscale was determined by Cronbach alpha coefficient. Analysis of variance was completed for each subscale.

#### Design and Statistical Analysis

Treatment method (METHOD) and strategy model (MODEL) are the independent variables of primary interest for this study. The dependent variables consist of scores obtained from: 1. the Stanford Achievement Test (Mathematics Applications subtest), (SAT) and 2. The Childhood Attitude To Problem Solving Inventory (CAPS).

Since it was impossible to randomly select subjects or conditions, this design is based on Campbell and Stanley (Design # 10), a nonequivalent control group design, in which the control and experimental groups lack pre-experimental sampling equivalence. Grouping constitutes naturally assembled collectives, as in predetermined self-contained classrooms.<sup>84</sup> For purposes of internal validity, this design controls for the main effects of history, maturation, testing and instrumentation, in that the difference for the experimental group between pretest and posttest cannot be explained by main effects as would be found affecting both experimental and control groups.

Campbell and Stanley  
Nonequivalent Control Group  
Design # 10

0	X	0
0		0

The design for the proposed study constitutes a two way (3x2) factorial design. Statistical analysis performed to test the null hypotheses consisted of using an ANOVA procedure among pretest and posttest scores to determine if differences in the dependent measures between experimental and control groups were significantly different. Use of this design allows for analysis of interaction effects among variables. Analysis was conducted utilizing the Statistical Package for the Social Sciences (SPSS) subprogram ANOVA.

Analytic Paradigm

FIGURE 2

		Method		
		A <sup>1</sup>	A <sup>2</sup>	A <sup>3</sup>
Model	B <sup>1</sup>			
	B <sup>2</sup>			

Dependent Variables

Stanford Achievement Test  
Childhood Attitude to  
Problem Solving Inventory

## CHAPTER III FOOTNOTES

<sup>81</sup>Thomas D. Cook and Donald T. Campbell, Quasi-Experimentation: Design and Analysis Issues for Field Settings, (Boston: Houghton Mifflin, 1979): p. 6.

<sup>82</sup>Fred Kerlinger, Foundations of Behavioral Research, (New York: Holt, Rinehart and Winston, 1973): p. 307.

<sup>83</sup>Ibid., p. 496.

<sup>84</sup>Thomas D. Cook and Donald T. Campbell, Quasi-Experimentation: Design and Analysis Issues for Field Settings, (Boston: Houghton Mifflin, 1979): p. 47.

## CHAPTER FOUR

### RESULTS AND DISCUSSION

#### Introduction

The major purpose of this investigation was to examine the efficacy of two treatment methods (METHOD) for improving the problem solving performance of selected fifth grade students. An additional variable, introduction to a strategy model (MODEL), was built into the experimental design. Figure 3, which presents a description of the experimental design, is included for clarification.

The results from the testing instruments administered to the subjects and the statistical analyses of the data are presented in this chapter. Research questions posed in Chapter 1 are restated in the discussion of each hypothesis. For additional clarification, Figure 4 presents the four research questions as subheadings of the four null hypotheses. These have been grouped according to the specific issue addressed in each hypothesis.

The analysis of data for this investigation was performed on the Loyola University IBM 3081 mainframe computer. The computer program chosen for this purpose was The Statistical Package for the Social Sciences (SPSS-X.) A two way analysis of variance was used to test each hypothesis. Further testing of these hypotheses was accomplished by performing an analysis of covariance on the posttest scores. These analyses are discussed in this chapter under the heading "Ancillary statistical analyses."



FIGURE 3

## Description of Experimental Design

<u>Group</u>	<u>IV#1 = Method (A<sup>1,3</sup>)</u>		A <sup>1</sup> WORDS	B <sup>1</sup> STRAT	<u>N</u>
	<u>IV#2 = Model (B<sup>1,2</sup>)</u>		A <sup>2</sup> COMPS	A <sup>3</sup> CONT B <sup>2</sup> NOSTRAT	
1	A <sup>1</sup>	B <sup>1</sup>	WORDS/STRAT		30
2	A <sup>2</sup>	B <sup>2</sup>	COMPS/STRAT		21
3	A <sup>3</sup>	B <sup>1</sup>	CONT/STRAT		21
4	A <sup>1</sup>	B <sup>2</sup>	WORDS/NOSTRAT		22
5	A <sup>2</sup>	B <sup>1</sup>	COMPS/NOSTRAT		24
6	A <sup>3</sup>	B <sup>2</sup>	CONT/NOSTRAT		26

---

 N = 144

## FIGURE 4

## Null Hypotheses with Related Research Questions

- 1)  $H_0$ : There are no significant differences in performance among the treatment method groups on the achievement scale.

Research Questions

Will problem solving worksheet practice (WORDS) facilitate higher performance on a math problem solving achievement test?

Will problem solving software practice (COMPS) facilitate higher performance on a math problem solving achievement test?

- 2)  $H_0$ : There are no significant differences in performance among the treatment method groups on the attitude scale.

Research Question

Will introduction of a problem solving strategy model facilitate higher performance on a math problem solving achievement test?

- 3)  $H_0$ : There are no significant differences in performance among the treatment method groups on the attitude scale.

Research Question

Will a change in student attitude toward self in terms of solving problems be demonstrated subsequent to treatment method intervention?

- 4)  $H_0$ : There are no significant differences in performance between the experimental (STRAT) group and the control (NOSTRAT) groups on the attitude scale.

Research Question

Will introduction of a strategy model facilitate a change in student attitude toward self in terms of solving problems?

For purposes of this investigation, data were not considered statistically significant unless the F-ratio was less than or equal to the .05 level of confidence.

### Testing Hypothesis 1

$H_0$ : There are no significant differences in performance among the treatment method groups on the achievement scale.

This hypothesis is designed to answer the following research questions:

Will problem solving worksheet practice (WORDS) facilitate higher performance on a math problem solving achievement test?

Will problem solving software practice (COMPS) facilitate higher performance on a math problem solving achievement test?

Means (of pretest, posttest and difference scores), standard deviations and rank order of Difference scores can be found in Table 1. Mean difference scores are ranked from highest (1) to lowest (6), while Table 2 affords further clarification for each classroom group. These results reveal that the four classrooms receiving treatment achieved greater gains in the problem solving computation test than did the two control classrooms with a range of difference scores from .04 to 4.8 points for all six classrooms.

In order to determine whether or not the means of the computation test differ significantly, t-tests were performed on the pretest, posttest, and difference scores. The t-test is used to compare the differences of two (2) means and will not reveal the magnitude, or strength of the relationship. The value of the t-test is found in its ability to suggest to the investigator those means having an apparent

TABLE 1

Comparison of Pretest and Posttest Mean Scores of  
SAT Computation Test

<u>Group</u>	<u>Test</u>	<u>Means</u>	<u>SD</u>	<u>Rank Order of Diff Scores</u>
1	Pre	11.53	4.76	2
	Post	15.37	6.14	
	(Diff)	3.8	4.8	
2	Pre	14.90	6.84	1
	Post	19.71	7.23	
	(Diff)	4.8	4.6	
3	Pre	19.05	9.85	6
	Post	19.10	8.95	
	(Diff)	.04	4.9	
4	Pre	19.27	6.82	3
	Post	22.05	7.86	
	(Diff)	2.7	5.7	
5	Pre	17.25	7.08	4
	Post	18.92	7.17	
	(Diff)	1.7	4.1	
6	Pre	19.58	8.62	5
	Post	21.04	6.64	
	(Diff)	1.4	6.1	

TABLE 2

Description of Classrooms in Rank Order of Stanford  
Achievement Test (SAT) Difference Scores

<u>Rank Order of Difference Scores</u>	<u>Difference Scores</u>	<u>Classroom Group</u>	<u>Experimental Design</u>
1	4.8	2	Computer/ Strategy Model
2	3.8	1	Worksheets/ Strategy Model
3	2.7	4	Worksheets/ NoStrategy Model
4	1.7	5	Computer/ NoStrategy Model
5	1.4	6	Control/ NoStrategy Model
6	.04	3	Control/ Strategy Model

difference. Table 3 shows that there is a significant difference between the Difference scores for both the experimental treatment groups, (WORDS) and (COMPS) and the control group. A significant difference was also revealed between one experimental treatment group (WORDS) and the control group on the pretest. In Figure 5, pretest to posttest raw score changes have been graphed. It is apparent that a wide range of scores exist between groups for the pretest scores. The effect of pretest significance on this investigation will be evident throughout this chapter and will be discussed in further detail in Chapter V.

An analysis of variance was used to determine whether or not the difference scores of the Stanford Achievement Mathematics Applications subtest were statistically significant with regard to Hypothesis 1. Data, contained in Tables 5 through 7 reveal the following:

1. Statistically significant differences exist for the main effects of Method and in the 2-Way Interaction of Method by Model, on the pretest scores of the achievement scale (Table 5).
2. Statistically significant differences exist for the main effect of Method using difference scores as the dependent variable (Table 7).

Examination of mean difference scores, (Table 2) reveal probable cause for significance reported in both t-test and analyses of variance. It appears that both problem solving worksheet practice and computer software practice will facilitate higher performance on a math problem solving achievement test measure.

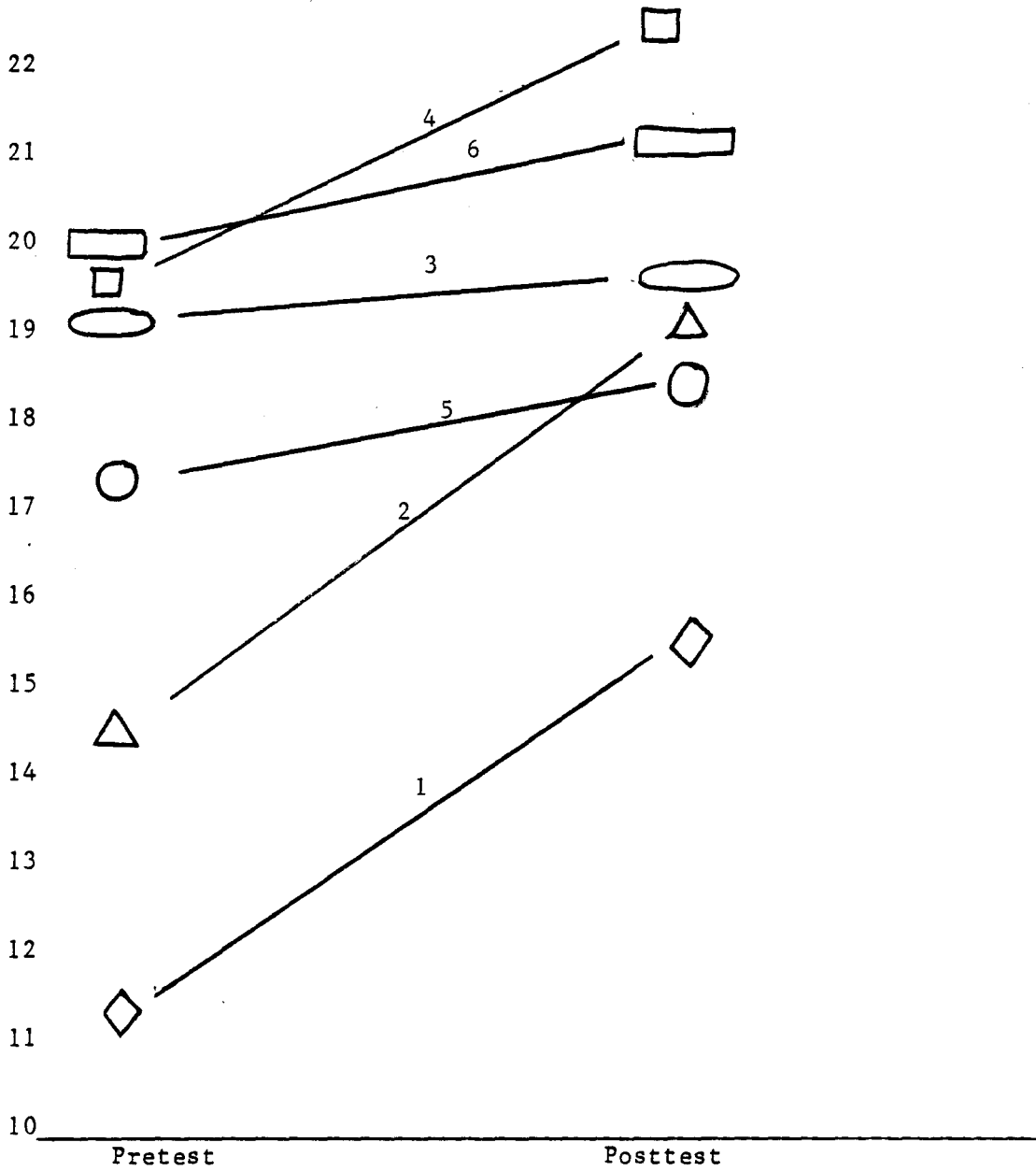
As a result of these analyses, Hypothesis 1 was rejected.

TABLE 3  
t-test by Method (1,3)

<u>Variable</u>	<u>Group</u>	<u>Mean</u>	<u>S.D.</u>	<u>T-Value</u>	<u>2-tail Prob</u>
SAT Pretest	1 WORDS	14.81	6.85		
	2 COMPS	16.26	7.00	-0.96	NS
	1 WORDS	14.81	6.85		
	3 CONT	19.34	9.09	-2.78	0.01
	2 COMPS	16.26	6.99		
	3 CONT	19.34	9.09	-1.89	NS
SAT Posttest	1 WORDS	18.19	7.62		
	2 COMPS	19.29	7.13	-0.73	NS
	1 WORDS	18.19	7.62		
	3 CONT	20.17	7.73	-1.28	NS
	2 COMPS	19.29	7.13		
	3 CONT	20.17	7.72	-0.57	NS
SAT Differ- ence	1 WORDS	3.38	5.21		
	2 COMPS	3.13	4.60	0.25	NS
	1 WORDS	3.38	5.21		
	3 CONT	0.83	5.66	2.33	0.02
	2 COMPS	3.13	4.60		
	3 CONT	0.83	5.66	2.15	0.03

FIGURE 5

SAT Pre/Posttest Computation Score Changes



- GR 1   ◇
- GR 2   △
- GR 3   ○
- GR 4   □
- GR 5   ○
- GR 6   ▭



## Testing Hypothesis 2

$H_0$ : There is no significantly different performance between the experimental (STRAT) group and the control (NOSTRAT) group on the achievement scale.

This hypothesis is designed to answer the following research question:

Will introduction of a problem solving strategy model facilitate higher performance on a math problem solving achievement test?

A recapitulation of the analytic paradigm is presented in Figure 6 in order to clarify this hypothesis, which deals with a Strategy Model as a second variable of interest.

Examination of Table 2 reveals mean difference scores for two experimental (STRAT) groups of 4.8 (Group 1), and 3.8 (Group 2), while the third experimental group (Group 3) obtained a mean difference score of .04. In addition, Figure 5 illustrates the Pretest mean score position of the six classroom groups, demonstrating that Group 1, with the highest mean Difference score (4.8) obtained the lowest pretest mean score, that Group 2, which ranked second from the highest in mean difference, obtained the second lowest pretest mean score, and that the third experimental group (Group 3), ranked last in mean Difference score, obtained the highest pretest mean score (19.1) of the three experimental (STRAT) groups. This data is included in this discussion as further evidence of the variance and potential influence of pretest scores on the results of this investigation. Additional statistical analyses were performed as a result of the significance of the analysis of variance on Pretest scores. These results are included

FIGURE 6

## Recapitulation of Analytic Paradigm

## METHOD

	A <sup>1</sup>	A <sup>2</sup>	A <sup>3</sup>
B <sup>1</sup>	WORDS/STRAT GROUP 1 N = 30	COMPS/STRAT GROUP 2 N = 21	CONT/STRAT GROUP 3 N = 21
Model			
B <sup>2</sup>	WORDS/NOSTRAT GROUP 4 N = 22	COMPS/NO STRAT GROUP 5 N = 24	CONT/NOSTRAT GROUP 6 N = 26

Dependent Variables

Stanford Achievement Test (SAT)  
 Childhood Attitude Inventory for  
 Problem Solving (CAPS)

in the section of this chapter headed "Ancillary Statistical Analyses." Implications derived from these effects will be discussed in Chapter V.

Table 4 contains the comparison of mean scores between the experimental group, which received the strategy model (STRAT), and the control group (NOSTRAT). Both the pretest and posttest mean score comparison reveal significant differences. However, there is no significance indicated on the difference score. Although the experimental classrooms achieved significantly higher mean difference scores than the control classroom, it appears that the higher pretest scores of the control classrooms indicate classroom groupings which did not meet the homogeneity desired for this investigation.

Tables 5 through 7 contain the results of the analysis of variance. Although Model is significant on both the main effect and 2-way interaction for both the Pretest and Posttest measures, there is no significant difference demonstrated through analysis of the difference scores.

1. Statistically significant differences exist in the main effect of Strategy Model (MODEL) on both the Pretest and Posttest achievement scale. (See Tables 5 and 6)

2. Statistically significant differences exist in the 2-way interaction, MODEL by METHOD, on both the Pretest and Posttest achievement scale. (See Tables 5 and 6)

3. No statistically significant differences were shown in the main effect of Strategy Model (MODEL) on the achievement test difference scores. (See Table 7)

TABLE 4  
t-test by Model (1,2)

<u>Variable</u>	<u>Group</u>	<u>Mean</u>	<u>S.D.</u>	<u>T-Value</u>	<u>2-tail Prob</u>
SAT Pre	1 (STRAT)	14.71	7.72	-3.41	0.00
	2 (NOSTRAT)	18.71	7.57		
SAT POST	1 (STRAT)	17.72	7.54	-2.37	0.02
	2 (NOSTRAT)	20.64	7.22		
SAT D	1 (STRAT)	3.01	5.13	1.24	NS
	2 (NOSTRAT)	1.93	5.39		

TABLE 5

Analysis of Variance of Pretest Computation Scores of  
SAT for Experimental and Control Groups

<u>Source of Variation</u>	<u>Sum of Squares</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F Ratio</u>	<u>P</u>
Main Effects	1007.88	3	335.96	6.17	0.00
Method	431.88	2	215.94	3.96	0.02
Model	480.67	1	480.68	8.82	0.00
2-Way Interactions	344.42	2	172.21	3.16	0.04
Model					
Method	344.42	1	172.21	3.16	0.04
Explained	1352.31	5	270.46	4.96	0.00
Residual	7519.43	138	54.49		
Total	8871.75	143	62.04		

TABLE 6

Analysis of Variance of Posttest Computation Scores of  
SAT for Experimental and Control Groups

<u>Source of Variation</u>	<u>Sum of Squares</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F Ratio</u>	<u>P</u>
Main Effects	370.08	3	123.36	2.32	NS
Method	63.83	2	31.92	0.60	NS
Model	272.73	1	272.73	5.14	0.02
2-Way Interactions	344.41	2	172.21	3.24	0.04
Model					
Method	344.41	2	172.21	3.24	0.04
Explained	714.49	5	142.90	2.69	0.02
Residual	7324.81	138	53.08		
Total	8039.31	143	56.22		

TABLE 7

Analysis of Variance of Difference Computation Scores of  
SAT for Experimental and Control Groups

<u>Source of Variation</u>	<u>Sum of Squares</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F Ratio</u>	<u>P</u>
Main Effects	219.00	3	73.00	2.77	0.04
Method	176.75	2	88.38	3.35	0.03
Model	29.26	1	29.26	1.11	NS
2-Way Interactions	118.86	2	59.43	2.26	NS
Model					
Method	118.86	2	59.43	2.26	NS
Explained	337.87	5	67.58	2.57	0.03
Residual	3636.01	138	26.35		
Total	3973.88	143	27.79		

Further examination of Table 4 reveals that while control classrooms had higher scores on both pretest and posttest means, experimental classrooms obtained a mean difference score 1.1 points higher than the control group. This indicates that although statistical analyses did not reveal significance, the experimental treatment did produce higher achievement gains.

As a result of these analyses, Hypothesis 2 was not rejected.

### Testing Hypothesis 3

$H_0$ : There are no significant differences in performance among the treatment method groups on the attitude scale.

This hypothesis is designed to answer the following research question:

Will a change in student attitude toward self in terms of solving problems be demonstrated subsequent to treatment method intervention?

The Childhood Attitude to Problem Solving Inventory (CAPS) was selected to evaluate attitude change in students participating in this investigation. A search for an instrument suitable to this purpose led to this scale written by Dr. Martin Covington. While this instrument was included in the Final Report of the Rochester, Minnesota problem solving project, (see Appendix D), it was never implemented, and there is no data concerning its reliability or validity beyond that provided by Dr. Covington. Due to the dearth of instruments designed for this purpose, it was decided to use the Inventory, as written, and to determine its reliability.

A total of thirty (30) items are included, with six components of attitude evaluated. For the purpose of analysis, each subtest is

interpreted as a separate unit, with an analysis of variance performed on each.

Table 8 displays reliability scores obtained by the investigator (Sample) and compared to those reported by Dr. Covington (Population). According to Kerlinger<sup>85</sup> reliability is the accuracy of a set of scores. The more reliable, the better we can identify and extract systematic variance and the smaller the error variance will be. Comparison of the two sets of reliabilities reveals a relatively high level of consistency.

Tables 9 through 14 contain the results of the analyses of variance conducted on the (CAPS) difference scores. In only one subtest, Persistence, was there a significant difference in the Method main effect. Subsequently, this Inventory, analyzed in subtests, was treated as a total unit. This analysis proved unsuccessful for detecting significant differences. Although one area displayed significance (Persistence), it is not considered sufficient evidence of an attitude change.

As a result of these analyses, Hypothesis 3 was not rejected.

#### Testing Hypothesis 4

$H_0$ : There are no significant differences in performance between the experimental (STRAT) group and the control (NOSTRAT) group on the attitude scale.

This hypothesis is designed to answer the following research question:

Will introduction of a strategy model facilitate a change in student attitude toward self in terms of solving problems?



TABLE 8

Reliability Scores (Cronbach) for CAPS Childhood Attitude  
Inventory for Problem Solving

<u>Subscale</u>	<u>Number of Items</u>	<u>Population</u>	<u>Sample</u>
Self-Confidence	5	.596	.576
Willingness	6	.619	.518
Persistence	7	.656	.553
Risk Taking	6	.664	.459
Efficiency Myth	3	.745	.707
Fixed Ability Myth	3	.637	.460

TABLE 9

Analysis of Variance of Self-Confidence Subscale of the  
Childhood Attitude to Problem Solving Inventory

<u>Source of Variation</u>	<u>Sum of Squares</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F Ratio</u>	<u>P</u>
Main Effects	37.16	3	12.39	0.83	0.48
Method	36.87	2	18.44	1.24	0.29
Model	0.93	1	0.93	0.06	0.80
2-Way Interactions	17.99	2	8.99	0.60	0.55
Method	17.99	2	8.99	0.60	0.55
Explained	55.15	5	11.03	0.74	0.59
Residual	1891.87	127	14.89		
Total	1947.03	132	14.75		

TABLE 10

Analysis of Variance of Willingness Subscale of the  
Childhood Attitude to Problem Solving Inventory

<u>Source of Variation</u>	<u>Sum of Squares</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F Ratio</u>	<u>P</u>
Main Effects	68.09	3	22.69	1.85	0.14
Method	64.24	2	32.12	2.62	0.08
Model	7.35	1	7.35	0.60	0.44
2-Way Interactions	27.47	2	13.74	1.12	0.33
Method	27.47	2	13.74	1.12	0.33
Explained	95.56	5	19.11	1.56	0.18
Residual	1558.51	127	12.27		
Total	1654.08	132	12.53		

TABLE 11

Analysis of Variance of Persistence Subscale of the  
Childhood Attitude to Problem Solving Inventory

<u>Source of Variation</u>	<u>Sum of Squares</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F Ratio</u>	<u>P</u>
Main Effects	142.49	3	47.50	3.31	0.02
Method	111.43	2	55.72	3.89	0.02
Model	23.32	1	23.32	1.63	0.20
2-Way Interactions	326.41	2	163.20	11.38	0.00
Method	326.41	2	163.20	11.38	0.00
Model	326.41	2	163.20	11.38	0.00
Explained	468.90	5	93.78	6.54	0.00
Residual	1820.83	127	14.34		
Total	2289.73	132	17.35		

TABLE 12

Analysis of Variance of Risk Taking Subscale of the  
Childhood Attitude to Problem Solving Inventory

<u>Source of Variation</u>	<u>Sum of Squares</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F Ratio</u>	<u>P</u>
Main Effects	118.62	3	39.54	1.57	0.20
Method	53.27	2	26.64	1.06	0.35
Model	59.70	1	59.70	2.36	0.13
2-Way Interactions	20.02	2	10.01	0.40	0.67
Method	20.02	2	10.01	0.40	0.67
Model	20.02	2	10.01	0.40	0.67
Explained	138.64	5	27.73	1.10	0.36
Residual	3202.31	127	25.22		
Total	3340.95	132	25.31		

TABLE 13

Analysis of Variance of Efficiency Myth Subscale of the  
Childhood Attitude to Problem Solving Inventory

<u>Source of Variation</u>	<u>Sum of Squares</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F Ratio</u>	<u>P</u>
Main Effects	38.42	3	12.81	1.31	0.28
Method	11.54	2	5.77	0.59	0.56
Model	24.72	1	24.72	2.53	0.11
2-Way Interactions	5.58	2	2.79	0.29	0.75
Method					
Model	5.58	2	2.79	0.29	0.75
Explained	43.99	5	8.80	6.54	0.48
Residual	1242.94	127	9.79		
Total	1286.93	132	9.79		

TABLE 14

Analysis of Variance of Fixed Ability Myth Subscale of the  
Childhood Attitude to Problem Solving Inventory

<u>Source of Variation</u>	<u>Sum of Squares</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F Ratio</u>	<u>P</u>
Main Effects	14.07	3	4.69	0.35	0.79
Method	5.38	2	2.69	0.20	0.82
Model	9.66	1	9.66	0.73	0.40
2-Way Interactions	13.32	2	6.66	0.50	0.61
Method					
Model	13.32	2	6.66	0.50	0.61
Explained	27.39	5	5.48	0.41	0.84
Residual	1686.69	127	13.28		
Total	1714.08	132	12.99		

The research question in both Hypothesis 3 and Hypothesis 4 concerns a change in attitude subsequent to both Treatment Method and Strategy Model intervention. Both deal with the dependent variable of difference scores obtained from the Childhood Attitude to Problem Solving Inventory, which was administered along with the pretest and posttest forms of the Stanford Achievement Test (SAT).

Discussion of the results from the six analyses of variance are found in the previous section of this chapter, "Testing Hypothesis 3", and may be applied in analysis of Hypothesis 4. Tables 9 through 14 reveal no evidence of significant changes in attitude as a result of strategy training intervention. As a result of these analyses, Hypothesis 4 was not rejected.

#### Ancillary Statistical Analyses

In this investigation, analyses of variance were conducted using gain scores to examine the difference, or change, in performance from the Pretest to the Posttest. The model is identical to the elementary ANOVA, except that the difference score (posttest minus pretest) is the dependent variable rather than just the posttest.<sup>85</sup> In an investigation in which pretest/posttest achievement test scores were to be compared, Lewin, in choosing to perform an analysis of covariance (ANCOVA) on posttest data, discusses the problem inherent in the use of gain, or change scores, which have been criticized due to the possible sensitizing effects of the pretest.<sup>86</sup>

Previous discussion in this chapter indicated that initial statistical analysis performed on data collected in this investigation revealed significant differences on pretest scores (See Tables 3

through 7). Kerlinger states that in an analysis of covariance (ANCOVA), the residual scores are the posttest scores purged of pretest influence, which, in effect, removes the influence of the pretest data from the posttest analysis.<sup>87</sup> In order to control for possible effects of the Stanford Achievement Test (SAT) pretest administered in this investigation, an analysis of covariance (ANCOVA) was performed on the posttest data, using the pretest as covariate. Table 15 supports the conclusion that significant differences existed between groups at the time of the pretest. Previous discussion of mean score comparisons and t-test results (See Tables 1 through 4) concerned the variance between pretest scores of experimental and control groups, with control groups obtaining significantly higher scores. In order to determine what factors contributed to this pretest significance, it was decided that additional data, consisting of scaled scores from the Language and Reading subtests of the California Achievement Test: Form C/D (McGraw Hill, 1979), would be built into the experimental design. These data were gathered by the school system during its systemwide testing program in March 1985. Scaled scores were selected because they could be evaluated across several testing levels. The data were added to evaluate the effect of language and reading as possible causes for the significance differences found between the six group pretest scores. Further description of the configuration of the six classroom groups will be included in the discussion in Chapter V.

Tables 15, 16 and 17 consist of analysis of covariance results, using the SAT pretest (Table 15), the CAT Language test (Table 17) and

TABLE 15

Analysis of Covariance of Posttest Scores of Stanford Achievement Test (SAT) Using Pretest as Covariate for Experimental and Control Groups

<u>Source of Variation</u>	<u>Sum of Squares</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F Ratio</u>	<u>P</u>
Covariates	4716.38	1	4716.38	205.25	0.00
SAT Pre	4716.38	1	4716.38	205.25	0.00
Main Effects	63.94	3	21.31	0.93	0.43
Method	63.94	2	31.97	1.39	0.25
Model	0.01	1	0.01	0.00	0.99
2-Way Interactions	110.83	2	55.42	2.41	0.09
Method					
Model	110.83	2	55.42	2.41	0.09
Explained	4891.15	6	815.19	35.48	0.00
Residual	3148.15	137	22.98		
Total	8039.31	143	56.22		

TABLE 16

Analysis of Covariance of Posttest Scores of Stanford Achievement Test (SAT) Using California Achievement Test Language Subtest as Covariate for Experimental and Control Groups

<u>Source of Variation</u>	<u>Sum of Squares</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F Ratio</u>	<u>P</u>
Covariates	2734.53	1	2734.53	76.74	0.00
Language	2734.53	1	2734.53	76.74	0.00
Main Effects	267.23	3	89.09	2.50	0.06
Method	135.46	2	67.73	1.90	0.15
Model	130.03	1	130.03	3.65	0.06
2-Way Interactions	195.16	2	97.59	2.74	0.07
Method					
Model	195.16	2	97.59	2.74	0.07
Explained	3196.92	6	532.82	14.95	0.00
Residual	4810.32	135	35.63		
Total	8007.24	141	56.79		

TABLE 17

Analysis of Covariance of Posttest Scores of Stanford  
Achievement Test (SAT) Using California Achievement Test  
Reading Subtest as Covariate for Experimental and Control Groups

<u>Source of Variation</u>	<u>Sum of Squares</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F Ratio</u>	<u>P</u>
Covariates	2449.82	1	2449.82	63.21	0.00
SAT Reading	2449.82	1	2449.82	63.21	0.00
Main Effects	182.34	3	60.78	1.57	0.20
Method	47.34	2	23.67	0.61	0.54
Model	141.35	1	141.35	3.64	0.06
2-Way Interactions	121.82	2	60.91	1.57	0.21
Method					
Model	121.82	2	60.91	1.57	0.21
Explained	2753.97	6	459.00	11.84	0.00
Residual	5270.64	136	38.76		
Total	8024.62	142	56.51		



the CAT Reading test (Table 17) scores as covariates. While each analysis confirms the existence of pretest significance, no main effect or interaction effects are detected. In other words, the cause of the pretest significance is not obvious from these analyses. However, it appears that using the CAT Language test as covariate indicates significance closely approaching the .05 level of significance, (.058 level for Method, .068 level for 2-Way interaction, Method by Model. Implications of this ancillary data will be discussed in Chapter V.

#### Summary

Chapter 4 was concerned with reporting the analysis of the data collected during this investigation. Hypothesis 1 was concerned with the problem solving performance of two treatment groups, worksheet practice and computerized problem solving software practice. An analysis of variance resulted in a statistical difference at the .05 level, which led to the rejection of Hypothesis 1 (Table 7). Hypothesis 2, which compared the problem solving performance of an experimental group, (STRAT), with a control group (NOSTRAT), did not disclose significant differences and therefore Hypothesis 2 was not rejected.

Hypotheses 3 and 4 were concerned with changes in attitude subsequent to treatment (METHOD) and strategy (MODEL) intervention. In neither hypothesis did analysis of variance of the attitude Inventory produce significant differences. Therefore, neither Hypothesis 3 nor Hypothesis 4 were rejected.

## CHAPTER IV FOOTNOTES

<sup>85</sup> Thomas D. Cook and Donald T. Campbell, Quasi-Experimentation: Design and Analysis Issues for field settings, (Boston: Houghton Mifflin, 1979): p. 182.

<sup>86</sup> Renee Z. Lewin, "An Investigation of the Effectiveness of Amplification as a Viable Method for Improvement of Language and Academic Achievement in a Noisy Environment." (Unpublished doctoral dissertation, Loyola University of Chicago, 1983), p. 37.

<sup>87</sup> Fred Kerlinger, Foundations of Behavioral Research, (New York: Holt, Rinehart and Winston, 1973): p. 330.

## CHAPTER FIVE

### FINDINGS, CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

#### Introduction

A major purpose of this investigation was to determine whether or not the problem solving performance of selected fifth grade students would be improved through one of two treatment methods: 1) teacher directed word problem worksheet practice or 2) student-computer interaction with problem solving software. A second purpose was to introduce a strategy model in order to determine whether or not awareness of the stages and strategies involved in the problem solving process might facilitate improved performance. An experimental study was designed to test the effects of the worksheet and computer software treatments, and to determine what aspect of those effects might be attributed to the strategy model.

A total of 144 fifth grade students from four elementary schools were involved in the study. Each classroom was self contained with instruction by the classroom teacher in all subject areas. Each class was grouped heterogeneously, reflecting the composition of the particular school.

Prior to the experimental treatment, all subjects were administered two pretests. The first pretest, the Mathematics Applications subtest of the Stanford Achievement Test, was administered by the investigator. This was used to measure the

problem solving ability of the selected fifth grade students. The second pretest was the Childhood Attitude to Problem Solving Inventory, an instrument developed by Dr. Martin Covington. This instrument was administered by the classroom teacher. The results from the pretesting instruments are presented in Chapter IV.

The experimental program consisted of ten weeks of problem solving worksheet practice (WORDS) or individualized student computer software participation (COMPS). These were also compared with a control group. One of each treatment group: 1) worksheet, 2) computer and 3) control also received the strategy model, which was presented in the form of a wall chart and individual student charts (See Figure 1). The experimental program lasted ten weeks, during which time each of the six groups received regular mathematics instruction.

Immediately following the experimental treatment, all subjects were administered two posttests, different forms of the same instruments used for pretesting. The data from these instruments were analyzed and each hypothesis was tested with the appropriate statistical test.

Included in this chapter are the findings and conclusions of the study based upon the data presented in Chapter IV, recommendations, suggestions for further research, and a summary of the chapter.

### Findings and Conclusions

The results from the statistical analyses are as follows:

1)  $H_0$ : There are no significant differences in performance among the treatment method groups on the achievement scale.

This study revealed that significant differences were found

between treatment groups subsequent to instructional intervention. Stanford Achievement Test mean difference scores (See Tables 1 and 2) were used to show rank order. The two control groups showed least gain from pretest to posttest. Both analysis of variance (Tables 5 through 7) and t-tests (Tables 3 and 4) showed that there was a significant difference between the mean difference scores. Therefore, Hypothesis 1 was rejected.

Pretest significance on both the analysis of variance and t-test data led to further efforts to interpret results. The two problem solving worksheet groups obtained difference scores of 3.8 and 2.7 points, ranking second and third among the six classrooms. However, pretest scores for these groups differed significantly, raising concern about the homogeneity among the groups. Although the participating school system is integrated and reflects the racial and ethnic composition of the total district, Group 1 contained a majority of Spanish speaking children, while Group 4 consisted of a more homogeneous middle-class population. This may be attributed in part to the limited number of sections of each grade level within each building and to the difficulty inherent in any school district's efforts to achieve homogeneity through district wide integration. Although efforts were made to implement this investigation in six similar classrooms, the selection process of intact classrooms carries with it the risk of not achieving the degree of desired homogeneity. A description of groups 1 and 4 led to the conclusion that language or reading deficiencies in Group 1 might have caused the wide variance between pretest scores, therefore revealing significant differences in

pretest data. Analyses of covariance, with pretest, Language, and Reading as covariates were performed in the interest of determining the effects of these three important issues. These analyses were discussed in Chapter IV. Since significance was shown as a result of each covariate, no conclusive evidence as to a greater effect of one of the three was obtained.

Computer problem solving software groups gained 4.8 and 1.6 points. Conditions within the two classrooms during the period of this investigation, which ranked third and fourth in mean difference scores, appear to further strengthen or influence the significance of the gains. In both classrooms, temporary problems with disk drives continued to plague teachers and students and the problem was not totally resolved until approximately one half, or five weeks into the investigation. In addition, the enthusiastic and computer competent teacher of Group 5 required surgery and was not in school for the first three weeks of the investigation. The climate in this classroom during this period might have contributed to the slight gain from Pretest to Posttest, as compared with those of Group 2.

Weekly word problem practice, as a separate unit from regular mathematics instruction, provided a focus which enabled students to improve in their problem solving ability. It may be concluded that specific problem solving practice will have a positive effect on problem solving performance, and therefore should be given greater priority in instructional planning (See Tables 1 and 2).

While it may be concluded that practice in word problem solving might lead to improved performance, a more significant conclusion

concerns the use of content-free problem solving software.

Significant gains by students in this group (Tables 1,2 and 3) support use of these programs as an additional tool in efforts to improve the ability of students to attack and solve problems in all subject areas.

While the two control groups showed least gain from pretest to posttest, examination of pretest data indicate very high pretest mean scores. The wide variance between experimental and control groups on pretest data reveal lack of homogeneity within the intact classrooms participating in this investigation.

2)  $H_0$ : There are no significant differences in performance between the experimental (STRAT) group and the control (NOSTRAT) group on the achievement scale.

One of each experimental treatment group and one control group received the strategy model. In each experimental group, the strategy model classroom improved in performance from pretest to posttest at a greater rate than its counterpart. However, although Chapter IV lists significance in interaction effects of Treatment Method (METHOD) and Strategy Model (MODEL), there is no significance shown by analysis of variance on difference scores. Therefore, Hypothesis 2 was not rejected.

It may be concluded from the analysis that the introduction of the strategy model does not provide sufficiently strong treatment effect to improve problem solving performance. It must be noted that this independent variable was included in this study in the belief that, as an integral component of the problem solving process, it might provide base line data concerning its effect on student

performance. Teachers were instructed to refer to the model, and to utilize it when appropriate, but no formal instruction was delivered on a regularly scheduled basis during the course of the experimental treatment. Although this hypothesis was not rejected, Table 4 does support the view that classroom groups exposed to the strategy model did show greater gains in problem solving performance than their control counterparts. Although the treatment effect was not sufficiently strong to show significance, gains are evident, and implementation of strategy instruction must be considered in the curriculum planning of classroom teachers.

3)  $H_0$ : There are no significant differences in performance among the treatment method groups on the attitude scale.

An analysis of variance was performed on each of the subscales of the Childhood Attitude to Problem Solving Inventory. Results did not reveal significant changes in attitude between different treatment groups from Pretest to Posttest. Hypothesis 3 was not rejected.

4)  $H_0$ : There are no significant differences in performance between the experimental (STRAT) group and the control (NOSTRAT) group on the attitude scale.

Results of analyses performed in both Hypothesis 3 and Hypothesis 4 revealed lack of significance in determination of attitude change subsequent to problem solving intervention. Hypothesis 4, which compared groups which did or did not receive the strategy model, was not rejected.

The Childhood Attitude to Problem Solving Inventory consisted of thirty statements. Choices of Strongly Agree (1) to Strongly Disagree



(5) may have diluted the effect of student responses. Examination of tally sheets confirm multiple repetition in response. This repetitive response mode may have led to response set biasing, further confounded by the students' age, attention span, and reading and language deficiencies. It is the investigator's belief that the Instrument failed to measure student attitude changes, and that no true conclusions may be derived concerning Hypotheses 3 and 4.

Subjective data gathered during and at the conclusion of this investigation consisted of teacher and student interviews, bi-weekly classroom observation, and weekly correction and comments of worksheet problems. An ongoing dialogue with teachers provided opportunity to question, make adjustments, suggestions and to maintain a strong sense of the progression of the investigation. Changes in attitude were expressed by the problem solving worksheet groups as the investigation proceeded. Students became more eager to receive corrected worksheets and proceeded to the next worksheet with expressed statements of confidence. Computer groups maintained interest in the two programs throughout, each group expressing relief to their teacher when told that, although the investigation was completed, their use of Code Quest and The Factory would continue uninterrupted. Although no formal data gathering procedures were included in this investigation, it is the belief of the investigator that such data might have revealed positive changes in student attitude toward problem solving.

### Recommendations

This investigation has produced evidence that the two methods consisting of solving word problems and content-free problem solving

computer software were effective in increasing the problem solving performance of selected fifth grade students. On the other hand, the casual presence of a strategy model resulted in no significance. The review of literature related to problem solving indicates the importance of problem solving as one of the basic skills of mathematics, as well as indicating the concern that it must become the major thrust of the 1980's. Furthermore, the role of computers in enhancing the problem solving process is increasing, as evident in both school system research and in software development. The recommendations which follow are of practical significance to classroom teachers and curricula coordinators in decisions involving classroom instructional programs.

1. Since the use of specific word problem worksheets improved the problem solving performance of selected fifth grade students, use of word problems should be incorporated in the fifth grade curriculum not as an occasional add on but as a major component of the mathematics curriculum.

2. Since the use of content-free problem solving software improved the problem solving performance of selected fifth grade students, adequate computer time should be made for all students and problem solving programs should be purchased by the school system. These programs should be considered to be a strategic part of a problem solving curriculum.

3. Teachers should receive in-service training in the use of the strategy model, and should be strongly encouraged to incorporate it into their formal instructional planning. Although no significant

model effects were perceived as a result of this investigation, the role of the problem solving model has been well accepted and documented.

#### Suggestions for Further Research

During the course of this ten week investigation, refinements, changes, other directions, and general hindsight reflections come to mind. Subsequent to analysis of the gathered data, those reflections crystallized into concrete conclusions. With this in mind, the writer believes that the following suggestions are logical extensions of this study:

1. The Childhood Attitude to Problem Solving Inventory should be revised in two ways. There were too few questions to evaluate each subscale on its own merit suggesting that the six subscales be ignored with data reported as an overall score. It is possible that there were too many response choices for students of elementary grade levels. Two (Agree or Disagree) or three (Agree, Not sure, Disagree) might better be the maximum number of possible responses. Another possible solution for problems with the Inventory could be to scale the test differently, therefore reducing the response set biasing.

2. Replication of this study, using departmentalized math classes which have been grouped by ability, would control for the lack of homogeneity revealed in the current investigation.

3. A similar investigation, with random selection of students, could be accomplished in a school situation in which there was access to a computer math lab.

4. This experimental program lasted for ten weeks. Replication

of the study, extending the experimental program over the entire school year should amplify the results found in the present investigation.

5. The population for this study consisted of students from a predominantly suburban environment. However, strong influences from populations of certain schools created significant differences which confounded the results of the statistical analyses. Researchers might focus on the results of a similar investigation, conducted within a more homogeneous setting, such as strictly inner-city, or upper-middle class suburban.

6. Three suggestions for use of the strategy model include:

- a. Removal of the strategy model from the experimental design.
- b. Strengthening of the use of the model in the experimental design.
- c. Use of the model as a single independent variable in an investigation of its effects on the problem solving process.

Suggestions listed above were compiled as a direct outcome of this investigation.

### Summary

This investigation was an attempt to determine whether practice with word problem worksheets or computer software would have an effect on the problem solving performance and attitude of selected fifth grade students. The study also considered the effect of an introduction to a specific strategy model.

It may be concluded from the results of this investigation that:

1. Regular practice in word problems increases problem solving performance.

2. Content-free problem solving computer software programs are effective in increasing problem solving performance.

3. A strategy model, merely introduced, is not effective in increasing problem solving performance.

4. No attitude changes could be determined as a result of the dependent variable used in this investigation, although informal subjective data suggests positive changes.

Throughout the history of public education in this country, schools have been called upon to meet the demands of society. In the 1980's, demands for improvement in students' thinking and problem solving skills are coupled with the additional burden of decreasing educational allocations, further pointing to the need for cost effective program development. Incorporation of microcomputers within elementary school classrooms has led to questions concerning the role and effectiveness of this technology.

As children of today become adults, they will be faced with the challenges of the Twenty-first century, and to them will fall the responsibility of seeking solutions to the problems of an ever increasingly complex society. Problem solving must not be viewed as a trend of the 1980's. As educators of today, we must view this as a major concern, and provide adequate opportunity for systematic practice and reinforcement in improving problem solving skills. There

is a need for continuing research on making the valuable area of problem solving meaningful and enjoyable.

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APPENDIX A

H-s-143

1. In an experiment a dog ran distances of 8.34 km, 12.2 km, 24.03 km, and 10.769 km. What total distance did the dog run?

L-c-97

2. The Nile River is 3,206 miles longer than the Ohio River. The Ohio River is 3,019 miles shorter than the Amazon River. The Amazon River is 4,000 miles long. How long is the Nile River?

AW-c-21

3. In June a ranger took 23 groups of visitors on hikes. There were 18 in each group. In July she took 38 groups on hikes, with 14 in each group. How many more did she take in one month than in the other?

AW-c-146

4. A weekday telephone call from San Francisco to New York City costs \$2.95 for the first three minutes and \$0.41 for each additional minute. How much would a 24-minute call cost?

AW-c-119\*

5. A paper route pays \$29 a week. The yearly expenses are \$5 for plastic bags and \$4 for rubber bands. What is the profit for the year?

L-c-248\*

6. Bonnie had a gallon of milk. She filled 4 cups with milk. How many quarts of milk were left in the gallon container?

7. Tara is 69 inches tall. Gina is 2 inches shorter than Tara. How tall is Gina in feet and inches?

8. The paint Carl wants comes only in quart cans. He needs one half gallon of the paint. How many quart cans should he get?

**Length**

12 inches = 1 foot

3 feet = 1 yard

5280 feet = 1 mile

**Capacity**

8 fluid ounces = 1 cup

2 cups = 1 pint

2 pints = 1 quart

4 quarts = 1 gallon

**Weight**

16 ounces = 1 pound

2000 pounds = 1 ton

## PROBLEM SET # 2

**Jogger's World**  
1238 Spring Street

We've taken  
**\$3 off all shoes!**

For men and women  
**NOW \$32.50**

For men  
**NOW \$24.65**

For men and women  
**NOW \$26.89**

For children  
**NOW \$23.69**



1. HM-s-114  
What is the cost of outfitting 3 children with running shoes?
2. Three men each bought the same kind of shoes. Their total bill was \$80.67. What price shoes did each buy?
3. What is the difference in cost between the least and most expensive shoes for men?
4. How much would 15 women and 12 men save by buying shoes on sale?
5. HM-c-62  
Melissa is buying a bike that costs \$177.50. She is going to give the storekeeper \$50.00 now and pay the rest in 5 monthly installments. How much money will she owe at each installment?
6. L-p-113\*  
Todd compared the price per pound for hamburger, turkey, chicken and steak. Steak costs the most. Chicken costs the least. Poultry costs less than beef. List the meats according to cost, starting with the most expensive.
7. HM-p-77  
Choices of colors for the school sweatshirt are red, green, and blue. Choices for the mascot are dolphin, leopard, and panda. How many different ways can the sweatshirt look?
8. AW-c-147  
Two cars pass each other going in opposite directions. One car is traveling 100 km/h and the other 80 km/h. How far apart will the two cars be after driving 45 minutes at these rates of speed?

## PROBLEM SET # 3

AW-p-99

1. A person's hair grows about 15 cm each year. A child's hair was 31 cm long on her fourth birthday. She cut off 5 cm of hair on her fifth birthday and 7 cm on her seventh birthday. How long was her hair on her ninth birthday?

AW-c-9\*

2. Adrienne had 9 records. She traded 4 of her records to Julius for 2 nearly new records. How many records did Adrienne have after the trade?

H-c-46

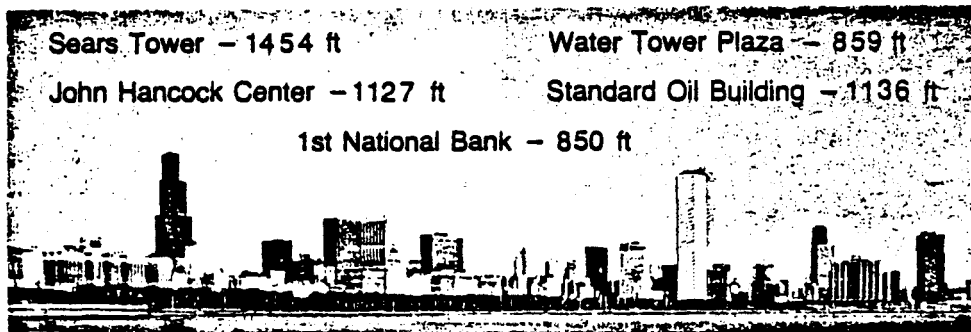
3. Sweaters which usually sell for \$25.95 were on sale for \$15.89. Chris bought two sweaters. How much money did he save by buying the sweaters on sale?

H-c-119

4. It costs \$450.00 to feed 60 students 5 meals. How much does each student meal cost?

HM-c-198\*

5. A company bought 3 small computers for each of the 4 floors of its home office. The same company bought 2 computers for each of the 2 floors of its out of town office. How many computers did the company buy altogether?



L-s-37\*

6. The Sears Tower is how many feet taller than the John Hancock Center?
7. If the three tallest buildings in Chicago were laid end to end, what would be the total length?

H-c-164

8. Fran wants to buy some tuna. Which is the best buy, 3 cans for \$2.67, 4 cans for \$2.98, or 6 cans for \$4.26?

## PROBLEM SET # 4

HM-c-85

Scott decided to enter his town's annual 10,000 Meter Race. To prepare for the race he has been following weekly schedules of exercise and diet. This chart shows Scott's goals for the final week before the race. Use the chart to answer the questions.

Mon	jog 5000 m; walk 2000 m; eat 150 g carbohydrates
Tues	bike ride 5000 m eat 150 g carbohydrates
Wed	jog 5000 m; walk 2000 m eat 175 g carbohydrates
Thurs	bike ride 7000 m eat 200 g carbohydrates
Fri	jog 6000 m; walk 2000 m eat 175 g carbohydrates
Sat	rest eat 205 g carbohydrates

1. How many more meters will Scott jog than bike ride?

2. If 2 ounces of spaghetti contain 41 grams of carbohydrates, how many ounces should Scott eat to fill his carbohydrate quota for Saturday?

3. On Friday Scott plans to eat 4 ounces of bread, 2 ounces of cheese and 6 ounces of noodles. An ounce of bread contains 13 grams of carbohydrates, an ounce of cheese contains 2 grams of carbohydrates, and an ounce of noodles 20 grams of carbohydrates. Will Scott fill his carbohydrate quota for Friday?

AW-s-65\*

4. Today's spacecraft travel fast enough to fly to Saturn and back to Earth in 4,453 days. How much longer is this than the 514 days it would take to fly to Mars and back to Earth?

H-s-219

5. Instructions on Spud's Mashed Potatoes calls for  $1\frac{1}{2}$  L of water and 2 L of milk. Peel's instructions call for  $2\frac{2}{3}$  L of water and  $\frac{2}{3}$  L of milk. Which brand uses more liquid?

HM-p-76

6. Jake wants to saw a log into 10 pieces to make stools for his clubhouse. If it takes 5 minutes to saw through the log, how long will it take to cut the log into 10 pieces?

H-c-185

7. August 31 is the last day of the season at camp. Next season begins July 1. How many days are there until camp reopens? (Do not use leap year.)

HR-p-181

8. Half of a treasure of coins was buried on White Island, and one-half of the remaining coins was buried on Sandy Island. That left 4,350 coins. How many coins were there at the start?



## PROBLEM SET # 5

SF-s-266

1. Mike paid \$16.50 for 6 tickets to a concert. Find the cost of each ticket.

HR-c-119\*

2. Al had 500 tickets to sell for Field Day. He sold 275 tickets. If 25 of the leftover tickets are sold each day, how many days will it take?

H-s-225

3. There were 356 sailboats in a regatta. Each boat had 3 sails. How many sails were there in all?

L-c-97

4. 33 students collected 825 cans the first day and 363 cans the second day. Find the average number of cans that each student collected.

HM-s-147\*

5. Daniel is making plant hangers for his friends at school. He needs 94 M of cord to make the plant hangers. The cord is sold in rolls of 25 m. How many rolls of cord should he buy?

HM-c-92

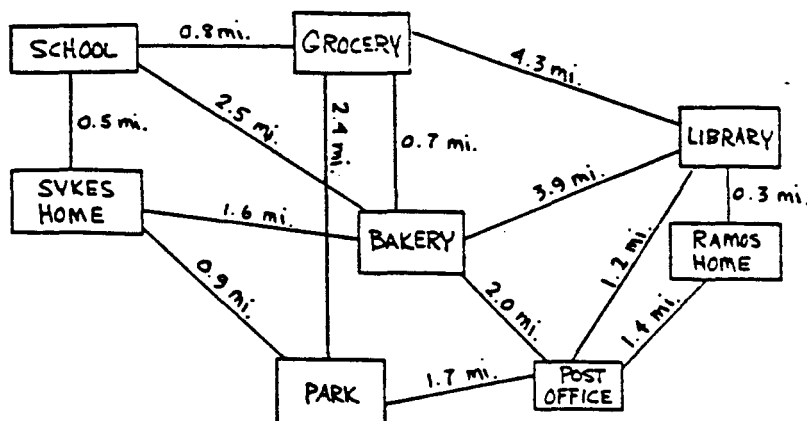
An odometer tells how far a car has been driven. The last number on an odometer shows the tenths of a mile. This odometer shows 7326.4 miles. Use the map of the town below to answer the questions.

7	3	2	6	4
---	---	---	---	---

6. How much farther is it from the grocery to the park than from the grocery to the school?

7. Mr. Ramos' odometer was on 12460.7 when he left his house. He went to the post office, then to the bakery, then to the grocery, then to the library, and then home again. What did his odometer show when he arrived home?

8. Gloria drove from the school to the grocery, then to the bakery, then to the Syke's house. Roberto drove from the library to the post office, then to the park, then to the grocery. Who drove the shortest distance?



## PROBLEM SET # 6

Soup & Sandwich Shop		
Homemade Soups & Homebaked Breads		
Soups	Sandwiches	Drinks
Fresh vegetable \$0.75	Egg salad \$1.24	Juices - small \$0.24
Chicken & noodle 0.87	Tuna salad 1.45	medium 0.49
Split pea w/ham 0.98	Roast beef 1.84	large 0.69
Chili 1.29	Ham 1.76	Milk - medium 0.39
		large 0.59
	Lunch Special \$2.39	
	(Soup, Salad, Sandwich, Milk)	

AW-c-124\*

1. Harry, Keith, Gil and Jess each are having a large milk and a roast beef sandwich. What will the total cost be?
2. Eunice and four friends are having the lunch special. How much will the 5 meals cost?
3. The Soup & Sandwich Shop serves an average of 476 customers a day. At this rate, how many customers are served in a year? (365 days)?

H-c-233

4. Singing star Kay Lynn can practice 4 1/2 hours on each of the next 5 mornings, or 3 1/4 hours on each of the next 7 evenings. Which way gives her more time to practice?

AW-c-16

5. Beth received \$54 for 9 hours work. Erin received \$36 for the same number of hours. How much more did Beth make per hour than Erin?

L-s-127

6. How many times must you run around a 1/2 mile track to run 5 miles.

HM-c-69

7. The school dance committee hopes to raise \$350 by selling admission tickets. They sold 428 tickets for \$.75. Did they reach their goal?

H-c-72

8. Cindy bought 2 rolls of film for \$4.56 each. She handed the cashier \$10.00. What was her change?

## PROBLEM SET # 7

Driving Distances (kilometers)	Chicago	Dallas	Denver	Miami	New York	Seattle
Chicago		1,506	1,614	2,189	1,352	3,261
Dallas	1,506		1,285	2,107	2,586	3,399
Denver	1,614	1,285	→	3,293	2,979	2,117
Miami	2,189	2,107	3,293	↑	2,140	5,506
New York	1,352	2,586	2,979	2,140		4,674
Seattle	3,261	3,399	2,117	5,506	4,674	

1. AW-p-59\*  
How far is a trip from Chicago to Seattle?
  2. How far is a trip from Chicago to Denver to Seattle and directly back to Chicago?
  3. How far is a trip from Seattle to Denver to Dallas and a return to Seattle the same way?
- HM-s-120\*
4. A cheetah moves about 9 times faster than a camel. The top speed of a cheetah is about 72 miles per hour. About how fast is the top speed of a camel?
- AW-p-74
5. Five girls ran in a 100-m dash. Debbie finished ahead of Carmen and Carmen was not last. Betty finished far ahead of Carmen, and Evelyn finished just behind Betty. If Darlene finished last, which girl finished next to last?
- H-s-261
6. Crenshaw Park is in the shape of a triangle. Its perimeter is 15 km. Two of the sides are each 4 km long. What is the length of the third side?
- H-c-85
7. Tickets to the roller coaster cost \$2 for adults and \$1 for children. Total ticket sales were \$27,372. If 9,872 children rode the roller coaster, how many adults rode it?
- H-c-193
8. John needs 1 cup of milk for one recipe, and 3 cups for another. How many pints of milk does he need in all?

## PROBLEM SET # 8

Carlson Family Monthly Expenses	
Rent	\$315 per month
Electricity	\$ 45 per month
Food	\$280 per month
Other Items	\$450 per month

- HM-c-103\*
1. What are the Carlson's total monthly expenses?
  2. How much more do the Carlson's pay for rent than food in 6 months?
- MW-c-5
3. An airliner has 50 rows of seats. Each row has 3 seats on one side, 4 seats in the middle, and 2 seats on the other side. How many seats are in the 50 rows?
- HM-c-139\*
4. One ladder costs \$57.75. A customer gave the clerk \$200 for 3 ladders. How much change will the customer receive?
- MW-c-9
5. Imported cheese costs \$1.70 for a half pound. How much will 2 pounds of the cheese cost?
- H-s-74
6. There were 196 people taking a plane to New York. There were 4 times as many people taking planes to California. How many people were going to California?
- MW-c-26
7. A restaurant has a special lunch. The lunch sells for \$3 for an adult's portion, and \$2 for a child's portion. How much will the restaurant charge for 11 adult's portions and 15 children's portions?
- MW-c-26
8. Suki's school collected 15,000 pounds of paper during a paper drive. The paper company paid \$1.45 for each 100 pounds of paper. How much money did the school get for the paper collected?

## PROBLEM SET #9

HM-c-43\*

1. About how many people went to animal shows?

2. The Dog Show attracted about how many more people than the Horse Show?

3. Total attendance at the county fair is expected to increase each year by 200. About what is the total attendance expected to be four years from now?

COUNTY FAIR	
Events	Attendance
Horse Show	1392
Bake Sale	832
Ring Toss	7356
Dog Show	2478
Balloon Burst	5942
Craft Sale	2359

AW-s-141

4. A scale model caboose is 12.2 cm long. Each centimeter on the model is exactly 0.87 m on the actual caboose. How long is the actual caboose?

AW-c-9

5. Each car of the Log Splash at the amusement park holds 9 people. An average of 8 cars are filled every 5 minutes. How many people ride the Log Splash in 10 minutes?

MW-p-14

6. You have a sheet of paper. You tear it in half. You stack the pieces and then tear the stack in half. Again you stack the pieces and tear the stack in half. How many pieces of paper do you have now?

HM-c-63

7. The local ice rink sent 5 free tickets, worth \$2.75 apiece, to each of 9 schools. What is the value of the tickets?

MW-s-3

8. A jet flight from Detroit to Los Angeles is 1969 miles. The flight from Los Angeles to San Diego is 109 miles. A passenger gets on at Detroit and gets off at San Diego, but the plane stops first in Los Angeles. How far does the passenger travel?

PROBLEM SET #10

WORLD OF SPORTS		
SALE! BIG SAVINGS		
Saturday Only!		
<b>Gold Seal Tennis Racquets</b> were \$47.00 NOW \$39.50		<b>Basketball</b> Sale Priced at \$15.99 Reg. \$19.99
	<b>All Tennis Shorts</b> NOW \$23.50 Save \$10.99	
<b>All Tennis Shirts</b> \$10.99 value NOW \$7.00		<b>10-Speed Bikes</b> were \$127.00 NOW \$108.75
	<b>Gold Seal Tennis Balls</b> Can of 3 NOW \$2.19 Reg. \$2.49	

HM-c-116\*

1. Tom earned enough money working at the sports shop to buy a tennis outfit. How much more money will he need to buy a racquet and one can of balls?

2. Tom's parents agreed to lend him one half the amount needed to buy a 10-speed bike. He has \$35.00 in his savings bank. The owner of the store has agreed to take the balance from his salary. Tom earns \$3.00 per hour. How many hours must he work to pay for the bicycle?

HR-s-277\*

3. Martha's cat climbed 3.75 m up the tree, then came down 1.69 m, before climbing up 2.09 m more. How far up the tree was the cat?

AW-p-182\*

4. If Gary multiplies his dog's age by 5 and subtracts 37, he gets 28. How old is his dog?

MW-p-2

5. A bus started out with only the driver on it. At the first stop, 7 people got on the bus. At the second stop, 2 people got on. At the third stop, 3 people got on and 2 got off. How many people were left on the bus?

MB-p-4

A cat, a small dog, a goat and a horse are named Angel, Beauty, King, and Rover. Read the clues to find each animal's name.

6. 1. King is smaller than both the dog and Rover.  
 2. The horse is younger than Angel.  
 3. Beauty is the oldest and is a good friend of the dog.

MW-p-3

7. A heavy truck had 6 axles. Five axles each had 4 wheels. The other axle had 2 wheels. What was the total number of wheels the truck had?

AW-p-70\*

8. Alton, Benton, Clinton, and Dunlap are towns on the same highway. Dunlap is between Alton and Clinton. Dunlap is 189 km from Alton. Clinton is between Dunlap and Benton. Clinton is 237 km from Benton. Alton and Benton are 671 km apart. How far apart are Dunlap and Clinton?

Problem Set # \_\_\_\_\_ Name \_\_\_\_\_

Show ALL work done to complete the problems.

1)	2)
Answer (labeled) _____	Answer _____
3)	4)
Answer _____	Answer _____
5)	6)
Answer _____	Answer _____
7)	8)
Answer _____	Answer _____

Problem Set # 1 Name Solution steps

$$\begin{array}{r} 1) \quad 8.34 \\ 12.2 \\ 24.03 \\ 10.769 \\ \hline \end{array}$$

Answer (labeled) 55.339 km

$$2) \text{ Amazon} = 4000$$

$$\text{Ohio} = A - 3019$$

$$\text{Nile} = \text{Oh} + 3206$$

$$\begin{array}{r} 4000 \quad 3206 \\ -3019 \quad +981 \\ \hline 981 \end{array}$$

Answer 4187 miles

$$\begin{array}{r} 3) \quad \text{June } 23 \times 18 = 414 \\ \text{July } 38 \times 14 = 532 \\ 532 \\ -414 \\ \hline 118 \end{array}$$

Answer 118 more in July

$$\begin{array}{r} 4) \quad \$2.95 \quad 24 \text{ min} \\ \$0.41 \quad 8.61 \quad - 3 \text{ min} \\ \times 21 \quad \hline 8.61 \quad 21 \text{ min} \end{array}$$

Answer \$11.56

$$\begin{array}{r} 5) \quad \$29 \text{ profit/week} \\ \times 52 \text{ weeks} \\ \hline 1508 \\ -9 \\ \hline 1499 \end{array} \quad \begin{array}{r} \text{Expenses} \\ \$9 \end{array}$$

Answer \$1,499 profit

$$\begin{array}{r} 6) \quad 1 \text{ gallon} = 4 \text{ qts} \\ 4 \text{ cups} = 1 \text{ qt} \\ 4 \text{ qt} - 1 \text{ qt} \end{array}$$

Answer 3 qt

$$\begin{array}{r} 7) \quad 69 \text{ inches} = 5 \text{ ft } 9 \text{ in.} \\ \text{Tara is } 5 \text{ ft } 9 \text{ in} \\ \text{Gina is } 2 \text{ inches shorter} \end{array}$$

Answer 5 ft. 7 in.

$$\begin{array}{r} 8) \quad 1 \text{ gallon} = 4 \text{ qt} \\ \frac{1}{2} \text{ gallon} = 2 \text{ qt.} \end{array}$$

Answer 2 qt

Show ALL work done to complete the problems.





Problem Set # 3 Name Solution steps

$$\begin{array}{r}
 1) \quad 15 \text{ cm each year} \\
 \times 5 \text{ yr} \\
 \hline
 75 \\
 + 31 \text{ at 4th birthday} \\
 \hline
 106 - 12 \text{ cm (cut)}
 \end{array}$$

Answer (labeled) 94 cm

$$\begin{array}{r}
 2) \quad 9 \text{ records} \\
 - 4 \text{ traded} \\
 \hline
 5 \\
 + 2 \\
 \hline
 \end{array}$$

Answer 7 records

$$\begin{array}{r}
 3) \quad \$25.95 \\
 - 15.89 \\
 \hline
 \$10.06 \text{ savings} \\
 \times 2 \\
 \hline
 \end{array}$$

Answer \$20.12

$$\begin{array}{r}
 4) \quad \begin{array}{l} \$7.50 / 5 \text{ meals} \\ 60 \overline{) 450.00} \\ \hline \\ \hline \end{array} \\
 \quad \begin{array}{l} \$1.50 \\ 5 \overline{) 7.50} \\ \hline \end{array}
 \end{array}$$

Answer \$1.50

$$\begin{array}{r}
 5) \quad 4 \text{ floors} \\
 \times 3 \text{ computers} \\
 \hline
 12 \text{ computers} \\
 \\
 2 \text{ floors} \\
 \times 2 \text{ computers} \\
 \hline
 4
 \end{array}$$

Answer 16 computers

$$\begin{array}{r}
 6) \quad 1454 \text{ Sears} \\
 - 1127 \text{ Hancock} \\
 \hline
 \end{array}$$

Answer 327 ft.

$$\begin{array}{r}
 7) \text{ Tallest buildings} \\
 \text{Sears} \quad 1454 \\
 \text{Standard Oil} \quad 1136 \\
 \text{Hancock} \quad \underline{1127}
 \end{array}$$

Answer 3,717 ft.

$$\begin{array}{r}
 8) \quad \text{Divide to find} \\
 \text{price per can.} \\
 2.67 \div 3 = .89 \\
 2.98 \div 4 = .75 \\
 4.26 \div 6 = .71
 \end{array}$$

Answer 6 cans for \$4.26

Show ALL work done to complete the problems.

Problem Set # 4 Name Solution steps

$$\begin{array}{r}
 \text{1) Jog} \\
 \underline{5000} \\
 5000 \\
 \underline{6000} \\
 16,000
 \end{array}
 \qquad
 \begin{array}{r}
 \text{Bike} \\
 \underline{5000} \\
 7000 \\
 \underline{\quad\quad} \\
 12,000
 \end{array}$$

Answer (labeled) 4000 m

$$\begin{array}{r}
 \text{2) } 2 \text{ oz} = 41 \text{ g} \\
 1 \text{ oz} = 20.5 \text{ g} \\
 10 \text{ oz} = 205 \text{ g}
 \end{array}$$

Answer 10 oz

$$\begin{array}{r}
 \text{3) } \begin{array}{c} \text{Food} \\ \text{Bread} \\ \text{Cheese} \\ \text{Noodles} \end{array}
 \quad
 \begin{array}{c} \text{Ounces} \\ 4 \\ 2 \\ 6 \end{array}
 \quad
 \begin{array}{c} \text{G} \\ \times 13 = 52 \\ \times 2 = 4 \\ \times 20 = 120 \\ \hline 176 \end{array}
 \end{array}$$

Answer yes

$$\begin{array}{r}
 \text{4) } 4,453 \\
 - 514 \\
 \hline 3,939
 \end{array}$$

Answer 3,939 days

$$\begin{array}{r}
 \text{5) } \begin{array}{c} \text{Spud's} \\ 1\frac{1}{2} \\ + 2 \\ \hline 3\frac{1}{2} \end{array}
 \quad
 \begin{array}{c} \text{Peel's} \\ 2\frac{2}{3} \\ + \frac{1}{3} \\ \hline 2\frac{4}{3} = 3\frac{1}{3} \end{array}
 \end{array}$$

Answer Spud

$$\begin{array}{r}
 \text{6) } \text{—————} \\
 9 \text{ cuts} \times 5 \text{ minutes}
 \end{array}$$

Answer 45 minutes

$$\begin{array}{r}
 \text{7) } \begin{array}{c} 30 \text{ S} \\ 31 \text{ Oc} \\ 30 \\ 31 \\ 31 \\ 28 \\ 31 \\ 30 \end{array}
 \quad
 \begin{array}{c} 31 \text{ M} \\ \underline{30 \text{ J}} \\ \hline \end{array}
 \end{array}$$

Answer 303 days

$$\begin{array}{r}
 \text{8) } 4,350 \times 2 = 8700 \\
 \quad \quad \quad \times 2 \\
 \hline 17,400
 \end{array}$$

Answer 17,400 coins

Show ALL work done to complete the problems.

Problem Set # 5 Name Solution steps

$$1) \quad \begin{array}{r} \$ 2.75 \\ 6 \overline{) 16.50} \end{array}$$

Answer (labeled) \$2.75

$$2) \quad \begin{array}{r} 500 \\ -275 \\ \hline 225 \text{ tickets} \\ \phantom{225} \overset{9}{\phantom{0}} \\ 25 \overline{) 225} \\ \underline{225} \phantom{0} \end{array}$$

Answer 9 days

$$3) \quad \begin{array}{r} 356 \\ \times 3 \\ \hline 1,068 \end{array}$$

Answer 1,068 sails

$$4) \quad \begin{array}{r} 825 \\ +363 \\ \hline 1188 \end{array} \quad 33 \overline{) 1188}$$

Answer 36 cans

$$5) \quad 25 \times 4 = 100 \text{ m}$$

Answer 4 rolls

$$6) \quad \begin{array}{r} \text{grocery to park } 2.4 \\ \text{" " school } 0.8 \\ \hline 1.6 \end{array}$$

Answer 1.6 miles

$$7) \quad 12460.7 \text{ (odometer)}$$

$$\begin{array}{r} 1.4 \\ 2.0 \\ .7 \\ 4.3 \\ .3 \\ \hline 12469.4 \end{array}$$

Answer 12469.4

$$8) \quad \begin{array}{r} \text{Gloria} \\ .8 \\ .7 \\ 1.6 \\ \hline 3.1 \end{array} \quad \begin{array}{r} \text{Roberto} \\ 1.2 \\ 1.7 \\ 2.4 \\ \hline 5.3 \end{array}$$

Answer Gloria

Show ALL work done to complete the problems.

Problem Set # 6 Name Solution steps

$$\begin{array}{r} 1) \quad 4 \times .59 = 2.36 \\ 4 \times 1.84 = 7.36 \\ \hline \$ 9.72 \end{array}$$

Answer (labeled) \$ 9.72

$$2) \quad 5 \times 2.39$$

Answer \$ 11.95

$$\begin{array}{r} 3) \quad 476 \\ \times 365 \\ \hline \end{array}$$

Answer 173,740 customers

$$\begin{array}{r|l} 4) \quad \text{Evenings} & \text{Mornings} \\ \hline 3\frac{1}{4} \times 7 = & 4\frac{1}{2} \times 5 = \\ \frac{13}{4} \times 7 = \frac{91}{4} = & \frac{9}{2} \times 5 = \frac{45}{2} \\ 22\frac{3}{4} \text{ hr.} & 22\frac{1}{2} \text{ hr.} \end{array}$$

Answer evenings

$$\begin{array}{r} 5) \quad \text{Beth} \quad \text{Erin} \\ \frac{\$ 6}{9 \overline{) 54}} \quad \frac{\$ 4}{9 \overline{) 36}} \end{array}$$

Answer \$ 2.00 per hour

$$\begin{array}{l} 6) \quad \frac{1}{2} \text{ mile track} \times 2 \\ 1 \text{ mile} = 2 \text{ times} \\ 2 \text{ times } 5 \text{ miles} = \end{array}$$

Answer 10 times

$$\begin{array}{r} 7) \quad \$ 350 \text{ to be raised} \\ 428 \text{ tickets} \\ \quad .75 \\ \hline \$ 321 \end{array}$$

Answer No, goal not reached

$$\begin{array}{r} 8) \quad \$ 4.56 \quad \$ 10.00 \\ \quad \times 2 \quad - 9.12 \\ \hline \$ 9.12 \quad \$ .88 \end{array}$$

Answer \$ .88

Show ALL work done to complete the problems.

Problem Set # 7 Name Solution steps

Show ALL work done to complete the problems.

1) Read schedule

Answer (labeled) 3,261 km

2) Chicago → Denver 1614  
 Denver → Seattle 2117  
 Seattle → Chicago 3261

Answer 6,992 km

3) Seattle → Denver 2117  
 Denver → Dallas 1265  
 Dallas → Denver 1265  
 Denver → Seattle 2117

Answer 6,764 km

4)  $9 \overline{)72}$

Answer 8 mph

5) 1 Betty  
 2 Evelyn  
 3 Debbie  
 4 Carmen  
 5 Darlene

Answer Carmen

6) Perimeter = 15 km  
 15 - 8 = 7

Answer 7 km

7) 9872 children @ \$1

$$\begin{array}{r} \$27,372 \\ - 9,872 \\ \hline \$17,500 \end{array}$$

Answer 8,750 adults

8) 1 c  
 3 c  
 $\frac{3c}{4c} = 2pt$

Answer 2 pt

Problem Set # 8 Name Solution steps

<p>1)</p> $\begin{array}{r} 315 \\ 45 \\ 280 \\ \hline 450 \end{array}$ <p>Answer (labeled) <u>\$1090.00</u></p>	<p>2)</p> $\begin{array}{r} \text{Rent } \$315 \times 6 = \$1890 \\ \text{Food } \$280 \times 6 = 1680 \\ \hline 210 \end{array}$ <p>Answer <u>\$210.00</u></p>						
<p>3)</p> $\begin{array}{r} 50 \text{ rows} \\ \times 9 \text{ seats/row} \\ \hline \end{array}$ <p>Answer <u>450 seats</u></p>	<p>4)</p> $\begin{array}{r} \$57.75 \quad \$200.00 \\ \times \quad 3 \quad -173.25 \\ \hline \$173.25 \end{array}$ <p>Answer <u>\$26.75</u></p>						
<p>5)</p> $\begin{array}{r} \$1.70 \times 2 = \$3.40 \\ \text{per pound} \\ \$3.40 \\ \times 2 \\ \hline \end{array}$ <p>Answer <u>\$6.80 for 2 lb.</u></p>	<p>6)</p> $\begin{array}{r} 196 \\ \times 4 \\ \hline \end{array}$ <p>Answer <u>784 people</u></p>						
<p>7)</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center; border-bottom: 1px solid black;">Adult</td> <td style="text-align: center; border-bottom: 1px solid black;">Children</td> </tr> <tr> <td style="text-align: center;"><math>11 \times 3</math></td> <td style="text-align: center;"><math>15 \times 2</math></td> </tr> <tr> <td style="text-align: center;"><math>33 + 30</math></td> <td></td> </tr> </table> <p>Answer <u>\$63.00</u></p>	Adult	Children	$11 \times 3$	$15 \times 2$	$33 + 30$		<p>8)</p> $\begin{array}{l} 15000 \text{ lb.} \\ 15000 \div 100 = 150 \\ 150 \times \$1.45 = \end{array}$ <p>Answer <u>\$217.50</u></p>
Adult	Children						
$11 \times 3$	$15 \times 2$						
$33 + 30$							

Show ALL work done to complete the problems.

Problem Set # 9 Name Solution steps

Show ALL work done to complete the problems.

1) Horse show 1392  
 Dog show + 2478  
                    

2) Dog show 2478  
 Horse show - 1392  
                    

Answer (labeled) 3,870 people

Answer 1086 people

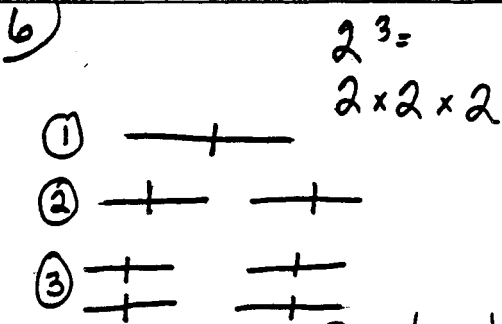
3) 1392                    20,359  
 832                    + 800  
 7356                                          
 2478                    21,159  
 5942                                          
 2359                                          
20,359

4) 12.2  
 x .87  
          

Answer 21,200 people

Answer 10.614 m

5) 8 cars  
 x 9 people / car  
        
 72 people / 5 minutes  
 72 x 2 = 144 people



Answer 144 people

Answer 8 sheets

7) \$ 2.75 / ticket  
 x 5 tickets  
        
 \$ 13.75  
 x 9 schools  
        
 \$ 123.75

8) Detroit to LA = 1969  
 LA to San Diego 109  
                      
 2,078

Answer \$ 123.75

Answer 2,078 miles



Problem Set # 10 Name Solution steps

Show ALL work done to complete the problems.

1) Racquet \$39.50  
 Balls 2.19  
\$41.69

2) \$35.00  
 \$108.75     24+hours  
 3 | 7325  
- 35.00  
 \$73.75 needed

Answer (labeled) \$41.69

Answer 25 hours

3)     3.75 ↑  
       -1.69 ↓  
       2.06  
       +2.09 ↑  
       4.15 m

4)  $(N \times 5) - 37 = 28$   
 $N \times 5 = 28 + 37$   
 $N \times 5 = 65$   
 $N = 13$

Answer 4.15 m

Answer 13 years old

5) Driver            1  
 Stop 1            +7            8  
 Stop 2            +2            10  
 Stop 3            +3            13  
                      -2            11

6)

	C	D	G	H
K	○	X	X	X
B	X	X	○	X
R	X	X	X	○
A	X	○	X	X

Answer 11 people

Answer \_\_\_\_\_

7) 6 axles      $5 \times 4 = 20$   
                   $1 \times 2 = 2$   
                            

8)     A     D     C     B  
       189     237  
                  671

Answer 22 wheels

      189            671  
      +237           -426  
      426           245  
                      245 km

Answer \_\_\_\_\_

APPENDIX B



Code Quest ②

#1 Backwards Code

Work Sessions

1 Date	
2 Date	
3 Date	
4 Date	
5 Date	
6 Date	
7 Date	
8 Date	
9 Date	
10 Date	
11 Date	
12 Date	
13 Date	



Alphabet Shift Code

Helpful Hints!  
Use H, T

Code Quest ④

#3

A														
B														
C														
D														
E														
F														
G														
H														
I														
J														
K														
L														
M														
N														
O														
P														
Q														
R														
S														
T														
U														
V														
W														
X														
Y														
Z														

Work Session Date →

1 2 3 4 5 6 7 8 9 10 11 12 13

## Code Quest ⑤

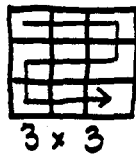
#	Word Code	Work Sessions
A	spaghetti	1
B	raisins	DATE
C	cream	
D	gum	2
E	fudge	DATE
F	sprinkles	
G	bananas	3
H	taffy	DATE
I	chili	
J	mustard	4
K	ketchup	DATE
L	hamburger	
M	pickles	5
N	prunes	DATE
O	pizza	
P	cookies	6
Q	soda	DATE
R	candy	
S	apples	7
T	cake	DATE
U	oranges	
V	strawberry	8
W	bread	DATE
X	milk	
Y	brownies	9
Z	beets	DATE

#5 Transposition Code

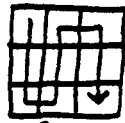
Helpful hints!

1. Use this code last!! It is difficult!
2. Use H to tell:  
Size of box grid  
Pattern used to place letters

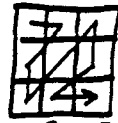
Examples :



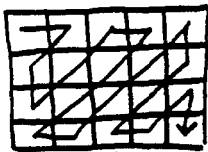
3 x 3



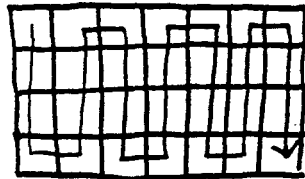
3 x 3



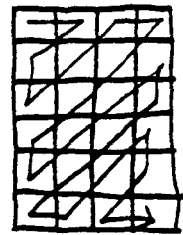
3 x 3



4 high 5 wide



4 high 6 wide



6 high 4 wide

### Work Sessions

1. Draw box grid
2. Trace pattern
3. Place letters



## Code Quest ⑦

#	Picture Code
A	apple
B	ball
C	cube
D	die
E	elephant
F	flower
G	ghost
H	heart
I	ice cream
J	jack-in-the-box
K	kangaroo
L	lips
M	mountain
N	nine
O	octopus
P	pencil
Q	quarter
R	rabbit
S	star
T	tree
U	umbrella
V	volcano
W	whale
X	X
Y	yacht
Z	zero

## Work Sessions

1	
DATE	
2	
DATE	
3	
DATE	
4	
DATE	
5	
DATE	
6	
DATE	
7	
DATE	
8	
DATE	
9	
DATE	

APPENDIX C

## APPENDIX B

CHILDHOOD ATTITUDE INVENTORY  
FOR PROBLEM SOLVING

SUBSCALES

2. SELF-CONFIDENCE (5 items): The higher the total score (5-25) the more confidence the student expresses in him/herself as an effective thinker. This component demonstrates a moderately high degree of internal consistency with a Cronbach alpha coefficient of .596 for the five-item scale. Underscoring this general conceptual unity, the composite factor accounts for almost 40% of the variation in the five contributing items ( $R^2 = 38.9$ ).
- I. Self-Confidence
4. I often have an idea for an answer which I don't tell because I am afraid it may be wrong. .714 (.367) (\*)
9. I usually find it hard to decide whether an idea is a good one or not. .532 (.273)
14. I would usually rather work on problems I know I can solve than on ones that may be too hard for me. .606 (.311)
19. Most of the students in my class are better at solving problems than I am. .645 (.331)
27. I often keep my ideas to myself because I think others may laugh at them. .610 (.314)
- My ideas for solving problems are not as good as the ones given by others in my class.
  - I usually get all confused when I am trying to solve a problem.
  - It is best to make very sure that an idea is a good one before suggesting it to the class.
  - I often make the same kinds of mistakes over and over again in solving problems.
  - I am a good solver of problems.

---

\* Accompanying each item is its factor loading on the parent factor, which is interpreted as the correlation coefficient between the item and the composite factor or as a regression weight in estimating the factor. Also designated in parentheses for each item is a factor score coefficient that can be multiplied by the student's response value (1-5) before the items are summed to derive the scale score.

SUBSCALES

- II. WILLINGNESS (6 items): *The lower the total score (6-30), the more the student expresses a willingness to open him/herself to experience, and to explore different, unusual and challenging ideas and tasks. This component demonstrates a moderately high degree of internal consistency ( $\alpha = .619$ ) with the composite factor accounting for 34.2% of the variation in the six items it includes.*

## II. Willingness

1. I think I have the makings of a really creative thinker. .570 (.278)
6. I am able to get unusual ideas, ideas that the other students don't often think of. .481 (.235)
12. When I am working on a problem, I usually like to figure things out by myself instead of getting my ideas from others. .508 (.248)
17. I like to work on problems like mysteries and puzzles that make me think. .694 (.338)
20. I am often curious about unexplained things around me and want to try to understand them. .520 (.253)
24. I am eager to learn. .696 (.339)
  - There is not enough work in school that makes you think up ideas of your own.

- III. PERSISTENCE (7 items): *The higher the total score (7-35) the more the student appreciates the need to be persistent in problem solving and receptive to a variety of ideas, and to avoid a habit-bound approach. The composite factor accounts for 33.0% of the variation in these 7 items as indicated by the relatively consistent internal structure of this component ( $\alpha = .656$ ).*

## III. Persistence

3. Problems are unfair that have more than one right way of solving them. .538 (.294)
5. It's best to stick with one idea. Students may become confused by too many ideas. .634 (.274)
8. It is unfair to make students keep searching for answers after they have already tried several times. .440 (.190)
21. If you don't have any good ideas after working on a problem a while, you will not be likely to get any. .680 (.294)
25. Finding new ideas for a problem that you have already finished just slows up things. .595 (.258)
29. The best advice for good thinking is to keep your desk neat so you can start off with a clear mind. .605 (.262)

SUBSCALES

## III. - Persistence - (cont'd)

30. Having too many ideas for solving a problem can be just as bad as having no ideas at all. .496 (.214)

- I am more interested in getting the right answer than knowing how to get it.

IV. RISK-TAKING (6 items): *The lower the total score (6-30) the less the student apprehends that good problem solving involves risks, making mistakes, exposing faulty thinking, and learning from errors. This component demonstrates a moderately high degree of internal consistency ( $\alpha = .664$ ), with the composite factor accounting for 37.8% of the variation in the remaining six items.*

## IV. Risk-Taking

2. Suggesting an idea that turns out to be wrong shows just how difficult thinking really is. .547 (.241)
7. Suggesting an idea which later is proven wrong shows that some students are better thinkers than others. .624 (.274)
10. Suggesting an idea which later turns out to be the wrong idea wastes time and holds things up. .786 (.254)
23. Students should keep ideas to themselves until they know they are right. .531 (.234)
26. Suggesting an idea which later turns out to be wrong means that someone was not paying attention. .549 (.242)

V. EFFICIENCY MYTH (3 items): *The higher the total score (3-15) the more the student presumes to appreciate the fact that good problem solving involves time and deliberation, and that progress is not always measured by speed of results. These three remaining items constitute a scale of relatively high reliability ( $\alpha = .745$ ) which indicates considerable consistency in this time perspective component of achievement behavior. This consistency is reflected in the fact that the parent factor (with its associated factor loadings) accounts for 66.2% of the variation in the three items it incorporates.*

## V. Efficiency Myth

15. The best problem solvers don't make mistakes. .762 (.384)
22. A good thinker usually sees the answer to a problem right away before most others. .798 (.402)
28. The best thinkers usually get the answer before most other students do. .877 (.441)
- When I'm trying to solve a problem, I often do not know how I got started on it.

VI. FIXED ABILITY MYTH (3 items): *The higher the total score (3-15) the more the student appreciates that individuals can improve in their problem solving capacity through the systematic application of practice and effort. The internal consistency of this scale ( $\alpha = .637$ ) allows us to tap this belief in a reasonably efficient manner with these three items. Consistency is further indicated by the proportion of variance in the three items ( $R^2 = .580$ ) accounted for by the composite scale.*

VI. Fixed Ability Myth

11. Some students are just naturally poorer at thinking than others and there is not much they can do to improve. .784 (.451)
16. Students who find it hard to work with ideas should be allowed to do other things in school. .795 (.456)
18. Ideas just seem to "come to you," and there isn't much you can do to get more. .705 (.405)







APPENDIX D

December 14, 1984

Dr. Don Torreson, Superintendent  
Waukegan Public Schools  
1201 North Sheridan Road  
Waukegan, Illinois 60085

Dear Dr. Torreson:

In order to provide you with necessary details concerning subject and school setting requirements, I am enclosing the following brief description of my project. I appreciate your taking the time to review this proposal.

In this study, two approaches to improved problem solving performance will be compared. Students in Group # 1 will participate in one period per week using math problem solving worksheet activities. In Group # 2 students will participate for one period per week using commercial computer programs designed to reinforce use of problem solving strategies.

Instruction will be delivered by the classroom teacher. Pre and posttesting on two evaluative instruments may be administered either by the classroom teacher, the school staff, or by myself or other Loyola personnel. These instruments will be:

1. a validated mathematics problem solving test and
2. the Childhood Attitude Toward Problem Solving, a survey to measure attitudes.

I also included a draft of the parental consent letter which may of course be modified to the specific district and school. I look forward to the opportunity to discuss further details in the near future. I may be contacted directly at the address indicated or through Dr. Hoover's office. Your interest in participation in this project is appreciated.

Sincerely,

Leah Melnik, Ph.D. candidate  
525 Aldine Avenue  
Chicago, Illinois 60657  
327-7764 (H) 955-2152 (W)

Todd Hoover, Ph.D., Acting  
Chairman  
Department of Curriculum and  
Instruction

## PROJECT OUTLINE

### Problem Solving Instruction Project

#### I Description

- A. This study will investigate the effects of specific instructional methods on the problem solving performance of selected fifth and/or sixth grade students.
- B. Instructional methods will consist of:
  - 1. Direct strategy training and instruction in written word problems.
  - 2. Student involvement with two commercial microcomputer software programs designed to facilitate use of problem solving strategies.

#### II Research Questions

- A. Will problem solving software facilitate higher performance on a math problem solving achievement test?
- B. Will problem solving worksheet instruction facilitate higher performance on a math problem solving achievement test?
- C. Will direct strategy training facilitate higher performance on a math problem solving achievement test?
- D. Will a change in student attitude toward selves in terms of problem solving be demonstrated?

#### III Procedure and Description of Treatment Groups

Six self contained classrooms will participate in ten weeks of instruction, with a total twelve week involvement (one week before and after for pre and posttesting.)

- 1. Two self contained (control) classrooms
- 2. Two problem solving worksheet classrooms participating in one hour per week of instruction within classrooms.
- 3. Two computer software classrooms, each student participating in one hour per week hands-on computer time.

#### IV Requirements from Participating School

- A. Up to six self contained classrooms (fifth or sixth grade)
- B. One hour available instructional period per week for worksheet groups
- C. Two microcomputer systems available for the ten week duration. The investigator will provide the software, which runs on the Apple II+ and Ile systems. (This software is also available for Atari and TRS-80 systems.)
- D. Teachers who are willing to participate.

WAUKEGAN PUBLIC SCHOOLS  
 Lincoln Center  
 For Educational Services  
 1201 North Sheridan Road  
 Waukegan, Illinois 60085

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OFFICE OF THE SUPERINTENDENT

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February 1, 1985

Dear Parent,

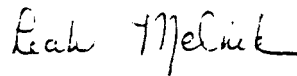
Your child is being offered an opportunity to participate in a mathematics problem solving program which will investigate two methods for improving the problem solving performance of fifth grade students. The program, which will be delivered by your child's teacher during regular school hours, will consist of one hour per week of specific problem solving and problem solving strategy instruction. No additional work will be required by you or your child.

Much attention is being given to the importance of problem solving for our students. A focus on problem solving skill development may improve not only academic performance as assessed by an achievement test, but may facilitate a positive attitude toward mathematics as well. Students who think of themselves as good problem solvers correlate this attribute with being good thinkers.

Students participating in this program will be pre and posttested at the beginning and conclusion of this twelve week program. Results of these tests will be kept confidential. Should you wish to know more about this study, please contact the principal, your child's teacher, or myself for further information.

Your cooperation in this study will be appreciated. Please fill in the lower portion of this letter and return it to school with your child.

Yours sincerely,



Leah Melnik

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I, the parent of \_\_\_\_\_  
 consent to his/her participation in the mathematics problem solving  
 instruction program.

Signature \_\_\_\_\_

APPROVAL SHEET

The dissertation submitted by Leah Melnik has been read and approved by the following committee:

Dr. Todd Hoover, Director  
Associate Professor, Curriculum and Instruction, Loyola

Dr. Diane Schiller  
Assistant Professor, Curriculum and Instruction, Loyola

Dr. Karen Gallagher  
Assistant Professor, Administration and Supervision, Loyola

The final copies have been examined by the director of the dissertation and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the dissertation is now given final approval by the Committee with reference to content and form.

The dissertation is therefore accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

11-2-85

Date

Todd Hoover

Director's Signature