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UMI®
COMPARATIVE EFFECTS OF THREE SUBSETS OF TEACHING EXAMPLES
ON GENERALIZED ARITHMETIC STORY PROBLEM SOLVING
BY FIRST GRADE STUDENTS

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By
Sayaka Endo, M. A.

*****

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2001

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ABSTRACT

Learning to solve arithmetic story problems is an important element of mathematics education. A significant number of students, including many students who can compute the underlying arithmetic operations, have difficulty with story problems. There are many different types and formats of story problems, and teachers, because they must cover the entire mathematics curriculum, can seldom provide students with explicit instruction and sufficient guided practice on each type and format. Therefore, it is important to know if teaching students to solve a subset of the full range of problem types and formats will enable them to solve the types of problems for which no instruction has been provided.

The purpose of this study was to explore if there were any differential effects of selected teaching examples on the generalization of story problem solving skills, and, if so, what kind of teaching examples would promote the most generalization.

Fifteen students in the first grade were divided into three groups and taught the following three different subsets of teaching examples. MCSP problems contained 6 teaching examples that sampled all 3 categories (Combination, Change, and Comparison) but that sampled only one type of mystery box equations. SCMP problems contained 6 teaching examples that sampled only one category (Change) but that sampled all 6 types of mystery box equations. MCMP problems contained 6 teaching examples that sampled
all 3 categories and all 6 types of mystery box equations. The three subsets of
teaching examples were taught through the instruction featuring the mystery box strategy,
choral responding, and response cards.

As results of the study, MCMP problems produced the most generalization of story
problem solving on answers and equations of untaught problems. Because the MCMP
problems were complicated, the students needed more instructional time for acquisition
of those problems as compared with MCSP and SCMP problems. However, students
were able to achieve more than 50% correct on answers and equations only after they had
received MCMP instruction. Moreover, the more instruction that students received on
MCMP problems, the more generalization they exhibited.
For all students who taught me joys and excitements of teaching
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INTRODUCTION

Learning to solve arithmetic story problems is an important element of mathematics education. After students have learned basic addition and subtraction facts (e.g., $4 + 5 = 9$, $7 - 3 = 4$), they are expected to solve story problems (e.g., "Joe has 5 marbles. Tom has 8 marbles. How many marbles does Tom have more than Joe?"). Story problem solving skills are worth learning because they are useful in everyday life for most people. For example, a homemaker examines the contents of the refrigerator, wondering what to prepare for dinner. The homemaker needs to use arithmetic story problem solving skills to find answers to questions that s/he has in his/her everyday life. Not only are story problem solving skills useful in everyday life, but it also has been noticed that instruction in arithmetic problem solving promotes students' mathematical understanding and achievement (Cathcard, Pothier, Vance, & Bezuk, 2000). The importance of instruction in story problems has been emphasized by National Council of Supervisors of Mathematics [NCSM] (1988) and National Council of Teachers of Mathematics [NCTM] (1989).

However, many students have difficulty solving story problems. National Assessment of Educational Progress [NAEP] (1992) reported that story problem solving presented
difficulties for students of all ability and age levels. A recent study also showed that significant numbers of students with and without disabilities do not demonstrate proficiency on story problems that are introduced or expected to be mastered at a specific grade level (Cawley, Parmar, Foley, Salmon, & Roy, 2001).

Solving story problems is difficult because it requires the use of various skills. One of the characteristics of arithmetic story problems is that they require integration of both reading and math skills. Therefore, to solve story problems, students need to have at least an adequate level of reading skills, including comprehension skills, and various math skills (e.g., number concept, correct use of math symbols).

Not only is solving a story problem complex, but there are also various types of problems within a large category of story problems. According to Kutz (1991), story problems are classified into three groups: nonroutine process problems, nonroutine puzzle problems, and routine problems. The nonroutine process problems are problems that deal with everyday problem solving and that have various processes to reach the correct answers. For example, “How much paint would be needed to paint the walls of your mathematics classroom?” is a nonroutine process problem. The second group, the nonroutine puzzle problems, contains problems that have many answers. For example, “How many different numbers can you make by inserting the operation symbols +, -, ., x, and ÷ along with the grouping symbols ( ) between the numbers 1, 2, 3, and 4? You may not change the order of the numbers or use any number more than once,” is a nonroutine puzzle problem. The final type is a routine problem. Problems in this group are traditional, typical story problems that are taught in mathematics education. An example of a routine problem is: “Dawn plants 6 rows of tomatoes in her garden, with 8 tomatoes in each row.
How many tomatoes does she plant? Moreover, each category of nonroutine and routine problems includes various subtypes of story problems. For example, in the category of routine problems, there are ones using addition, subtraction, multiplication, and division, as well as ones that can be solved by one-step operations and by two or more step operations.

Students have difficulty solving story problems because story problem solving is a complex task and there are various types of story problems; therefore, it is important to find and deliver effective and efficient instruction to teach story problems to students. The instructional time that is available for classroom teachers is limited, and in such a limited amount of instructional time, teachers need to teach students to solve various types of story problems with high accuracy.

Currently, various instructional strategies have been suggested for story problems (e.g., using manipulatives, using diagrams, emphasizing mathematical key words, teaching explicit number family concepts, teaching cognitive and metacognitive strategies, etc.). Previous research has demonstrated that students’ accuracy in solving story problems improved through the use of certain strategies. However, the focus of those previous studies is on the effectiveness of instruction but not on efficiency.

Efficient instruction can be defined as instruction that allows students to acquire more skills in less instructional time. Because there are various subtypes of story problems and the instructional time is limited, “efficient” instructional strategies are necessary to implement for teaching story problems.
Instruction that is more “efficient” allows students to solve, for example, one particular problem in one day, rather than allowing students to solve one problem in two days. However, instruction that has a great generalization effect—i.e., after which students could solve many untaught or not directly instructed problems—is also efficient.

Several studies have investigated the generalization effects of instructional strategies to find more efficient ways of instruction in math education. For example, Haugland (2000) reported that students do not need to practice all subtypes of multiplication facts, but that practicing half of them to a high level of fluency resulted in the desired effects of learning all the facts. Cooke and Reichard (1996) also found that students drilling a set of multiplication or division facts that contained 70% untaught facts and 30% taught facts resulted in higher acquisition and generalization on multiplication and division facts compared with drilling a set of facts that contained 30% untaught and 70% taught and a set of facts that contained 50% untaught and 50% taught. Thus, all subtypes of basic facts do not need to be taught, but students can solve untaught problems after certain types of instruction. If students can solve many untaught problems as a result of instruction, the instruction can be described as efficient.

However, not many studies have been conducted focusing on the generalization effects of instruction for story problem solving. The studies that have shown improvements of students’ story problem solving skills on taught problems have suggested the need for future research into the generalization effects (Endo, 2000; Harper, Mallette, Maheady, & Prenna, 1993). If teachers deliver efficient instruction that has the maximum generalization effects, students will be able to solve more story problems in a certain amount of instruction time. Since previous studies have successfully shown the
effectiveness of some instructional strategies on the acquisition of story problem solving, now would seem to be the time to shift focus from acquisition to the effects of instruction on generalization.

Several strategies have been suggested for promoting generalization. One of those strategies is called the general case strategy. In the general case strategy, students are taught a target skill through carefully selected teaching examples during the instruction sessions. As a result, the acquired skill tends to be generalized into many kinds of situations that the students face in non-instruction settings.

The general case strategy has been used to promote correct responding to untaught examples in purchasing skills (Frederick-Dugan, Test, & Varn, 1991), conversation skills (Hughes, Harmer, & Killian, 1995), staff skills at a institution for students with disabilities (Ducharme & Feldman, 1991), packaging skills (Hughes & Rusch, 1989), vending machine operation skills (Sprague & Horner, 1984), and appliance operation skills (Neef, Lenspower, Hockersmith, DePalma, & Gray, 1990).

For example, Sprague and Horner (1984) taught six students with moderate to severe retardation to use vending machines. At first, the students were taught how to use only one particular vending machine. Thus, when teaching the skills with one particular vending machine, the skill to use vending machines was not generalized to other types of vending machines. Sprague and Horner conducted then delivered two additional trainings: one with three similar vending machines (multiple training), and one with three machines that sampled the range of stimulus and response variation in a defined class of vending machines (general case training). As a result, after the general case training, the
participants showed a great extent of generalization. In sum, training with various kinds of examples that sample the range of characteristics of tasks could promote generalization.

Thus, the general case strategy allows students to respond to various types of untaught examples through instruction on some examples that have been systematically selected. Applying the framework of the general case strategy for story problems, instruction on some subtypes of story problems that are systematically selected may promote generalization of story problem solving skills.

PURPOSE OF THE STUDY

The purpose of this study was to explore if there were any differential effects of selected teaching examples on the students' ability to solve untaught story problems, and if so, what kind of teaching examples would promote the most generalization. Three sets of teaching examples were selected from 18 subtypes of addition and subtraction story problems. Instruction on the mystery box strategy with scripted lessons featuring choral responding and response cards was delivered for teaching those three sets of examples. Which set affected most positively on the generalization of story problem skills was studied.

RESEARCH QUESTIONS

This study was designed to obtain objective data in response to the following research questions.

1. How will students' accuracy in writing answers and equations to basic arithmetic story problems during and after instruction featuring the mystery box strategy, choral responding, and response cards compare to their pre-instruction performance on such problems?
2. What are the differential effects of three subsets of teaching examples selected regarding problem categories and types of positions of the mystery box on students' generalization of writing answers and equations to untaught story problems?

GLOSSARY OF KEY TERMS

Baseline - the first experimental conditions. No instruction was delivered and the target students answered several worksheets containing 18 subtypes of story problems.

Category - groups into which story problems using addition or subtraction were categorized. There were three categories: combination, change, and comparison.

Change problems - story problems dealing with the change of values through a process such as give-take, sell-buy, get-lose, etc. (e.g., “Mary had 5 pens. She bought 2 new pens. How many does she have now?”). The six subtypes of change problems are called change 1, change 2, and so on. The unknown values are the start value, the change value, or the ending value.

Choral responding - each student in the class or group responding orally in unison to a question, problem, or item presented by the teacher.

Combination problems - story problems combining two subgroups into one large group (e.g., “Sam has 3 papers. Amy has 5 papers. How many do they have in all?”). The six subtypes of combination problems are called combination 1, combination 2, and so on. The unknown values are the total or the value of one of the subsets.

Comparison problems - story problems comparing two sets and determining the difference (e.g., “Bob has 5 apples. Sue has 3 apples. How many apples does Bob have more than Sue?”). The six subtypes of comparison problems are called comparison 1,
comparison 2, and so on. The unknown value is the difference of two sets, the value of
the compared set, or the value of the referent set.

Equation - represents the story problems by numbers and math signs (e.g., +, -, =). In
this study, the mystery box that represents the unknown value of the story problem was
used in the equations in addition to numbers and math signs. For example, the equation
for the problem, "Mary had 5 apples yesterday. She ate some apples today. Now, she has
3 apples. How many apples did Mary eat?" was 5-□=3.

Follow-up - condition assessing the extent of maintenance effects of instruction. The
students answered the generalization test 1 or 2 weeks after the final generalization
session. One of the three groups did not have the follow-up phase.

Generalization - an experimental condition assessing the effects of instruction on
generalization. The students answered to the untaught problems in this condition.

Generalization test - worksheets used during generalization assessment and follow-up.
It contained 18 subtypes of story problems.

Individual Review Session - review sessions provided for students who could not
meet the criteria of mastery through small-group response card instruction sessions and
small-group worksheet instruction sessions. Problems that the student did not answer
correctly were reviewed individually through teacher modeling, teacher-directed practice,
and independent practice. The duration of an individual review session was 5 minutes.

Instructed problems - problems taught during instruction lessons through teacher
modeling, teacher-directed practice, and independent practice.

Instructed problems worksheet - worksheet used during small-group worksheet
sessions.
Instruction – the mystery box strategy was taught to solve some of the 18 subtypes of story problems. Instructions were scripted and they featured response cards and choral responding. Based on the teaching examples used in instruction, there were three kinds of instruction phases in this study with three different types of sessions: small-group response card instruction sessions, small-group worksheet instruction sessions, and individual review sessions.

Keywords - story problems contain some mathematical key words that suggest the types of operations. For example, “in all” in the sentence “They have 8 apples in all” is one of the key words. In addition, “get,” “more,” “less,” “younger,” “bought,” “give” and so on are key words.

Lesson Script – scripts describing what the teachers and the students say and do during instruction lessons. All instructions and responses were scripted in detail.

Lottery ticket – reinforcers delivered to individual students based on their performance on the worksheets. If a student answered all 6 problems correctly, three lottery tickets were delivered. If 5 problems were correct and 1 was incorrect, two tickets were delivered. When a student answered less than 5 problems correctly and did not skip any problems, 1 ticket was delivered. Each student’s name was written on the back of each earned lottery ticket, and the tickets stored in a can for a week. One or two tickets were picked on Fridays, and the students whose names were on the picked tickets received surprise presents.

Marble jar – For students’ good behavior during instruction phases, marbles were put into a marble jar as a group reinforcer. The marble jar filled with marbles could be exchanged for a pizza party.
Multiple-Category/Multiple-Position (MCMP) Group - the group of students who experienced Multiple-Category/Multiple-Position (MCMP) instruction twice as their instruction 1 and instruction 2.

Multiple-Category/Multiple-Position (MCMP) Instruction - instruction targeting teaching examples selected from multiple categories. The position of the mystery box in the correct equations also varied.

Multiple-Category/Single-Position (MCSP) Group - the group of students who experienced Multiple-Category/Single-Position (MCSP) instruction first, and Multiple-Category/Multiple-Position (MCMP) instruction next.

Multiple-Category/Single-Position (MCSP) Instruction - instruction targeting teaching examples selected from multiple categories. However, the position of the mystery box in the correct equations remained fixed.

Multi-step story problem - story problems solved by more than one addition and/or subtraction. For example, “3 people are in the bus. At the next stop, 2 got off and 3 got on. How many people are there in the bus now” is solved by more than one addition and subtraction, 3-2+3=4.

Mystery box - a box used to represent an unknown value in an equation. For example, the problem, “Mary has some marbles. Tom has 5 marbles. They have 8 marbles in all. How many marbles does Mary have?” can be represented by the equation, □+5=8. The box in the equation was called the mystery box.

Position of the Mystery Box - the position of the mystery box in the equation. For example, the position of the mystery box in the equation, □+3=5, is the beginning, and the middle for 3+□=5, and the end for 3+2=□, respectively.
Practice problems - problems given to the students at the end of each instruction session. Practice problems and Instructed problems were the same subtypes. However, the numbers, the subject names, and the object names were different.

Practice problems worksheet - worksheet used after instruction to assess students’ performance on instructed problems. Students answered to the worksheets independently.

Pre-experiment assessment - the assessment conducted before the experimental conditions to select the potential target students for this study. Computation skills, story problem solving skills, and reading comprehension were assessed.

Pre-experiment assessment test - the package consisting of a series of problems for pre-experiment assessment. The package contained addition and subtraction facts, story problems, and reading comprehension problems.

Prize – small toys or school supplies that were presented to the students whose lottery tickets were selected.

Probe – students’ performances were reported by probes, not by sessions. One probe contained 6 taught problems during instruction condition and contained 18 problems (taught and untaught) during baseline, generalization assessment, and follow-up condition.

Regrouping - carrying the value over to the next column (e.g. from one's column to ten's column) for addition facts, and borrowing the value from the next column (e.g., from ten's column to one's column) for subtraction facts.

Response cards - cards, signs, or other items that are held up by each student in the class to signal his/her answer to teacher-posed questions or problems. In this study, a white board with an equation line and an answer line were used as response cards.
Session – the period of time that students worked with the experimenter a day was called session. During an instruction phases, the students had at least 4 sessions (2 small-group response card instruction sessions and 2 small-group worksheet instruction sessions).

Single-Category/Multiple-Position (SCMP) Group - the group of students who experienced Single-Category/Multiple-Position (SCMP) instruction first and Multiple-Category/Multiple-Position (MCMP) instruction next.

Single-Category/Multiple-Position (SCMP) Instruction - Instruction targeting teaching examples selected from a single category, in this case Change. Although the category was single, the position of the mystery box varied from the beginning to the middle to the end of the correct equations.

Small-group response card instruction – One of the three types of instruction. New story problems were introduced according to the lesson script. Response card activities along with teacher modeling, teacher-directed practice, and independent practice were conducted. Response card instruction sessions took place on the first and the third days of each instruction phase.

Small-group worksheet instruction – One of the three types of instruction. Story problems that were taught on the previous day through response card instruction were reviewed using Instructed Problems Worksheets. The Independent practice stage was repeated for practicing taught story problems. The Worksheet instruction session took place on the second and the third days of each instruction phase.

Subtypes - six variations of story problems in each of the three categories. All six subtypes are different problems.
**Taught Problems** - problems taught during instruction phases. These problems were assessed during instruction phase to determine the level of acquisition and were also assessed during the generalization assessment phase to determine the level of maintenance.

**Teaching Examples** - problem subtypes selected for each of the three instructions. For Multiple-Category/Single-Position (MCSP) instruction, the teaching examples were Combination 1, Combination 5, Change 1, Change 2, Comparison 2, and Comparison 3. For Single-Category/Multiple-Positions (SCMP) instruction, they were Change 1, 2, 3, 4, 5, and 6. For Multiple-Category/Multiple-Position (MCMP) instruction, Combination 3, Combination 4, Change 4, Change 6, Comparison 3, and Comparison 5 were the teaching examples.

**Unknown value** - the number that represents the correct answer to a story problem.

**Untaught problems** - problems used to assess the extent of generalization. No instructions were delivered for these problems.
CHAPTER 2

REVIEW OF LITERATURE

The literature review has two major sections: teaching story problems and promoting generalized outcomes. The story problem section describes the definitions and categories of story problems, the factors affecting students' difficulties with story problems, and instructional strategies. The necessity of generalization programming during story problem instruction is also discussed. The section on generalized outcomes describes the types of generalized outcomes and various strategies used to promote generalization. Research on the general case strategy, an approach promoting generalized outcomes, is reviewed in detail.

Teaching Story Problems

Teaching arithmetic story problems is an important element of mathematics education and an area with which many students have difficulty. NAEP (1992) reported that story problem solving presented difficulties for students of all abilities and age levels. A recent study also showed that significant numbers of students with and without disabilities do not demonstrate proficiency on story problems introduced or expected to be mastered at a specific grade level (Cawley et al., 2001).
Story problems are difficult because several skills are required to solve them, and there are so many varieties of story problems.

Arithmetic story problems require integrating reading skills and math skills. To solve these kinds of story problems, students need to have an adequate level of reading skills, including comprehension skills, and various math skills (e.g., number concept, correct use of math symbols). Furthermore, they need to complete several steps to reach the correct answer. For example, to solve the problem, “Mary has 2 apples, Bob has 5 apples. How many do they have in all?” students need to (1) read the problem, (2) write an appropriate equation using arithmetic operation, and (3) compute the answer from the equation. To create an appropriate equation, students need to find the numbers needed for the equation, select the correct arithmetic operation(s), and put the numbers into the appropriate position in the equation sequence. In addition, to solve the equation, students need to complete various steps, especially when the equation is complex. Thus, solving story problems can be analyzed as a chain of behaviors (Cooper, Heron, & Heward, 1987). Since performing all of these steps of the chain correctly is necessary to reach the correct answer, it would be understandable that it is difficult for students to acquire story problem solving skills.

Not only is solving a story problem complex, but also there are various types of problems within a large category of story problems. According to Kutz (1991), story problems are classified into three groups: nonroutine process problems, nonroutine puzzle problems, and routine problems. Nonroutine process problems present problem solving that is relevant to everyday life, and students can follow various types of processes to reach the correct answer. For example, “How much paint would be needed
to paint the walls of your mathematics classroom?" is a nonroutine process problem. Nonroutine puzzle problems are the kind that have many answers. An example of a nonroutine puzzle problem is: "How many different numbers can you make by inserting the operation symbols +, -, \times, and ÷ along with the grouping symbols ( ) between the numbers 1, 2, 3, and 4? You may not change the order of the numbers or use any more than once." Finally, routine problems are traditional, typical story problems taught in mathematics education. Routine problems are ones that have only one correct answer, for example, "Dawn plants 6 rows of tomatoes in her garden, with 8 tomatoes in each row. How many tomatoes does she plant?" Moreover, each category of nonroutine and routine problems includes various subtypes of story problems. For example, in the category of routine problems, there are ones using addition, subtraction, multiplication, and division, as well as ones that can be solved by one-step operations and by two or more step operations.

Recently, mathematics education has emphasized teaching nonroutine problems. NCSM (1988) stated the following: "Learning to solve problems is the principal reason for studying mathematics. Problem solving is the process of applying previously acquired knowledge to new and unfamiliar situations. Solving word problems in texts is one form of problem solving, but students also should be faced with non-text problems" (p. 9 to 12). In addition, NCTM (1989) emphasized the importance of a "comprehensive and rich approach to problem solving in a classroom climate that encourages and supports problem solving effort" (p. 23). These two statements shifted researchers' and teachers' attention from teaching routine problems to teaching nonroutine problems (Catchcart, Pothier, Vance, & Bexuk 2000).
Catchcart et al. (2000) also stated that "traditional story problems [routine problems] found at the end of textbook chapters" do not qualify as bona fide problems (p. 40). I agree with the author that, compared with routine problems, nonroutine problems require higher mathematical thinking skills and other important general problem solving skills such as analyzing information or testing hypotheses. Therefore, students need to be able to solve nonroutine problems. However, in my opinion, students may not solve nonroutine problems if they do not have the skills to solve simple routine problems. In fact, many students have difficulty solving routine problems (Cawley et al., 2001).

Classifying Story Problems Using Addition or Subtraction

Routine story problems can be classified into two major groups: problems solved by addition or subtraction, and problems solved by multiplication or division. Moreover, each group is classified into subgroups based on the numbers used (e.g., single or multiple digits, fractions, decimals, etc.), the numbers of steps used to solve the equation (single step vs. multiple step), distracters (no irrelevant information vs. including irrelevant information), and sentence structure and vocabulary (familiar vs. unfamiliar).

Story problems requiring one addition or subtraction step are the focus of this dissertation. Those problems can be divided into three categories: combination, change, and comparison (Riley & Greeno, 1988). All subtypes in these three categories require just one addition or one subtraction to be solved. Table 2.1 shows all the subtype problems in these three categories. Combination problems combine two subgroups into one large group (e.g., "Sam has 3 papers. Amy has 5 papers. How many papers do they have in all?"). Change problems deal with the change of values from the beginning to the end through a process such as give-take, sell-buy, get-lose etc. "Mary had 5 pens. She
Table 2.1: Classification of arithmetic story problems based on Riley and Greeno (1988)
<table>
<thead>
<tr>
<th>Category</th>
<th>Subtype</th>
<th>Unknown Value</th>
<th>Key Word</th>
<th>Operation</th>
<th>Mystery Box Equation</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combination</td>
<td>1</td>
<td>Total</td>
<td>in all</td>
<td>+</td>
<td>3+5=8</td>
<td>Mary has 3 candies. Amy has 5 candies. How many candies do they have in all?</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Total</td>
<td>in all</td>
<td>+</td>
<td>3+5=8</td>
<td>Mary and Amy have some candies. Mary has 3 candies. Amy has 5 candies. How many candies do they have in all?</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Subset</td>
<td>in all</td>
<td>-</td>
<td>3+□=8</td>
<td>Mary has 3 candies. Amy has some candies. They have 8 candies in all. How many candies does Amy have?</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Subset</td>
<td>in all</td>
<td>-</td>
<td>□+5=8</td>
<td>Mary has some candies. Amy has 5 candies. They have 8 candies in all. How many candies does Mary have?</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Subset</td>
<td>in all</td>
<td>-</td>
<td>8-3=□</td>
<td>Mary and Amy have 8 candies in all. Mary has 3 candies. How many candies does Amy have?</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Subset</td>
<td>in all</td>
<td>-</td>
<td>8-□=5</td>
<td>Mary and Amy have 8 candies in all. Mary has some candies. How many candies does Mary have?</td>
</tr>
<tr>
<td>Change</td>
<td>1</td>
<td>Ending</td>
<td>Gave</td>
<td>+</td>
<td>3+5=8</td>
<td>Mary had 3 candies. Then Amy gave her 5 candies. How many candies does Mary have now?</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Ending</td>
<td>Gave</td>
<td>-</td>
<td>8-5=□</td>
<td>Mary had 8 candies. Then she gave 5 candies to Amy. How many candies does Mary have now?</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Change</td>
<td>Gave</td>
<td>-</td>
<td>3+□=8</td>
<td>Mary had 3 candies. Then Amy gave her some candies. Now Mary has 8 candies. How many candies did Amy give Mary?</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Change</td>
<td>Gave</td>
<td>-</td>
<td>8-□=3</td>
<td>Mary had 8 candies. Then she gave some candies to Amy. Now Mary has 3 candies. How many candies did she give to Amy?</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Start</td>
<td>Gave</td>
<td>-</td>
<td>□+5=8</td>
<td>Mary had some candies. Then Amy gave her 5 candies. Now Mary has 8 candies. How many candies did Mary have in the beginning?</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Start</td>
<td>Gave</td>
<td>+</td>
<td>□-5=3</td>
<td>Mary had some candies. Then she gave 5 candies to Amy. Now Mary has 3 candies. How many candies did Mary have in the beginning?</td>
</tr>
<tr>
<td>Compare</td>
<td>1</td>
<td>Difference</td>
<td>More</td>
<td>-</td>
<td>8-3=□</td>
<td>Mary has 8 candies. Amy has 3 candies. How many candies does Mary have more than Amy?</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Difference</td>
<td>Less</td>
<td>-</td>
<td>8-3=□</td>
<td>Mary has 8 candies. Amy has 3 candies. How many candies does Amy have less than Mary?</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Compared</td>
<td>More</td>
<td>+</td>
<td>3+5=□</td>
<td>Mary has 3 candies. Amy has 5 more candies than Mary. How many candies does Amy have?</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Compared</td>
<td>Less</td>
<td>-</td>
<td>8-3=□</td>
<td>Mary has 8 candies. Amy has 3 candies less than Mary. How many candies does Amy have?</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Referent</td>
<td>More</td>
<td>-</td>
<td>8-5=□</td>
<td>Mary has 8 candies. She has 5 more candies than Amy. How many candies does Amy have?</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Referent</td>
<td>Less</td>
<td>+</td>
<td>3+5=□</td>
<td>Mary has 3 candies. She has 5 candies less than Amy. How many candies does Amy have?</td>
</tr>
</tbody>
</table>
bought 2 new pens. How many does she have now?” is an example of a change problem.

Comparison problems compare two sets of objects and look at the difference between the two (e.g., “Bob has 5 apples. Sue has 3 apples. How many apples does Bob have more than Sue?”).

Problem categories (i.e., combination, change, and comparison) are shown in the first column of Table 2.1. Each category is composed of six problem subtypes. These six subtypes vary from one another based on the position of the unknown value (column 3). For combination, the unknown value that the students need to determine would be the total or value of one of the subsets. For change, it would be the start value, change value, or the ending value. For comparison, it would be the difference between two sets, the value of a compared set, or the value of a referent set. Column 4 represents the mathematical key words, such as “in all,” “gave,” “more,” and “less,” of each story. Each key word has the tendency of addition or subtraction. In other words, problems that contain the words “in all” are likely to evoke addition as the solution, and ones with “gave” are likely to evoke subtraction. The correct operation signs are shown in Column 5. For example, subtype 3 of the Change problem (Change 3) is solved by 8-3=; therefore, the operation of the subtype is -. Column 6 represents the mystery box equation for each subtype. The mystery box equation is an equation that represents the unknown value by an empty box and that put the values of each subtype in the order of the story. Since the mystery box equation is a key factor of this dissertation, it is described in detail later. An example of each subtype is shown in Column 7.
According to Riley and Greeno (1988), comparison problems are the most difficult to solve, and in each group, subtype 1 and 2 are easiest and subtype 5 and 6 are the most difficult. As can be seen, the operation suggested by the key word of the story and the correct operation are sometimes inconsistent (see Combination 3, Change 6, etc.). Such inconsistent problems are more difficult than consistent ones.

The mystery box equation helps to reduce the issue of the inconsistency described above between the key words and the operation. The mystery box equation is an equation that represents the unknown value as an empty box. If the problems are described with the mystery box, the mathematical key word and operation tend to be consistent. For example, Change 6 on Table 2.1 has the mathematical key word, “gave,” which suggests subtraction, but it is solved by addition. However, it can be described as subtraction if the mystery box is used. Thus, the operation in the equation and the operation suggested by the mathematical key word become consistent if the mystery box equation is used.

In this section, the story problems solved by one step addition or subtraction were described. This study focuses on those 18 subtypes of story problems (6 each of combination, change, and comparison). Although the levels of difficulty were discussed above regarding those 18 subtypes, the factors affecting the difficulties of story problems in general are introduced below.

Factors Affecting Story Problem Difficulty

Several factors affect the level of difficulty of story problems. The factors can be divided into two groups: student factors and problem factors. Student factors are students’ characteristics such as IQ, attention span, etc. Problem factors are
characteristics of the story problems themselves. Engelman and Carnine (1982, 1991) stated that it is better to analyze problems instead of analyzing students because we know how to control problem factors but not student factors at this point. Taking this position, I would like to describe only problem factors below as factors affecting the difficulty level of story problems.

First, as described above, the difficulty level of story problems is often dependent upon the category into which they fall. As Riley and Greeno (1988) reported, combination and change problems are easier than comparison problems.

Even within the same category, the level of problem difficulty varies greatly. For example, comparison problems with “unknown referents” (i.e., Comparison 5 and 6 on Table 2.1) are more difficult than comparison problems with “unknown differences” (Comparison 1 and 2) or with “unknown compared” (Comparison 3 and 4) (Geary, 1994; Lewis, 1989; Riley & Greeno, 1988). One factor that affects such a difference of difficulty among comparison problems is students’ varying levels of language development (Fuson, Carroll, & Landis, 1996). If students can change the sentence “I have 3 more than Tom,” into “Tom has 3 less than me,” they can solve the most difficult “referent unknown” comparison problem as a relatively easier “compared unknown” comparison problem. Stern (1993) found that, out of 47 participants in his investigation, most of the first graders could not identify the correct verbal statement describing a picture of, for example, three circles and four triangles. Also, Parmer, Cawley, and Frazita (1996) reported that when the key word and correct operation were not consistent
(e.g., solving problems including the word “more” with subtraction), students tended to show low performance compared with problems in which the key word and correct operation were consistent.

The problem text of the story also affects problem solving. Although many students cannot solve comparison problems correctly, they can answer the following question; “There are 5 birds and 3 worms. How many birds won’t get worms?” This “won’t get” problem can be solved by the same strategy used for solving comparison problems. However, if the problem is described differently, for example, “There are 5 birds and 3 worms. How many birds are there more than worms?” students cannot solve it (Geary, 1994). That is probably because the situation described by the word “more” is recognized differently from the one with the words “won’t get.”

The context described in the story problems is also one of the factors affecting the level of difficulty. The story of the problem should represent a real world situation. For example, Bassok, Chase, and Martin (1998) reported that a problem that required putting apples into baskets (i.e., dividing 30 apples by 5 baskets) was easier than one that required dividing baskets by apples (i.e., dividing 30 baskets by 5 apples).

Also, when the context of the problem is familiar for students, they tend to solve it correctly. Therefore, using “you” and “your sister” or the names of classmates as characters in the story problems helps lead them to the correct answer.

Although the context should be familiar, it is said that the use of “you” sometimes confuses students, on the other hand. d’Ailly, Simpson, and MacKinnon (1997) investigated the effects of “you” as a character in the solving of “compared unknown”
problems and “referent unknown” problems. In their investigation, 100 third to fifth grade students solved the following 6 problems:

1. “You have 3 apples. Bob has 2 more than you do. How many does Bob have?” 
   (Compare unknown, you-known);

2. “Bob has 3 apples. You have 2 more than Bob does. How many do you have?” 
   (Compare unknown, you-unknown);

3. “You have 3 apples. You have 2 more than Bob does. How many does Bob have?” 
   (referent unknown, you known);

4. “Bob has 3 apples. Bob has 2 more than you do. How many do you have?” 
   (referent unknown, you unknown);

5. “Tom has 3 apples. Bob has 2 more than you do. How many does Bob have?” 
   (compared unknown, control); and

6. “Tom has 3 apples. Tom has 2 more than Bob does. How many does Bob have?” 
   (referent unknown, control).

As a result, the percentage of correct answers on problems (1), (2), and (3) was better than control. However, the percentage of correct answers on problem (4) was worse than control. The authors concluded that the character “you” should not be used as the unknown part of “referent unknown” problems.

In addition to the above factors, if a problem requires two-step operations instead of one-step, the problem tends to be more difficult (Geary, 1994; Parmer, Cawley, & Frazita, 1996). Extraneous information (i.e., information that is not directly related to the correct problem solution) also disturbs appropriate solving behavior (Parmer, Cawley, & Frazita, 1996). High demands on students’ computation skills are one of the factors affecting
difficulties as well. When a problem requires addition without regrouping, it tends to be
easier than a problem with three-digit addition, even if the structure of the problem is
exactly the same (Geary, 1994).

In summary, the factors affecting the level of difficulty of story problems are the
semantic structure of the problem, students’ level of familiarity with the story, the
number of steps of operation required, the presence or absence of extraneous information,
and calculation demands.

**Instructional Strategies**

In this section, several instructional strategies for story problems are reviewed.
Unfortunately, there are not many studies experimentally investigating addition and
subtraction story problems. Therefore, strategies that can be used for other types of story
problems (e.g. multiplication/division, multi-step, algebraic) as well as strategies without
experimental investigations are introduced below.

All instructional strategies have two common features: (1) demonstration/modeling
of skills by teachers and (2) student practice with feedback until the skill is mastered
(Carnine, 1997). Studies looking for effective instructional strategies, in general, have
investigated what to teach and how to teach it. In terms of how to teach, researchers agree
on the usefulness of demonstration/modeling and practice with feedback. Therefore, the
aspects of “how to teach” are not targeted in this review. However, there are various
instructional strategies for story problems regarding “what to teach.”

**Manipulatives**

Using manipulative is a typical instructional strategy used in the classroom. Although
some researchers say that it is effective (Marsh & Cooke, 1996; Mwange & Sweller,
1998), or partially effective, (Endo, 2000; Endo, Sugiyama, & Sato, 1997; Stellingwerf & Van Lieshout, 1999), concerns over too much dependency on manipulatives (Jaspers & Van Lieschout, 1994) have been noted. When using manipulatives, we need to be careful about the logical use of manipulatives.

Geary (1994) stated that each story problem is solved by different strategies even when using manipulatives. Addition problems are solved by the "counting all" strategy, and there are three types of "counting all." The "adding" method is used for change problems, the "join" method for comparison, and the "no move" method for combination (see Figure 2.1).

"Adding" method: (Change problem)
Mary had 3 apples. She was given 2. How many does she have?
○ ○ ○ ○ ○ ○ ○

"Join" method: (Comparison problem)
Mary has 3 apples. Amy has 2 more apples than Mary. How many does Amy have?
○ ○ ○ ○ ○ ○ ○ ○

"No Move" method: (Combination problem)
Mary has 3 apples. Amy has 2 apples. How many do they have in all?
○ ○ ○ ○ ● ●

Figure 2.1: Manipulative strategies for addition problems

To solve change problems, the "adding" method is used. Students select three manipulatives (e.g., white blocks) when they read the first sentence of the change
problem, for example, “Mary had 3 apples.” Then they add two of the same type of manipulatives (e.g., if white blocks are used to represent the first sentence, students take the white blocks again) along with the second sentence, “She was given 2.” To answer the problem (“How many does she have?”), they count all the manipulatives in front of them.

To solve comparison problems, students tend to use the “join” method. They select three manipulatives when they read the first sentence of the problem, “Mary has 3 apples.” Then, after reading the second sentence, “Amy has 2 more apples than Mary,” the students select two more of the same type of manipulatives. The first three manipulatives represent the part of Amy’s apples, and the students answer the question “How many does Amy have?” by counting all the manipulatives.

The last method, “no move,” is used for combination problems. Students represent the sentence, “Mary has 3 apples,” by three, for example, white blocks, and use, for example, black ones to show “Amy has 2 apples.” Then they count all the manipulatives to answer the question.

When the problems are solved by subtraction, the “separating from” method is used for change and combination problems, and the “matching” method is used for comparison problems (See Figure 2.2).

The “separating from” method is used for combination and change. After reading the first sentence of a combination problem—for example, “Mary and Amy have 5 apples in all”—students take 5 manipulatives. Then they separate them according the second sentence, “Mary has 3,” and the rest of the manipulatives are Amy’s.
"Separating from" method:
Mary and Amy have 5 apples in all. Mary has 3. How many does Amy have?

\[ \begin{array}{c}
\text{O O} \\
\text{O O O} \\
\end{array} \]

"Matching" method
Mary has 5 apples. Amy has 2 apples. How many apples does Mary have more than Amy?

\[ \begin{array}{c}
\text{O O O O O} \\
\text{● ●} \\
\end{array} \]

Figure 2.2: Manipulative strategies for subtraction problems

The subtraction version of comparison problems is solved by using the "matching" method. Students take one type of manipulative to represent, for example, Mary’s apples, and take a different type of manipulative for Amy’s. Then they conduct one-to-one matching between Mary’s and Amy’s and find the answer.

If attention is paid to those strategies that are differently used for each type of problem, manipulatives may function successfully.

Also, the fading out of manipulatives is an issue to be treated with care. Marsh and Cooke (1996) report that the participants in their study could solve problems without manipulatives soon after the manipulative instruction. However, if students fail to transform their manipulative strategies into abstract strategies, the fading out of manipulatives should be carefully planned.

Diagram and Pictures

A diagram is a picture that represents a problem situation. In general, the use of diagrams is effective. For example, Bennet and Maier (1996) reported that diagrams were useful to teach algebraic mixture problems (e.g., “A doctor has one liter of a solution that
is 25 percent antiseptic and 75 percent water. How much water must be added to obtain a solution that is 15 percent antiseptic?"'). Lewis (1989) used diagrams to teach inconsistent problems (i.e., correct operation does not match the key word in the problem) with addition, subtraction, multiplication, and division.

There are some examples of use of diagrams for solving simple addition and subtraction problems (Jitendra & Hoff, 1996; Willis & Fuson, 1988). The diagram used in Willis and Fuson's study is seen in Figure 2.3. As a result of instruction using this diagram, students' correct use of equations was improved. Jitendra and Hoff's study is described in the later section.

Figure 2.3: Diagram used by Willis and Fuson (1988)
Teaching the use of diagrams for a particular problem type may not be so hard. However, if different types of diagrams have to be used, students need to learn which diagram can be used for which problem. Unfortunately, there is no research to investigate this issue. Also, the response generality of diagram-writing behavior should be considered. If students are taught to write diagrams for some problems, they may produce different but functionally working diagrams for other types of problems. This response generality issue should also be investigated in the future.

**Key Words**

Story problems usually contain mathematical key words such as "in all," "lose," "give," "more," "less," etc. Traditionally, story problems are taught by encouraging students to do addition if the key word suggests addition (e.g., "in all," "is given") and to do subtraction if the key word suggests subtraction (e.g., "lose," "less"). However, as I discussed before, the operation suggested by the key words and the correct operation are not always consistent. For example, the following problem, "Mary has 3. Joe has some. They have 6 in all. How many does Joe have?" requires subtraction even though it contains additive key words, "in all." Therefore, many researchers state that focusing on the key word is not an effective instructional strategy (e.g., Goldman & Hasselbring, 1997).

Cawley and Parmer (1992) suggest that examples of the relation between the key words and the operation should be presented negatively to students. Through such negative examples, students could understand that they should not focus solely on key words. For example, at the beginning, the relation between "left" and subtraction, "together" and addition, "times" and multiplication, and "among" and division are taught.
Then, the following question is introduced: “The boy divided his apples among his 6 friends so that each friend got 3 apples. How many apples did the boy start with?” As a result, the students may be able to clearly understand that they should not infer operation directly from the key word.

In addition, lessons that have students focus on the last problem sentence (e.g., “How many apples does Mary have?”) are typical. However, Cawley and Parmer (1992) cautioned that the teachers should be careful about this strategy because students may ignore the rest of the problem even though that information may be important to solve the problem correctly. To teach the importance of all parts of the problem, Cawley and Parmer suggested using the following four questions.

1. “A girl had 6 apples. The girl bought 3 more apples. How many apples does the girl have now?”
2. “A girl had 6 apples. The girl ate 3 apples. How many apples does the girl have now?”
3. “A girl had 6 apples. The girl bought 3 times as many apples. How many apples does the girl have now?”
4. “A girl had 6 apples. She divided them evenly between herself and a friend. How many apples does the girl have now?”

Given those examples, incorrect stimulus control by the last sentence of the problem can be prevented.

In summary, instruction emphasizing key words or key sentences of story problems should be carefully used, and it is important to avoid over stimulus control by such words and sentences.
Explicit Number Family Instruction

Problem solving can be interpreted as a chain of some behaviors, and it may be necessary to teach all steps of the chain in order to have students reach the final answer. Some instructional strategies focus on teaching each step of the problem solving chain explicitly (Carnine, 1997; Neef, 2001; Stein, Silbert, & Carnine, 1997).

Direct Instruction includes a strategy explicitly explaining the steps to solve story problems (Stein et al., 1997). This strategy focuses on the concept of the number family. First, students are taught transformation from word to math signs through teachers' demonstration and their own practice accompanied by feedback. For example, "get more" is transferred to a "+" sign. Next, students practice the calculation of number family facts. For example, they practice that "?" of $\frac{2}{5} \rightarrow 8$ can be obtained by 8-2, as well as $\frac{7}{2} \rightarrow 8$ by 8-2 and $\frac{6}{2} \rightarrow 8$ by 6+2. After students have acquired the concept of the number family, a story problem is introduced. A combination problem such as "Mary has 5. Amy has some. They have 8 in all," is taught in the following way. First, students are introduced to the concept of the "big number." For the example above, the big number is the total ("in all"), which is 8. Then the big number is put next to the arrow (e.g., $\frac{5}{?} \rightarrow 8$). Then, the other number, "5," and a "?" mark, which represents the answer, are put before the arrow (e.g., $\frac{5}{?} \rightarrow 8$). The problem solving is completed by obtaining the value for "?". Change and Compare problems are taught in the same manner using the concept of the number family and the big number. After students have learned each type of problem, all types are presented in mixed order and practiced.
The advantage of the Direct Instruction method is that students do not need to identify if the problem requires addition or subtraction. In addition, all types of problems can be solved in the same way by using simple diagrams. However, this method is logically difficult to apply, especially for comparison problems, because the diagram used is based on the addition concept (i.e., \(a + b \rightarrow c\) means \(a + b = c\)). However, the nature of the comparison problem is subtraction (i.e., bigger set – smaller set = difference) (Tucker, Singleton, & Weaver, 2001). Therefore, it may not sound logical to represent such comparison problems as smaller set + difference = bigger set. Research to address this concern is needed.

Darch, Carnine, and Gersten (1984) compared the effects of the Direct Instruction type explicit translation strategy against a basal instruction. The participants were 73 fourth graders. The tasks used were story problems using one-step multiplication or division. The explicit strategy group was taught to solve problems using multiplication if (1) the problems use the same numbers again and again, (2) they contain the word “each” or “every,” or (3) the big number is not given. Otherwise, they were taught that the problems could be solved by division. The basal instruction group was taught to (1) write the numbers used in the questions, (2) select the operation by restating the questions, deciding what is missing, (3) write the complete equation, and (4) find the answer. The four steps were taught through guided-discovery (i.e., discussion). As a result, the explicit strategy group exhibited a higher posttest score and a higher maintenance score. The authors concluded that it was important to teach each step required in solving the problems explicitly.
Gleason, Carnine, and Boriero (1990) reported that the same explicit Direct Instruction type strategy was effective when it was implemented not only by teachers but also by computers ("Computer-Aided Instruction." (CAI)).

Harper et al. (1993) used the Direct Instruction strategy in conjunction with classwide student tutoring teams. In their experiments, the Direct Instruction strategy was delivered by peers to small groups. The participants were 52 second graders. The task used was two types of combination problems and change problems. Multiple baseline design across problems was used, and the number of correct answers and correct strategies used (i.e., the correct use of the diagram \[ a \rightarrow b \rightarrow c \]) was observed. As a result, the number of correct answers improved. However, the number of correct strategies was not improved so clearly. The authors concluded that the students could find the answers without using the number family strategy and that they did not use the diagrams very well.

Jitendra and Hoff (1996) applied the direct instruction method to teach simple addition and subtraction story problems to three students (ages 8 to 10) with learning disabilities. However, they changed the diagrams from arrow diagrams to Schemata diagrams, as can be seen in Figure 2.4.

A multiple probe across subject design was used. Change, Combine, and Compare problems, as well as a mixture of all three types, were taught through two interventions. After each of the two interventions, probe data were taken. As the first intervention, students were presented with a story without the actual question sentence (i.e., the last sentence, "How many...?"") and taught how to put the numbers into schemata diagrams through demonstration and guided practice. During the second intervention, stories with question sentences were presented, and the students were instructed to identify the big
number and to solve the problems using the number family strategy. During the second intervention, students could access cue cards with rules to identify the big number and to solve the problems. As a result, the first intervention was not effective in changing the percentage of correct answers. After the second intervention, the level of percentage correct was drastically improved. However, the score decreased during maintenance.

Figure 2.4: Diagram used by Jitendra and Hoff (1996)
Neef (2001) argued that there were five steps in the chain of behavior to solve change problems. The five steps are (1) Finding the initial value, (2) Finding the change value, (3) Finding the operation, (4) Finding the ending value, and (5) Finding the solution. The participants of the study were two males (19 years old and 23 years old) who had second grade level reading skills and could solve number family facts using one digit numbers. They were first taught to identify the initial value (e.g., “How many does Mary have at the beginning?”). If the initial value was unknown, the participants were required to put a question mark. After they mastered this step, they were taught to identify change and the final value. Then the identification of the operation was taught. Each step was taught through modeling and social reinforcement, and the effects of the instruction were investigated by a multiple baseline across steps design. As a result, each step was acquired effectively, and the last single step for one participant and last two steps for another participant were acquired without any instruction. From this research, Neef concluded that building the earlier steps of the problem solving chain effectively evokes final solution of the problem. Furthermore, the final answer can be reached with a few lessons focusing solely on earlier components of the chain instead of teaching all steps of the chain.

Using response cards, Endo (2000) also used number family strategies to teach change problem to a group of elementary students. The nine participating students were taught to represent each sentence of the problem by a number or mystery box to create the equation. Most of the students improved their performance on the instructed problem subtypes, but the generalization of the effects of instruction to other subtypes of change problems could not be seen. In addition, the maintenance was not good.
In general, explicit teaching of the steps in the problem solving chain is effective. Such a conclusion is believable because relatively more studies have been conducted to examine the effects of this strategy. However, the effects of explicit teaching on maintenance and generalization should be investigated more carefully in the future.

Cognitive and Metacognitive Strategy Instructions

Explicit strategies, which are described above, basically originated from the field of behavioral analysis. On the other hand, cognitive psychology has suggested a different type of instructional strategies, called cognitive and metacognitive strategy instruction.

According to Montague and his colleagues (Montague, 1997; Montague, Warge, & Morgan, 2000), solving story problems includes seven types of cognitive processes: read (comprehension), paraphrase (translation), visualize (transformation), hypothesize (planning), estimate (prediction), compute (calculation), and check (evaluation). Furthermore, it contains three properties of metacognitive process: self-instruction, self-question, and self-monitor. During the cognitive and metacognitive instruction, students are introduced to the cognitive processes with self-regulations. Actually, students are taught the following list (see Figure 2.5). First, a teacher demonstrates how to do these steps when solving story problems. Then, students memorize all the steps and practice actual story problem solving.

Montague (1997) asserted the effectiveness of this instructional strategy for secondary students by reporting how the number of correct answers increased from the beginning of the instruction to the end of it. However, since the description of the experimental conditions and tasks was not clear enough, it is hard to find functional relations between this cognitive strategy and students’ performance.
Read (for understanding)
Say: Read the problem. If I don’t understand, read it again.
Ask: Have I read and understood the problem?
Check: For understanding as I solve the problem.

Paraphrase (your own words)
Say: Underline the important information. Put the problem in my own words.
Ask: Have I underlined the important information? What is the question?
Check: That the information goes with the question.

Visualize (a picture of diagram)
Say: Make a drawing or diagram.
Ask: Does the picture fit the problem?
Check: The picture against the problem information.

Hypothesize (a plan to solve the problem)
Say: Decide how many steps and operations are needed. Write the operation symbols (+, −, ×, ÷).
Ask: If do __, what will I get? If I do __, then what do I need to do next? How many steps are needed?
Check: That the plan makes sense.

Estimate (predict the answer)
Say: Round the numbers, in the right order.
Ask: Did I round up and down? Did I write the estimate?
Check: That I used the important information.

Compute (do the arithmetic)
Say: Do the operation in the right order.
Ask: How does my answer compare with my estimate? Does my answer make sense? Are the decimals or money signs in the right places?
Check: That all the operations were done in the right order.

Check (make sure everything is right)
Say: Check the computation.
Ask: Have I checked every step? Have I checked the computation? Is my answer right?
Check: That everything is right. If not, go back. Then ask for help if I need it.

Figure 2.5: Cognitive processes and self-regulation strategies for mathematical problem-solving instruction (Montague et al., 2000)
Mercer, Jordan, and Miller (1996) suggested a method of mnemonic instruction called FAST for solving story problems. FAST is a generic strategy that can be used. The components of this mnemonic are the following:

F – Find what you are solving: Underline the information that tells what to solve. This information is usually in the last sentence or in the sentence that poses a question.

A – Ask yourself, “What information is given?”: List information described with numbers as you read it.

S – Set up the equation: Determine the correct order of the numbers and determine the operation. With whole numbers, if the answer appears to decrease, the operation is subtraction or division; if the answer appears to increase, the operation is addition or multiplication.

T – Take the equation and solve it: Solve the problem from memory or use other strategies (e.g., DRAW, a mnemonic for a computation problem).

Cassel and Reid (1996) used these FAST and DRAW strategies to teach 4 elementary students to solve addition and subtraction story problems. The participants were 2 third graders and 2 fourth graders, with mildly handicapped. The tasks used were two-digit change, combination, and equalize (a variation of comparison) problems. The dependent variables were the number of correct equations and the number of correct answers. A combination of reversal and multiple baseline across subject design was used as the experimental design. Each student explored the first baseline followed by intervention for change and equalize problems, then the second baseline was implemented followed by intervention for combination and comparison questions and maintenance. Because of the nature of the experimental design they used, the generalization effects of the intervention...
to other uninstructed types of problems and the maintenance effects could be assessed. During intervention, the FAST and DRAW strategies were taught through discussion of the strategy, modeling by the teacher, memorization, guided practice, and independent practice. As a result, the number of correct equations for the intervened problems was improved for all four students soon after the interventions. In addition, some generalization effects resulted, and the improved levels of performance were maintained. However, the effect of intervention on the number of correct answers was not clear. The authors explained that was because they used two digit numbers.

Making Their Own Problems

Not only solving given problems, but also having students make their own story problems is one of the instruction methods that is also used. For example, Mercer and Mercer (1998) suggested having students write a story problem for a particular operation such as \(7-4=3\).

Rudnitsky, Etheredge, Freeman, and Gilbert (1995) experimentally investigated the effects of having students write their own problems. The participants for the study were 401 students in the third and fourth grades. They were separated into three groups. The structure-plus-writing group was taught problem solving through writing their own problems. The writing instruction was structured. The students were first introduced to various types of story problems (e.g., change, combination, comparison, multiple step, containing extraneous information), and then they were encouraged to make up all types of problems. They also solved problems that their classmates had made. The second group, the explicit group, was taught various types of story problems sequentially (change, combination first, then comparison, and multiple step) through independent
worksheets. In addition, on the board, problem solving tips (see Figure 2.6) were posted. The third group was the control group in which only the worksheet was used. As a result, the structure-plus-writing group showed greater improvement and better maintenance as compared with other two groups.

<table>
<thead>
<tr>
<th>Problem Solving Tips</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Understand the problem</td>
</tr>
<tr>
<td>State the problem in your own words.</td>
</tr>
<tr>
<td>Draw a picture.</td>
</tr>
<tr>
<td>Make a list of the information.</td>
</tr>
<tr>
<td>What is the question?</td>
</tr>
<tr>
<td>2. Make a plan</td>
</tr>
<tr>
<td>Decide on information to use.</td>
</tr>
<tr>
<td>Write a number sentence.</td>
</tr>
<tr>
<td>3. Use the plan.</td>
</tr>
<tr>
<td>Solve.</td>
</tr>
<tr>
<td>4. Check the answer.</td>
</tr>
<tr>
<td>Check your work.</td>
</tr>
<tr>
<td>Did you answer the question?</td>
</tr>
<tr>
<td>Does your answer make sense?</td>
</tr>
</tbody>
</table>

Figure 2.6. Problem solving tips used by Rudnitsky et al. (1995)

**Summary of Instructional Strategies**

The studies reviewed above reported on the effectiveness of their strategies, such as using manipulatives, diagrams, key words, explicit number family instruction, cognitive and metacognitive strategy instruction, and students making their own problems. However, it is hard to conclude which strategy is most effective at this point because there is little research that compares the effects of two (or more) strategies. If we want to find the most effective strategy, more comparison studies are needed.
Summary

There are various types of story problems, and they can be categorized in various ways. However, for story problems using addition and subtraction, Riley and Greeno’s (1988) taxonomy (i.e., categorizing story problems into three categories, Combination, Change, and Comparison with 6 subtypes in each category) has been considered as the most popular categorization.

Many studies have investigated factors affecting the level of difficulty of story problems. The factors reported include semantic structure of problems, students’ familiarity with the story, the number of steps of operation required, the presence or absence of extraneous information, and calculation demands. These factors should be controlled properly based on the types of research questions to be answered.

Currently, there are various instructional strategies available for teaching story problems, such as using manipulatives, diagrams, key words, explicit number family instruction, cognitive and metacognitive strategy instruction, and having students make their own problems. However, it cannot be said that enough research has been conducted to conclude which instructional strategy is the best for whom.

Although much more research is required to be conducted to find effective instructional methods for teaching story problems overall, I would like to list two ideas for future research below.

First, studies directly focusing on maintenance and generalization are necessary. Xin and Jitendra (1999) reported that 10 experiments out of the 15 they reviewed conducted maintenance assessment, but only within 2 weeks, and that only 7 assessed generalization effects. No matter which instructional strategies are used, skills acquired once should be
maintained long term. In spite of the importance of maintenance, much research has failed to show substantial maintenance results. Instead of hoping for automatic maintenance, maintenance should be planned and controlled experimentally and actively. The same argument can be applied to the generalization issue. It is very hard to teach all instances of story problems because there are hundreds of variations of them. Therefore, it would be helpful if we can find the ways that the skills taught once could be generalized to other uninstructed problems through stimulus generalization and response generalization. Such a generalization issue should be studied in the future.

Second, future research should target not only correct answers but correct strategy use as well. Answering correctly and using correct strategies are different behaviors. For simple addition and subtraction story problems that do not place a high demand on their computation skills, many students can reach correct answers without any rule-governed type strategies (Endo, 2000; Endo et al., 1997; Harper et al., 1993). In other words, students can get answers without any equations; instead, the answers pop up to them as intraverbals (Skinner, 1957, 1992). However, to aim for generalization from simple problems to large number problems, it is necessary to teach producing correct equations or correct strategies. Studies that consider the rate of correct strategy use as a dependent variable are thus necessary.

Based on those two ideas, this dissertation study focuses on the generalization of story problem solving skills. There has been various empirical research studies that have suggested ways of promoting generalization. In the following section, the literature on the topic of promoting generalized outcomes is reviewed.
Promoting Generalized Outcomes

As reviewed in the story problem section, one of the topics that needs future research is generalization. The concept of generalized outcomes is defined as behavior changes that have not been taught directly. Obtaining generalized outcomes is considered to be a desirable outcome of an applied behavior analysis program because it represents additional dividends in terms of behavior change (Cooper et al., 1987). Generalization of behavior has occurred when a newly learned behavior possesses one or more of the following outcomes: (1) the behavior proves durable over time, (2) the behavior appears in settings or situations different from the training setting and situations, and (3) functionally related behaviors that were not directly taught are emitted (Baer, Wolf, & Risley, 1968).

In this section, those three types of generalized outcomes and the strategies promoting them are briefly reviewed, and the general case strategy, which is one of the strategies promoting generalization and which was used in this dissertation study, is described in detail.

Types of Generalized Outcome

There are three types of generalized outcomes: maintenance, response generality, and stimulus generality.

Maintenance is the extent to which the target behavior that has been taught occurs after the termination of instruction. Response generality is the extent to which the learner exhibits a variety of untrained behaviors that are functionally equivalent to but
topographically different from the target behavior that was taught. Stimulus generality is the extent to which the target behavior occurs in settings that are different from the instructional settings.

In general, a behavior can be analyzed through a three-term contingency—its discriminative stimulus, its occurrence, and its reinforcement. For each of the generalized outcomes, the three term contingencies are not as same as the ones in their instructional settings. Table 2.2 shows whether or not each component of the three term contingencies is the same or different between instructional settings and generality settings.

<table>
<thead>
<tr>
<th>Generalized Outcome</th>
<th>Discriminative Stimulus</th>
<th>Response</th>
<th>Reinforcement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Stimulus Generality</td>
<td>Different</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Response Generality</td>
<td>Can be same or different</td>
<td>Same response class but different</td>
<td>Same</td>
</tr>
</tbody>
</table>

Table 2.2. Difference of antecedent, behavior, and consequence between instruction setting and generality setting

According to the definition, for maintenance, discriminative stimulus (Sd) and response should be the same from instructional setting to generality setting. Different reinforcers can be contingent, but if the response is the same between instructional
settings and generalized settings, the reinforcers or at least the class of reinforcers should be the same. For response generality, the response should be different from the one that was trained, but it should be functionally equivalent. In other words, response generality requires the occurrence of another response in the same response class of trained behavior. The reinforcer for the behavior can be different, but it should be the same if the generalized behavior is truly functionally equivalent. The definition of response generality does not clearly explain the sameness of discriminative stimulus/antecedents for response generality. Therefore, I interpret the definition to mean that the discriminative stimulus can be the same but also can be different from those in the instructional settings. For stimulus generality, the response has to be the same and it has to be followed by the same class of reinforcers in the generality settings. However, the discriminative stimulus preceding the response should be different in some ways from those in the instructional settings.

Therefore, it can be said that stimulus generalization is different from maintenance because stimulus generalization must occur in a situation different from the training setting. In addition, stimulus generalization is different from response generalization because stimulus generalization requires the occurrence of the target behavior that was taught.

**Strategies for Promoting Generalized Outcomes**

For the most desirable outcome, the target behavior should be maintained, and positive stimulus generalization and positive response generalization should occur. These generalized outcomes should be promoted by several strategies rather than simply be expected to occur naturally. There are six strategies (Aim for Natural Contingency of
Reinforcement, General Case Strategy/Teaching Enough Examples, Program Common Stimuli, Teach Loosely, Use Indiscriminable Contingencies, and Teach Self-management Skills) that have been suggested for promoting generalization (Stokes & Baer, 1977). In the following sections, each strategy is described.

Aim for Natural Contingency of Reinforcement

Generalization sometimes occurs but disappears because of a lack of sufficient reinforcement. Therefore, the researcher should control the nature of the reinforcement that follows the generalized behaviors that occur in generality settings.

To maximize reinforcement of the generalized behavior, the target skills need to be taught in the instructional setting until the student has sufficient strength and fluency in the skill.

In addition to teaching the skills in that way, the persons in the generality settings can be instructed to reinforce the generalized behavior if it occurs in the generality settings. The persons in the generality settings can be included in the instruction setting so that they could learn how to reinforce the behavior in the generality settings. Much research has used peers in the roles of reinforcement deliverers in the instruction setting and this has shown positive effects on generalized outcomes (e.g., Anderson, 1999; Farmer-Dougan, 1994; Marchand-Martella et al., 1992; Stewart, Van Houten, & Van Houten, 1992).

Recruiting reinforcement is another strategy that aims for a natural contingency of reinforcement. The students are taught to recruit teacher attention to receive feedback on their performance not only in the instructional setting but also in generality settings. If they can use the recruiting skill in the generality settings, the generalized behavior
occurring in the generality settings is likely to be maintained (e.g., Connell, Carta, & Baer, 1993; Craft, Alber, & Heward, 1998). Behavior traps can be also used as a strategy that aims for a natural contingency of reinforcement (Alber & Heward, 1996).

**General Case Strategy/Teaching Enough Examples**

Engelman and Carnine (1982, 1991) argued that selecting appropriate teaching examples is crucial to promote generalized outcomes. It is necessary to select multiple examples that systematically sample the full range of stimulus and response variation in the class of stimulus situations where responding is desired (Sprague & Horner, 1984).

Not only should many examples be taught in the instruction setting, but also those examples should be carefully selected. Since the taught behaviors should occur under various stimulus situations in the generality settings, the stimulus requirements of tasks that the subjects would face in the generality settings need to be carefully analyzed and to be included as teaching examples in the instruction setting. The response requirements also vary depending on the variation of the stimulus requirements of the tasks in the generality settings. Therefore, the response requirements of the tasks should also be analyzed and efficiently included as teaching examples.

Furthermore, presenting negative examples in addition to positive teaching examples reduces overgeneralizations (Horner, Eberhard, & Sheehan, 1986).

The relationship between example selection and generalization is supported by many studies (Ducharme & Feldman, 1992; Frederick-Dugan et al., 1991; Hughes et al., 1995; Hughes & Rusch, 1989; Neef et al., 1990; Sprague & Horner, 1984). Since this dissertation study used this general case strategy, literature dealing with this particular topic is reviewed in detail later.
Program Common Stimuli

When the target skills are taught in the instruction setting—particularly one that shares common stimulus characteristics with the generality settings—the target skills are likely to be generalized to untaught situations.

The integration of peers (who are the key characteristics of certain generality settings) into the instruction process showed positive effects on the promotion of generalized outcomes (e.g., Anderson, 1999; Farmer-Dougan, 1994; Marchand-Martella et al., 1992; Stewart et al., 1992).

The use of contrived portable stimuli that the target students can carry to the generalization settings has also been demonstrated as an effective strategy for generalization (For picture schedule, see MacDuff, Krantz, & McClannahan, 1993; For Tape-Recorded Recipes, Trask-Tyler, Grossi & Heward, 1994).

Teach Loosely

When the instruction setting includes various stimuli, it promotes generalized outcomes. The generality settings have a wide range of stimulus characteristics, such as people, physical objects, etc. On the other hand, the instruction settings tend to always have the same, specific stimuli. If so, the taught skills may be controlled by those specific stimuli in the instruction settings, then they may not occur in generality settings that have different stimulus characteristics from the instruction setting. To prevent this problem, varying the stimulus existing in the instruction setting is a useful strategy to promote generalization. Pierce and Schreibman (1997) demonstrated that the use of multiple peers...
as instructors was effective on generalization, and Matson, Sevin, Box, Francis, and Sevin (1993) showed positive generalization effects through instruction conducted by multiple therapists and in multiple settings.

**Use Indiscriminable Contingencies**

Behavior occurs as a function of reinforcement. When the occurrence of reinforcement can be expected for some reasons by the target students, the behavior occurs when the reinforcement is expected and does not occur when it is not expected. In the generality settings, the target behavior tends not to be reinforced continuously compared with the instructional setting. The reinforcement schedule expected in generality settings would be relative, and it may prevent the high rate of occurrence of the target behavior in the generality settings. Therefore, the training/instruction needs to be conducted using an intermittent, indiscriminable contingency of reinforcement.

Some studies showed that this “Use Indiscriminable Contingencies” strategy is effective on generalization (Baer, Blount, Detrich, & Stokes, 1987; Dunlap & Johnson, 1985; Dunlap, Koegel, & Johnson, 1987).

**Teach Self-management Skills**

The last strategy promoting generalized outcomes is to teach self-management skills. The person who always exists in the generality settings is the target student himself or herself. Therefore, if the student manages the presentation of discriminative stimulus and the delivery of reinforcement, the target behavior is likely to occur in the generality settings. Many studies have suggested various types of self-management skill teaching as
effective strategies for generalization (e.g., Ackerman & Shapiro, 1984; Grossi, Kimball, & Heward, 1994; Koegel, Koegel, Hurley, & Frey, 1992; Pierce & Schreibman, 1994; Smith, 1992; Stahmer & Schreibman, 1992).

**General Case Strategy**

In this section, the studies that used the general case strategy, which was featured in this dissertation study, are reviewed in detail.

Sprague and Homer (1984) taught six male high school students with moderate to severe retardation how to purchase items from vending machines. This skill was taught through prompts, praise, and error corrections. To investigate the effects of teaching an example selection, they set three conditions: (1) Single instance training, (2) Multiple instance training, and (3) General case training. The students were taught the purchasing skill with one certain vending machine in the single instance training condition, and with three similar vending machines in the multiple instance training. In the general case training, the teaching examples used were three machines that sampled the available range of stimulus and response requirements. These three conditions were introduced sequentially to three students, and the other three students experienced the single instance training followed by the general case training. The trials to criterion during the instructional sessions and the frequency of correct responding on non-trained probes were assessed. As a result, all students showed a great extent of generalization to untaught vending machines only after the general case training. The trials to criterion during instructional sessions were 14.8, 40.7, and 41.3 trials for the single instance training, the multiple instance training, and the general case training, respectively. This study showed
that only the general case training resulted in the generalized outcome although the
training took more time compared with the single instance and the multiple instance
training.

Ducharme and Feldman (1991) also compared the generalization effects of general
case training with single case training and the effects of common stimuli with simulation.
Nine staff members of a group home were trained to develop some staff skills for
teaching self-care routines to clients with developmental disabilities. They were exposed
to the following four conditions. The first condition was the provision of written
instruction. The staff members read the written instructions explaining tooth brushing or
hand washing. The second condition was the single case training. During this condition,
the staff members experienced performance-based training using a single program (tooth
brushing or hand washing) with a simulated client (one of the other staff members). In the
third, common stimuli training condition, the staff members taught the skills using a
single program but with an actual client. In the last condition, the general case training,
the teaching examples were selected from 12 programs such as putting on a shirt, doing
up snaps, lacing shoes, folding a towel, etc. A simulated client was used in this condition
as well. Within-program generalization (using the taught program(s) for the different
clients) and across-program generalization (using untaught programs for the different
clients) were assessed. The results showed that no staff members reached the criterion of
skill mastery for across-program generalization before they finished the general case
training. The same result was obtained from Ducharme and Feldman's study 2 in which
seven other staff members were taught the skills only through the general case training
following baseline. This study indicated that the common stimuli training had relative
effects on the within-program generalization but not on the across-program generalization. In addition, only the general case training was effective on the across-program generalization. The sequential effects were denied by their study 2.

Another comparative study was conducted by Neef et al. (1990). They taught the use of washing machines and dryers to four adults with mental retardation. In terms of instruction conditions, only one example of the appliances was used in the single case training while various types of machines were used as teaching examples in the general case training. In addition, the effects of in vivo training (using actual appliances) and simulation training (using photographs) were compared. A within subject Latin square design was used. The results indicated that more errors were made after the single case than after the general case training during the probe sessions. Although both the general case in vivo training and the general case simulation training promoted the generalized outcome, their time and cost analysis indicated that the general case simulation training was the more efficient one.

The effect of the general case strategy on the generalization of taught skills was demonstrated by Hughes et al. (1995) for the conversational skills of high school students with mental retardation, by Frederick-Dugan et al. (1991) for the calculator-assisted purchasing skills of students with moderate mental retardation, and by Hughes and Rusch (1989) for the soap packaging skills of two adults with severe mental retardation.

**Studies Promoting Generalization of Math Skills**

Several studies have succeeded in showing the effects of instruction on the generalization of students’ math skills (Abramson, Cooney & Vincent, 1980; Haugland, 2000; Cooke & Reichard, 1996; McDougall & Brady, 1998; Roca & Gross, 1996).
McDougall and Brady (1998) and Roca and Gross (1996) taught students with disabilities to use self-management strategies, which resulted in the generalization of instructed basic math computation skills across settings and time.

Cooke and Reichard (1996) found that drilling a set of multiplication or division facts that contained 70% untaught facts and 30% taught facts had more acquisition and generalization effects on multiplication and division facts when compared with drilling a set of facts that contained 30% untaught and 70% taught or a set of facts that contained 50% untaught and 50% taught. All subtypes of basic facts do not need to be taught since students can solve untaught problems after certain types of instruction.

In Haugland’s (2000) study, students practiced half of the multiplication facts to high level of fluency, based on the commutative property of multiplication facts (e.g., $7 \times 4 = 4 \times 7$). The author reported that the students did not need to practice all subtypes of the multiplication facts but that practicing half of them to a high level of fluency resulted in the desired effect of learning all the facts. Abramson et al. (1980) also reported that intensive training to a prespecified criterion was capable of producing generalization across concepts dealing with logicomathematical reasoning (i.e., identity conservation, equivalence conservation, and transitivity).

Although there is little research on the generalized outcomes of instruction on story problem solving, several studies have shown that generalization could be promoted in math skills.

**Summary**

To promote generalized outcomes, particular strategies need to be included in instruction for that purpose. Various studies have shown the effectiveness of six
strategies (Aim for Natural Contingency of Reinforcement, general case strategy, Program Common Stimuli, Teach Loosely, Use Indiscriminable Contingencies, and Teach Self-management Skills) on maintenance, stimulus generalization, and response generalization. Many of the studies reviewed resulted in the effectiveness of the general case strategy on generalization. Based on the research questions, the nature of the task to be taught, and the experimental resources, one or more strategies for promoting a generalized outcome are recommended to be included into instructional procedures. Those strategies can be and need to be included for math instruction as well.

Summary of Literature Review

The literature review demonstrated the following three points: (1) Effective strategies for story problem solving have not yet been established; (2) There is very little research on the maintenance and generalization of story problem solving skills; and (3) Several effective strategies for promoting generalization have been suggested in the field of behavior analysis. Therefore, in this dissertation study, the generalization of story problem solving was investigated using one of the strategies for promoting generalized outcomes that was suggested in the field of behavior analysis.

The 18 subtypes of story problems (Riley & Greeno, 1988) have been recognized as the clearest categorization of story problems. Therefore, those were used as tasks in this study. Among the various strategies for solving story problems, this study focused on the mystery box strategy because this strategy can be taught explicitly and can be used for all problem subtypes (Endo, 2000; Stein et al, 1997). To promote a generalized outcome, a variation of the general case strategy was implemented. The literature reviewed has suggested that students do not need to be taught all existing examples (Abramson et al., 55
1980; Haugland, 2000; etc.) and that the teaching examples should sample the range of stimulus and response requirements of the behavior that needs to occur in the generality settings (Ducharme & Feldman, 1992; Frederick-Dugan et al., 1991; Hughes et al., 1995; Hughes & Rusch, 1989; Neef et al., 1990; Sprague & Horner, 1984). However, the fuller range of teaching examples may need more time to be learned rather than less complicated teaching examples. Therefore, it is favorable to use teaching examples that not only promote the greatest extent of generalization but also ones that can be taught in less time. This study taught story problems through three different subsets of teaching examples and investigated what the most efficient instructional strategies are, if any, regarding the extent of generalization and the time needed to meet the criteria for skill mastery.
CHAPTER 3

METHOD

This chapter describes the methods used to conduct the study. It begins with a description of the participants and settings. The materials used are described next. The dependent variables are defined and the observation and measurement techniques are described. Procedures to assess believability of the data and integrity of the independent variable are explained. Procedures implemented during each of the study's experimental conditions—baseline, instruction, generalization, and follow-up—are detailed.

Subjects

Students in a first-grade classroom of one of the Columbus Public Schools served as potential subjects in this study. The classroom was chosen based on the school's curriculum content, needs and appropriateness of students as participants, and teachers' interest. A pre-experiment assessment was administered to all 19 students in the classroom to assess the students' computation, story problem solving, and reading skills. Based on the results of the pre-experiment assessment, the students were assigned into three groups. The general procedures and purpose of this study were described to the students' parents or guardians in letters from the experimenter (see Appendix A) and from the classroom teacher (see Appendix B). Parents were asked to sign a consent form
(see Appendix C) to allow their children to participate in the study. The procedures and purpose of the study were also explained to the principal of the school, and she was asked to sign a consent form (see Appendix D).

In the following section, the students’ demographic information, the procedure and results of the pre-experiment assessment, and the grouping are described.

**Students’ Demographic Information**

Table 3.1 shows demographic information as well as the results on the pre-experiment assessment for the 15 students who served as subjects of this study. At the beginning of the study, there were 19 students in the classroom and all of them participated in the study. However, three students had a high absentee rate and one student moved away from the school district. Therefore, the subjects who participated in the entire study totaled 15 students.

Of these 15 students participating in the study, 9 were boys and 6 were girls. Their ages ranged from 6 years 5 months old to 7 years 3 months old at the beginning of the study. At their school, the first graders were divided into three classrooms based on their reading performance. The students who participated in this study were in the classroom with the highest reading performance among the three first-grade classrooms in the school. None of the students had diagnosis of any disabilities.

**Pre-experiment Assessment**

Before the study, all students in the classroom participated in the pre-experiment assessment that was conducted to identify the level of computation skills and story problem solving skills of each student.
<table>
<thead>
<tr>
<th>Instruction Group and Student</th>
<th>Age</th>
<th>Sex</th>
<th>Computation Accuracy (%)</th>
<th>Story Problem Accuracy (%)</th>
<th>Reading Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Addition</td>
<td>Subtraction</td>
<td>Answer</td>
</tr>
<tr>
<td>MCSP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Andy</td>
<td>6-7</td>
<td>M</td>
<td>94</td>
<td>100</td>
<td>33</td>
</tr>
<tr>
<td>Ed</td>
<td>6-6</td>
<td>M</td>
<td>82</td>
<td>100</td>
<td>39</td>
</tr>
<tr>
<td>Alice</td>
<td>6-8</td>
<td>F</td>
<td>88</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>Amber</td>
<td>7-3</td>
<td>F</td>
<td>100</td>
<td>100</td>
<td>44</td>
</tr>
<tr>
<td>SCMP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Matthew</td>
<td>7-2</td>
<td>M</td>
<td>96</td>
<td>100</td>
<td>6</td>
</tr>
<tr>
<td>Theresa</td>
<td>6-10</td>
<td>F</td>
<td>100</td>
<td>75</td>
<td>28</td>
</tr>
<tr>
<td>Willy</td>
<td>6-11</td>
<td>M</td>
<td>83</td>
<td>100</td>
<td>22</td>
</tr>
<tr>
<td>Jason</td>
<td>7-3</td>
<td>M</td>
<td>75</td>
<td>100</td>
<td>28</td>
</tr>
<tr>
<td>Sam</td>
<td>6-5</td>
<td>M</td>
<td>67</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>MCMP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chuck</td>
<td>6-10</td>
<td>M</td>
<td>100</td>
<td>100</td>
<td>28</td>
</tr>
<tr>
<td>Debbie</td>
<td>6-8</td>
<td>F</td>
<td>100</td>
<td>100</td>
<td>28</td>
</tr>
<tr>
<td>Al</td>
<td>6-5</td>
<td>M</td>
<td>100</td>
<td>88</td>
<td>33</td>
</tr>
<tr>
<td>Amy</td>
<td>7-2</td>
<td>F</td>
<td>100</td>
<td>100</td>
<td>28</td>
</tr>
<tr>
<td>Tim</td>
<td>6-6</td>
<td>M</td>
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<td>0</td>
<td>17</td>
</tr>
<tr>
<td>Ali</td>
<td>6-5</td>
<td>F</td>
<td>86</td>
<td>80</td>
<td>22</td>
</tr>
</tbody>
</table>

Table 3.1: Students' demographic information and results of the pre-experiment assessment
Based on the results of the pre-experiment assessment, the experimenter planned to select some particular students who had high computation and reading skills but low story problem solving skills as participants in the study. However, since the classroom teacher preferred to have all students participate in the study, all students participated in the study regardless of their computation, story problem solving, and reading skills. Because it seemed that there was no correlation between the students' performance on the pre-experiment assessment and their final results in the study, all 15 students were considered to be participants.

During the pre-experiment assessment, the students answered questions on the Pre-experiment Assessment Test (see Appendix E). The test contained the following four subsections:

A. Addition Facts without Regrouping
   A.1. 45 single digit addition facts using the numbers 1 to 9 presented in the x+y= format (e.g., 3+2=)
   A.2. 45 single digit addition facts using the numbers 1 to 9 presented in the x+□=z format (e.g., 6+□=9)
   A.3. 45 single digit addition facts using the numbers 1 to 9 presented in the □+y=z format (e.g., □+1=3)

B. Subtraction Facts without Regrouping
   B.1. 45 subtraction facts using the numbers 1 to 10 presented in x-y= format (e.g., 8-3=)
   B.2. 45 subtraction facts using the numbers 1 to 10 presented in x-□=z format (e.g., □-□=5)
B.3. 45 subtraction facts using the numbers 1 to 10 presented in □-y=z format (e.g., □-8=2)

C. Story Problems

C.1. 18 subtypes of addition and subtraction story problems solved without regrouping (See Table 2.1)

D. Comprehensions

D.1. 3 reading comprehension problems (e.g., Mary has 5 candies. Tom has 3 chocolates. Who has candies?)

Procedures

Pre-experiment assessment was conducted over a period of 3 days. Students sat at their own desks, and all participated in the assessment at the same time. Instructions were delivered by the classroom teacher under the experimenter’s observation.

First, the students were instructed to open the first page of the Test so that Section A1 was revealed. The students answered the addition problems for one minute. Before beginning the 1-minute timing, the experimenter showed a model of 1-minute timing on the blackboard. The students were instructed to answer the questions in section A1 as quickly as they could.

The same 1-minute assessment was conducted for Sections A2 to B3.

Next, the students were asked to answer the story problems in Section C. They were told to write an equation and an answer for each problem. The classroom teacher read each problem to the students and they were given about 15 seconds to answer each problem. In Section D, the students’ reading comprehension was assessed informally. For
reading comprehension, the students read three questions written in a couple of short sentences and answered questions pertaining to what they had read. A period of approximately 3 minutes was given for Section D.

The completed pre-experiment assessment tests were collected and scored by the experimenter.

Results

Table 3.1 on page 59 shows a summary of the results of the pre-experiment assessment. The “Computation Accuracy” in Table 3.1 represents the percentage of correct answers on Sections A1 and B1 of the pre-experiment assessment test. Students showed a high percentage of correct answers for those problems. “Story Problem Accuracy” represents the percentage of correct answers and equations in Section C1 of the pre-experiment assessment. Students showed low accuracy on answers and even lower accuracy on equations. Most of the students showed high reading accuracy scores; however, some showed very low scores. Therefore, the experimenter decided to read the problems to the students in the study instead of having them read the problems by themselves. Complete sets of results can be seen in Appendix F.

Grouping

The students were divided into three groups based on their performance in the pre-experiment assessment and their results on baseline, which are described later.

This study was designed to assess the comparative effects of three subsets of teaching examples on generalized story problem solving; therefore, it was required that students could not yet solve story problems. However, some students showed high accuracy on problems that were included in one of the three subsets of teaching examples called
Multiple-Category/Single-Position. Therefore, students who performed extremely well on the Multiple-Category/Single-Position problems were assigned to the Multiple-Category/Single-Position group in order to leave enough room for assessing the generalized effects on untaught problems. In addition, the students were assigned to three groups to make the average skills of the students on computations equal across groups.

As mentioned before, 19 students participated in the study at the beginning. Therefore, each of the three groups had 6 to 7 students. Since four students were dropped from the study, the number of students in each group became 4, 5 or 6. Andy, Ed, Alice, and Amber were assigned to the Multiple-Category/Single-Position (MCSP) group, and Matthew, Theresa, Willy, Jason, and Sam were assigned to the Single-Category/Multiple-Position (SCMP) group. The rest, Chuck, Debbie, Al, Amy, Tim, and Ali were assigned to the Multiple-Category/Single-Position (MCMP) group.

Setting

The study was conducted in the students’ classroom. For the study, one group of students took part in small-group instruction and assessment sessions led by the experimenter while the students in other groups participated in activities conducted by their classroom teacher. The small group instruction and assessment was carried out in one corner of the classroom. For the instruction sessions that were conducted after the pre-experiment assessment and baseline, 30-minute lessons were delivered to the small group at the corner of the classroom. Twenty-minute generalization assessments (described in the Maintenance and Generalization Section) were also conducted in the setting. Follow-up assessments were conducted after all instruction was terminated.
Research Team

This study was conducted by an experimenter and two assistants.

Experimenter

The primary experimenter is a full-time Ph.D. student in special education at The Ohio State University. She holds B.S. and M.A. degrees in Psychology from Keio University in Tokyo, Japan, and a grade 7-9 social studies teaching certificate. She is a Board Certified Behavior Analyst and will have an Ohio K-12 teaching certificate in Specific Learning Disabilities upon completion of 2001. The experimenter delivered small-group instruction and assessment in this study, as well as scored the worksheets that the students completed during the study.

Assistants

Two other graduate students in special education at The Ohio State University helped as assistants to conduct this study. They implemented some of the generalization assessment sessions and scored some of the students’ worksheets as second scorers for accuracy checks (described in the later section).

Arithmetic Story Problems

The story problems used in this study were classified into two types: taught problems and untaught problems. Taught problems were the problems presented and practiced during instruction sessions, and untaught problems were the problems used for generalization assessments.

There are 18 subtypes in story problems as shown in Table 2.1 in Chapter 2 (page 18). The story problems are divided into three categories—Combination, Change, and Comparison—and each category is composed of six problem subtypes. Each subtype can
be solved by utilizing one of the 6 types of equations: \(x+y=D\) (e.g., \(3+5=8\)), \(x-y=0\) (e.g., \(8-5=0\)), \(x+\square=z\), \(x-\square=z\), \(\square+y=z\), and \(\square-y=z\). These six equations can be categorized further into three groups based on the position of the mystery box: beginning, middle, or end. Therefore, it can be said that each of the 18 problem subtypes can be characterized by two dimensions: category and position of the mystery box in the equation.

**Taught Problems**

This study investigated the comparative effects of subsets of teaching examples chosen from the 18 subtypes on generalization. The three subsets of teaching examples, which were taught to the students, were called as taught problems in this study.

The problems used as teaching examples were selected based on two dimensions: category and position of the mystery box in the equation. Category can be single (i.e., selecting all the teaching examples from one category, like Change) or multiple (i.e., selecting teaching examples from all three categories, Combination, Change, and Comparison). In the same way, the position of the mystery box in the equations can be single (i.e., selecting teaching examples from equations with the mystery box at the end, like \(x+y=\square\) or \(x-y=\square\)) or multiple (i.e., selecting teaching examples that cover all three positions of the mystery box in their required equations). Thus, four types of selection of teaching examples are possible. The first one is that the category is single and the position of the mystery box is also single (Single-Category/Single-Position). The second one is that the category is multiple but the position of the mystery box is single (Multiple-Category/Single-Position). The third one is that the category is single but the position of the mystery box is multiple (Single-Category/Multiple-Position). The fourth one is that both the category and the position of the mystery box are multiple (Multiple-Category/Multiple-Position).
Multiple-Position). From these four types of selections, three subsets other than Single-Category/Single-Position problems were used in this study. Single-Category/Single-Position problems were eliminated because previous research has reported that less generalization occurs when teaching examples are simple (Sprague & Horner, 1984).

Three instruction conditions were set in this study, and one of the three subsets of teaching examples were taught in each condition. The three instruction conditions were respectively called Multiple-Category/Single-Position Instruction (MCSP), Single-Category/Multiple-Position (SCMP) Instruction, and Multiple-Category/Multiple-Position (MCMP). The procedures in each instruction were the same, but the problems taught were different. The types of the taught problems are described in the next section.

Taught Problems for Multiple-Category/Single-Position (MCSP) Instruction

The problems taught during the MCSP instruction phase were taken from all three categories but the position of the mystery box remained fixed ($x+y=\Box$ or $x-y=\Box$). During the MCSP Instruction phase, the six problems shown in Table 3.2 were taught.

Taught Problems for Single-Category/Multiple-Position (SCMP) Instruction

The problems targeted in this SCMP instruction phase were selected from only one category, the Change problems. However, the equations that the students were required to use covered all six types. The problems taught in the SCMP Instruction are shown in Table 3.3.

Taught Problems for Multiple-Category/Multiple-Position (MCMP) Instruction

For the MCMP instruction phase, the six problems were selected from all three categories, and the required equations for those six problems covered all six types. The problems taught in the MCMP Instruction are shown in Table 3.4.
<table>
<thead>
<tr>
<th>Category</th>
<th>Mystery Box Position</th>
<th>Example Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combination 1</td>
<td>End x+y=□</td>
<td>Mary has x marbles. Joe has y marbles. How many do they have in all?</td>
</tr>
<tr>
<td>Change 2</td>
<td>End x-y=□</td>
<td>Mary had x marbles. Then she gave y marbles to Joe. How many marbles does Mary have now?</td>
</tr>
<tr>
<td>Comparison 2</td>
<td>End x-y=□</td>
<td>Mary has x marbles. Joe has y marbles. How many marbles does Joe have less than Mary?</td>
</tr>
<tr>
<td>Combination 5</td>
<td>End x-y=□</td>
<td>Mary and Joe have x marbles in all. Mary has y marbles. How many marbles does Joe have?</td>
</tr>
<tr>
<td>Change 1</td>
<td>End x+y=□</td>
<td>Mary had x marbles. Then Joe gave y marbles to Mary. How many marbles does Mary have now?</td>
</tr>
<tr>
<td>Comparison 3</td>
<td>End x+y=□</td>
<td>Mary has x marbles. Joe has y more marbles than Mary. How many marbles does Joe have?</td>
</tr>
</tbody>
</table>

Table 3.2: Taught problems for Multiple-Category/Single-Position (MCSP) instruction
<table>
<thead>
<tr>
<th>Category</th>
<th>Mystery Box Position</th>
<th>Problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change 1</td>
<td>End ( x+y=d )</td>
<td>Mary had ( x ) marbles. Then Joe gave ( y ) marbles to Mary. How many marbles does Mary have now?</td>
</tr>
<tr>
<td>Change 2</td>
<td>End ( x-y=n )</td>
<td>Mary had ( x ) marbles. Then she gave ( y ) marbles to Joe. How many marbles does Mary have now?</td>
</tr>
<tr>
<td>Change 3</td>
<td>Middle ( x+D=z )</td>
<td>Mary had ( x ) marbles. Then Joe gave some marbles to Mary. Now Mary has ( z ) marbles. How many marbles did Joe give to Mary?</td>
</tr>
<tr>
<td>Change 4</td>
<td>Middle ( x-D=z )</td>
<td>Mary had ( x ) marbles. Then she gave some marbles to Joe. Now Mary has ( x ) marbles. How many marbles did Mary give to Joe?</td>
</tr>
<tr>
<td>Change 5</td>
<td>Beginning ( □+y=z )</td>
<td>Mary had some marbles. Then Joe gave ( y ) marbles to Mary. Now Mary has ( z ) marbles. How many marbles did Mary have at the beginning?</td>
</tr>
<tr>
<td>Change 6</td>
<td>Beginning ( □-y=z )</td>
<td>Mary had some marbles. Then she gave ( y ) marbles to Joe. Now Mary has ( z ) marbles. How many marbles did Mary have at the beginning?</td>
</tr>
</tbody>
</table>

Table 3.3: Taught problems for Single-Category/Multiple-Position (SCMP) instruction
<table>
<thead>
<tr>
<th>Category</th>
<th>Mystery Box Position</th>
<th>Problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comparison 3</td>
<td>End</td>
<td>Mary has x marbles. Joe has y more marbles than Mary. How many marbles does Joe have?</td>
</tr>
<tr>
<td></td>
<td>x+y=□</td>
<td></td>
</tr>
<tr>
<td>Combination 3</td>
<td>Middle</td>
<td>Mary has x marbles. Joe has some marbles. They have z marbles in all. How many marbles does Joe have?</td>
</tr>
<tr>
<td></td>
<td>x+□=z</td>
<td></td>
</tr>
<tr>
<td>Combination 4</td>
<td>Beginning</td>
<td>Mary has some marbles. Joe has y marbles. They have z marbles in all. How many marbles does Mary have?</td>
</tr>
<tr>
<td></td>
<td>□+□=z</td>
<td></td>
</tr>
<tr>
<td>Comparison 5</td>
<td>End</td>
<td>Mary has x marbles. Mary has y marbles more than Joe. How many marbles does Joe have?</td>
</tr>
<tr>
<td></td>
<td>x-□=□</td>
<td></td>
</tr>
<tr>
<td>Change 4</td>
<td>Middle</td>
<td>Mary had x marbles. Then she gave some marbles to Joe. Now Mary has x marbles. How many marbles did Mary give to Joe?</td>
</tr>
<tr>
<td></td>
<td>x-□=z</td>
<td></td>
</tr>
<tr>
<td>Change 6</td>
<td>Beginning</td>
<td>Mary had some marbles. Then she gave y marbles to Joe. Now Mary has z marbles. How many marbles did Mary have at the beginning?</td>
</tr>
<tr>
<td></td>
<td>□-□=z</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.4: Taught problems for Multiple-Category/Multiple-Position (MCMP) Instruction
Instructed Problems and Practice Problems

In each instruction session, the students learned about taught problems through small-group instruction and subsequent independent practices. Problems for small-group instruction were called instructed problems, and ones for the independent practices were called practice problems. Instructed problems and practice problems in each of the three instruction conditions had the same structure as the teaching examples described above. However, the numbers, subject name, and object name (e.g., for “Bob has 9 apples,” “Bob” is the subject name, “9” is the number, and “apple” is the object name) in the stories varied across problems.

Untaught Problems

Untaught problems were the problems that were not taught to the students during the instructions and that were used to assess the generalization effects.

In this study, problems from the 18 subtypes that were different from the problems selected as taught problems were used as untaught problems.

Table 3.5 shows the taught and untaught problems for each instruction condition.

Materials

In this study, Lesson Scripts, Response Cards, Instructed Problems Worksheets, Practice Problems Worksheets, and Generalization Tests were used as well as some reinforcers. Each type of material is described below.

Lesson Scripts

All small-group instructions were guided by Lesson Scripts. The Lesson Script (see Appendix G) described the experimenter’s instruction and prompts, and the expected student responses, for lessons using choral responding and response card activities.
Table 3.5: Taught and untaught problems for each instruction condition
<table>
<thead>
<tr>
<th>MCSP Instruction</th>
<th>SCMP Instruction</th>
<th>MCMP Instruction</th>
<th>Category</th>
<th>Mystery Box Equation</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taught</td>
<td>Untaught</td>
<td>Untaught</td>
<td>Combination</td>
<td>$3+5=0$</td>
<td>Mary has 3 candies. Amy has 5 candies. How many candies do they have in all?</td>
</tr>
<tr>
<td>Untaught</td>
<td>Untaught</td>
<td>Untaught</td>
<td></td>
<td>$3+5=0$</td>
<td>Mary and Amy have some candies. Mary has 3 candies. Amy has 5 candies. How many candies do they have in all?</td>
</tr>
<tr>
<td>Untaught</td>
<td>Untaught</td>
<td>Taught</td>
<td></td>
<td>$3+□=8$</td>
<td>Mary has 3 candies. Amy has some candies. They have 8 candies in all. How many candies does Amy have?</td>
</tr>
<tr>
<td>Untaught</td>
<td>Untaught</td>
<td>Taught</td>
<td></td>
<td>□+5=8</td>
<td>Mary has some candies. Amy has 5 candies. They have 8 candies in all. How many candies does Mary have?</td>
</tr>
<tr>
<td>Taught</td>
<td>Untaught</td>
<td>Untaught</td>
<td></td>
<td>$8-3=□$</td>
<td>Mary and Amy have 8 candies in all. Mary has 3 candies. How many candies does Amy have?</td>
</tr>
<tr>
<td>Untaught</td>
<td>Untaught</td>
<td>Untaught</td>
<td></td>
<td>$8-□=5$</td>
<td>Mary and Amy have 8 candies in all. Mary has some candies. Amy has 5 candies. How many candies does Mary have?</td>
</tr>
<tr>
<td>Taught</td>
<td>Taught</td>
<td>Untaught</td>
<td>Change</td>
<td>$3+5=0$</td>
<td>Mary had 3 candies. Then Amy gave her 5 candies. How many candies does Mary have now?</td>
</tr>
<tr>
<td>Taught</td>
<td>Taught</td>
<td>Untaught</td>
<td></td>
<td>$8-5=□$</td>
<td>Mary had 8 candies. Then she gave 5 candies to Amy. How many candies does Mary have now?</td>
</tr>
<tr>
<td>Untaught</td>
<td>Taught</td>
<td>Untaught</td>
<td></td>
<td>$3+□=8$</td>
<td>Mary had 3 candies. Then Amy gave her some candies. Now Mary has 8 candies. How many candies did Amy give Mary?</td>
</tr>
<tr>
<td>Untaught</td>
<td>Taught</td>
<td>Taught</td>
<td></td>
<td>$8-□=3$</td>
<td>Mary had 8 candies. Then she gave some candies to Amy. Now Mary has 3 candies. How many candies did she give to Amy?</td>
</tr>
<tr>
<td>Untaught</td>
<td>Taught</td>
<td>Untaught</td>
<td></td>
<td>□+5=8</td>
<td>Mary had some candies. Then Amy gave her 5 candies. Now Mary has 8 candies. How many candies did Mary have in the beginning?</td>
</tr>
<tr>
<td>Untaught</td>
<td>Taught</td>
<td>Taught</td>
<td></td>
<td>□-5=3</td>
<td>Mary had some candies. Then she gave 5 candies to Amy. Now Mary has 3 candies. How many candies did Mary have in the beginning?</td>
</tr>
<tr>
<td>Untaught</td>
<td>Untaught</td>
<td>Untaught</td>
<td>Comparison</td>
<td>$8-3=□$</td>
<td>Mary has 8 candies. Amy has 3 candies. How many candies does Mary have more than Amy?</td>
</tr>
<tr>
<td>Taught</td>
<td>Untaught</td>
<td>Untaught</td>
<td></td>
<td>$8-3=□$</td>
<td>Mary has 8 candies. Amy has 3 candies. How many candies does Amy have less than Mary?</td>
</tr>
<tr>
<td>Taught</td>
<td>Untaught</td>
<td>Taught</td>
<td></td>
<td>$3+5=□$</td>
<td>Mary has 3 candies. Amy has 5 more candies than Mary. How many candies does Amy have?</td>
</tr>
<tr>
<td>Untaught</td>
<td>Untaught</td>
<td>Untaught</td>
<td></td>
<td>$8-3=□$</td>
<td>Mary has 8 candies. Amy has 3 candies less than Mary. How many candies does Amy have?</td>
</tr>
<tr>
<td>Untaught</td>
<td>Untaught</td>
<td>Taught</td>
<td></td>
<td>$8-5=□$</td>
<td>Mary has 8 candies. She has 5 more candies than Mary. How many candies does Amy have?</td>
</tr>
<tr>
<td>Untaught</td>
<td>Untaught</td>
<td>Untaught</td>
<td></td>
<td>$3+5=□$</td>
<td>Mary has 3 candies. She has 5 candies less than Mary. How many candies does Amy have?</td>
</tr>
</tbody>
</table>
The script precisely illustrated each step of the lessons such as (1) introduction of new problems targeted, (2) teacher-modeling (i.e., the experimenter shows how to solve the problems), (3) teacher directed practice, and (4) independent practice. The scripts also showed the timing of questions by the experimenter, praise, and corrections. For example, teacher directed practice could be seen in the script as follows:

Experimenter: "Read the next question with me. Put your finger at the beginning of the first sentence. I’ll count to 3, then read it. 1, 2, 3!” (signal)

Students: (chorally responding) “Bob has 5 apples.”

Experimenter: “Good! Bob has 5 apples. So I’m going to write 5 here on the board.”

(Then experimenter writes 5 on the response card and shows it to the students as a model.) “Now your turn. Bob has 5 apples; so write 5 on your board.”

Students: (Write 5 on their response cards.)

Experimenter: “Show me your board. Cards up!”

Students: (Hold up response cards to display the answer to the experimenter.)

Experimenter: (After checking all the answers,) “Great! All Correct! Let’s go on to the next sentence. Put your finger on the second sentence…”

By following the scripts during the lesson, the experimenter provided students many opportunities for active student responding, as well as positive and corrective feedback.

Response Cards

Response cards are cards, signs, or other items that are held up by each student in the class to signal his/her answer to teacher-posed questions or problems (Heward, Gardner, Cavanaugh, Courson, Grossi, & Barbetta, 1996). In this study, each student used response
cards during instruction. Each response card was a 10-inch x 16-inch piece of particleboard with white laminate one side (see Appendix H). On the white side, the line for the equation and the line for the answer were printed permanently. In addition, there was a yellow line over which the first number of the equation was written, a circle for the operation symbol (plus "+" or minus "-"), a pink line for the second number of the equation, an equal sign "="; and a green line for the last number of the equation. Students used dry erase markers to write answers to the experimenter's questions.

Instructed Problem Worksheet

The students answered the Instructed Problem Worksheet during some of the scripted lessons (see Appendix I). The worksheet was on 8½ x 11-inch paper and contained examples of each of the instructed problems. The same structure was used for each problem, but the numbers and names in the problems were changed.

During a session of each instruction phase, the students were taught three problems from the six taught problems so that two examples of the three taught problems were on the instructed problem worksheet. The lessons using Instructed Problem Worksheets were delivered 6 to 9 times, so that 6 to 9 different worksheets were prepared for each instruction condition.

Practice Problems Worksheet

At the end of each lesson, students were given time to practice the taught problems independently. During the practice time, the practice problems worksheet was used (see Appendix J). The worksheet was on 8½ x 11-inch paper and contained six problems (one example each of six of the taught problems). This worksheet served as a
probe during the instruction phase. Students answered one worksheet in a session and there were six to eleven sessions in each instruction condition. Therefore, six to eleven different worksheets were prepared as Practice Problem Worksheets.

Generalization Test

The students took a Generalization Test (see Appendix K) in the week after they had been instructed. The test was presented on 8 ½ x 11-inch paper and contained two sets of taught and untaught problem subtypes.

Taught problems that had been previously taught were included in the Generalization Test as a maintenance measure. Untaught problem subtypes were used to assess the generalization.

All taught and untaught problems were randomly ordered, and six problems were presented on each worksheet. The numbers, subject names, and object names were changed across the problems.

These worksheets were used for baseline and follow-up phases as well. A total of 4 sets of generalization tests were prepared (2 for baseline, 2 for the generalization assessment phase).

Answer Key

Answer keys (see Appendix L) for all of the Instructed Problem Worksheets, the Practice Problem Worksheets, and the Generalization Tests were used for the experimenters and the assistants to score the students’ worksheets.

Lottery Tickets and Prizes

Lottery tickets were used as reinforcers. Students received scored worksheets on the day after they had turned them in. One lottery ticket was stapled to a student’s worksheet.
if the student had answered all the equations and answers. Two tickets were stapled if five of the student’s answers were correct. When all answers were correct, the student received three lottery tickets. The students wrote their names on the backs of the lottery tickets they received and put them into a can. The tickets were stored for 1 week for the lottery on Fridays. On Fridays, the lottery was conducted and one or two students whose lottery tickets were selected from the can received small prizes (e.g., school supplies such as pencils, pens, erasers, pencil sharpeners, and crayons or small toys such as super balls, stickers, and bubbles). Examples of lottery tickets and prizes can be seen in Appendix M.

**Marble Jar**

Marbles and a tall glass (see Appendix N) were used for group reinforcement. The tall glass called the Marble Jar was able to store approximately 100 marbles. The experimenters put a marble into the jar during instruction sessions if the group of students showed good behavior (e.g., following the experimenter’s directions, quietly listening to the instruction, and making quick transitions). Once the jar was filled with marbles, it could be exchanged for a lunchtime pizza party.

**Definition and Measurement of Dependent Variables**

Two dependent variables were measured in this study: accuracy of answers and accuracy of equations.

**Accuracy of Answers**

As a measure of the extent of acquisition, maintenance, and generalization of problem solving skills, correct answers on Practice Problems Worksheets and Generalization Test were recorded. On the worksheet, each problem was presented as shown in Figure 3.1.
Bob has 5 apples. Tom has some apples. They have 8 apples in all. How many apples does Tom have?

\[
5 + □ = 8
\]

EQUATION

\[
3
\]

ANSWER

Figure 3.1: Example of a problem presented on a worksheet

The students needed to write an equation on the line above “EQUATION” and an answer on the “ANSWER” line.

The correct answer was defined as the correct number for the story problem written on the “ANSWER” line on the worksheet. For example, in the problem above, the correct number on the “ANSWER” would be “3.” If the students did not write the correct number on the “ANSWER” line, the problem was scored as incorrect, even if they wrote the correct number in the correct equation.

The percentage of correct answers on taught problems and on untaught problems was calculated for each experimental phase (i.e., baseline, instruction, generalization assessment, and follow-up) using the following equation: the number of correct answers / the total number of problems x 100.

The recording sheet is shown in Appendix O.

Accuracy of Equations

As a measure of the extent of acquisition, maintenance, and generalization of problem solving skills, correct equations on Practice Problems Worksheets and Generalization Test were recorded as well.
The correct equation was defined as an appropriate representation of the story situation presented using math symbol and numbers. For example, in the above problem, the correct equation was \( 5 + \Box = 8 \) or \( 8 - 5 = \Box \). The vertical version of these equations was also scored as a correct response. Even if the students wrote an incorrect answer to the equation (e.g., \( 8 - 5 = 2 \)), the equation was scored as correct. When students wrote equations without a box (e.g., \( 5 + 3 = 8 \) for the example story problem in Figure 3.1), it was scored as incorrect. The worksheets that the students completed were scored by the primary experimenter and one of the assistants. The percentage of correct equations on taught and untaught problems was calculated for each experimental phase (i.e., baseline, instruction, generalization assessment, and follow-up) by the following equation: the number of correct equations used / the total number of problems \( \times 100 \).

The recording sheet can be seen in Appendix O.

Procedures to Ensure Accuracy and Believability of Data

The assistants scored some of the worksheets completed by the students to ensure accuracy of the data. A total of eleven worksheets completed by each student was photocopied before the experimenter scored them. The assistant scored the photocopied worksheets independently from the experimenter. The worksheets scored by the experimenter and by the assistant were compared, and the percentage of agreement on answers and equations was calculated using the following formula: \( \text{the number of agreed answers or equations} / \text{the total number of problems on the worksheet} \times 100 \). The agreement scores were calculated for all students and all phases except follow-up. When
there were disagreements between the experimenter’s and the assistant’s score, the experimenter checked the answers/equations against the answer key, and the corrected scores were used for the results of the study.

The treatment integrity was not assessed for this study because the independent variables of the study were not the instruction delivered by the experimenter but were the types of taught problems. Prior to each session, the experimenter compared the target problems for instruction with the list of taught problems to ensure that the appropriate problems were taught to the students.

Experimental Design

Three different sets of story problems were taught in different order across the three groups. The three sets were called Multiple-Category/Single-Position problems (MCSP), Single-Category/Multiple-Position problems (SCMP), and Multiple-Category/Multiple-Position problems (MCMP). The instruction phase during which MCSP problems were taught was called MCSP instruction, and it was introduced to one of the three groups of students (called the MCSP group). The second group, called the SCMP group, received SCMP instruction in which SCMP problems were taught. The last group, the MCMP group, was introduced to MCMP instruction in which MCMP problems were taught. Based on the results of the first generalization assessment that was conducted after the first instruction phase, the experimenter planned to implement the best practice, if any, to all three groups as the second instruction. As the result, MCMP instruction was the best practice (described in the Results Section). Therefore, the SCMP and MCSP groups received MCMP instruction during their second instruction phase. The MCMP group also received MCMP instruction again as their second instruction. The second instruction
phase was followed by the second generalization assessment. The SCMP and MCSP
groups also received follow-up assessment. Follow-up assessment was not delivered to
the MCMP group because of their limited school schedule. Instruction was terminated
when the students answered two consecutive Practice Problems Worksheets with 80%
accuracy on the equations as well as on the answers. Table 3.6 shows the sequence of the
conditions for each group of students.

<table>
<thead>
<tr>
<th>MCSP Group</th>
<th>SCMP Group</th>
<th>MCMP Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>Baseline</td>
<td>Baseline</td>
</tr>
<tr>
<td>MCSP instruction</td>
<td>SCMP instruction</td>
<td>MCMP instruction</td>
</tr>
<tr>
<td>Generalization Asm’t</td>
<td>Generalization Asm’t</td>
<td>Generalization Asm’t</td>
</tr>
<tr>
<td>MCMP instruction</td>
<td>MCMP instruction</td>
<td>MCMP instruction</td>
</tr>
<tr>
<td>Generalization Asm’t</td>
<td>Generalization Asm’t</td>
<td>Generalization Asm’t</td>
</tr>
<tr>
<td>Follow-up</td>
<td>Follow-up</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.6: Sequence of the conditions for each group of students

Procedures

This section describes the procedures of the study by conditions (baseline, instruction,
generalization, and follow-up).

General Procedures

There were four experimental conditions during the study: baseline, instruction,
generalization assessment, and follow-up. Baseline and follow-up were conducted as
whole-class activities. During the whole class activity, the students sat in their own seats
in their classroom and participated in the activity. However, all instruction sessions and most of the generalization assessments were conducted in small-group situations. For the small group activities, the participating students sat in a semi-circle with the experimenter in one corner of their classroom. The rest of the class engaged in other activities prepared by their classroom teacher during the small group activity.

During baseline, generalization assessments, and follow-up, the students were presented all of the 18 story problems on three worksheets containing 6 problems each. The students completed one or two worksheets on one day and the remaining worksheets on the next school day. During the instruction phase, 6 taught problems were presented on a Practice Problem Worksheet, and the students completed the worksheet at end of each instruction session.

Whenever the students worked on worksheets in any part of the study, the experimenter or the assistants read each problem twice and paused approximately 15 seconds for the students to answer each problem. The completed worksheets were collected immediately.

The collected worksheets were scored by the experimenter. The correctly answered equations and answers were marked with a “✓” and incorrect answers and equations were marked with an “X.” In the case of incorrect answers and equations, the experimenter wrote the correct answers or equations next to the students’ incorrect ones.

Students received their scored worksheets at the next session. If all problems were answered correctly, three lottery tickets that had the student’s name on the back were stapled to the scored worksheet when it was returned. If a student missed just one answer, two tickets were stapled to the returned worksheet. Students who missed more than one
answer but responded to all equations and answers—in other words, when they did not leave any blanks on the worksheet—received one lottery ticket. When the scored worksheets and lottery tickets were delivered, the students were asked to check the correct equations and answers and to put the lottery tickets they earned into a can. The experimenter then collected the scored worksheets.

The stored lottery tickets in the can were used for a “Surprise” on Fridays. At the end of each session on Friday, the experimenter picked one or two lottery tickets from the can. The students whose names were on the selected tickets earned a prize (e.g., pencils, pens, super balls, stickers). The number of tickets picked by the experimenter was determined by the number of students and number of days of the week the students participated in the study. If all 15 students participated in the session as a whole-class for 5 days of the week (this happened during baseline), three tickets were picked for the “Surprise.” However, if only a small group of students participated that week and if they missed a couple of days of instruction because of their school events (e.g., field day), just one ticket was picked on Friday.

**Baseline**

During baseline, using the same format and types of worksheets as the generalization test (i.e., 18 problem subtypes were presented on three separate worksheets), students’ performances on 18 problem subtypes were assessed three times over 5 school days. All students participated in baseline at the same time. The procedures used to obtain baseline data were the same as described in the general procedure section.
Instruction

In this study, the students were instructed how to use the mystery box strategy to solve story problems. Each of the three groups received the same form of instruction that featured the mystery box strategy, a response card, and choral responding, but the taught problems consisted of different subtypes. During the instruction, the mystery box strategy was taught to students through (1) small-group response card instruction, (2) small-group worksheet instruction, and (3) individual review with a teacher.

In the following section, the mystery box strategy and the types of taught problems are described as well as the structure of instruction.

Mystery Box Strategy

The procedure called “mystery box strategy” was used to represent an unknown value (i.e., answer) in the problem. For example, the problem “Bob has 3 apples. Mary has 5 apples. How many do they have in all?” can be described by the equation, $3+5=\square$. The empty square ($\square$) is the mystery box. The problem, “Bob has 3 apples. Mary has some apples. They have 8 in all. How many does Mary have?” is represented by $3+\square=8$. The students were taught how to write mystery box equations that contain a mystery box in the appropriate position.

This mystery box strategy contains the following three steps: (1) writing numbers or a mystery box on the equation in the order of the story, (2) deciding if the problem’s solution requires addition or subtraction, and (3) performing computation to find the number that goes in the box. Each step is described below in detail.

Mystery Box Step 1. Students wrote the number, if any, of the first sentence on the left side of the equation, and the number, if any, in the second sentence at the middle, and
the number, if any, of the next sentence at the end of the equation. If a sentence did not include any numbers and said “some” or asked a question (e.g., How many…?), students drew an empty box instead writing of a number. For example, for the story problem “Mary has 3 candies. Bob has 5 candies. How many candies do they have in all?” students wrote 3 (the number in the first sentence) at the left part of the equation, 5 (the number in the second sentence) in the middle, and a mystery box at the right part of the equation (because the last sentence is question and does not have any number). The correct response for the problem at this point is 3 5 □. For the story problem “Mary had some pencils. Then she gave 5 pencils to Karen. Now Mary has 3 pencils. How many pencils did Mary have at the beginning?” students drew a mystery box first because the first sentence did not have any number but says “some.” Then they wrote the number 5 from the second sentence in the middle and the number 3 in the third sentence at the end. At the end of step 1, students would have two numbers and one mystery box in various orders based on the type of story problems.

**Mystery Box Step 2.** The experimenter read the whole story problem again and asked students to think if it was plus or minus. Since there are no simple rules for identifying the operation sign, no rules were given to the students. It was expected for students to learn what was the correct operation through repeated practice. Students should learn to write the correct operation sign between the first and second elements of the equation (numbers or mystery box) and to write an equal sign between the second and third elements. However, the equal signs were preprinted on the response cards used in this
study (see Appendix H). Therefore, writing the equal sign was omitted during the small-group response card instruction. At the end of step 2, the students had a complete mystery box equation such as 3+5=□ or □−5=3.

**Mystery Box Step 3.** Then students solved the mystery box equation to determine the number that went into the box. The students were instructed to write the number in the box as the answer for the problem.

**Target Taught Problems for Three Different Instruction Groups**

There are three different subsets of taught problems, Multiple-Category/Single-Position (MCSP) problems, Single-Category/Multiple-Position (SCMP) problems, and Multiple-Category/Multiple-Position (MCMP) problems. These three different subsets of taught problems were taught through the same form of instruction. Although the types of the target problems were described in the "Arithmetic Story Problem" section (p.64 to 70), they are summarized here. Instruction in which MCSP problems were taught was called MCSP instruction. Similarly, instruction in which SCMP problems and MCMP problems were taught were called SCMP instruction and MCMP instruction, respectively.

**MCSP Instruction.** During the Multiple-Category/Single-Position Instruction (MCSP) phase, Combination 1, Change 2, and Comparison 2 were taught first among the six problems described under the taught problem section, and the rest (Combination 5, Change 1, Comparison 3) were taught in the second instruction session.

**SCMP instruction.** The problems targeted in the second instruction, Single-Category/Multiple-Position (SCMP) Instruction, were selected from only one category, Change problems. Changes 1, 3, and 5 were introduced at first and the rest were instructed later on.
MCMP instruction. For the Multiple-Category/Multiple-Position (MCMP) instruction phase, the six problems were selected from all three categories, and the mystery box equation that the students needed to use covered all 6 types. First Combination 3, Change 4, and Comparison 3 were taught, and the rest (Combination 4, Comparison 5, and Change 6) followed.

Structure of Activities during Each Instruction

Each instruction phase took four small-group sessions (two sessions for small-group response card instruction and two sessions for small-group worksheet instruction) and individual review sessions were added, if needed. Table 3.7 shows the structure of instruction.

<table>
<thead>
<tr>
<th>Session</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Small-group response card instruction on the first three problems</td>
</tr>
<tr>
<td>2</td>
<td>Small-group worksheet instruction on the problems taught in Ses. 1</td>
</tr>
<tr>
<td>3</td>
<td>Small-group response card instruction on the rest or the problems</td>
</tr>
<tr>
<td>4</td>
<td>Small-group worksheet instruction on the problems taught in Ses. 3</td>
</tr>
<tr>
<td>5 and more</td>
<td>Individual review sessions as needed</td>
</tr>
</tbody>
</table>

Table 3.7: Structure of instruction phase

In the first session, three out of six target problems were taught during small-group response card instruction. In the second session, the three problems taught at the previous session were dealt with again through small-group worksheet instruction. The rest of the
six problems were taught at the third session using response cards, and they were covered again at the fourth session through worksheet instruction. At the end of each session, students completed a Practice Problem Worksheet containing 1 example problem of each of the 6 taught problems. If students did not meet the predetermined criteria for termination of instruction after four sessions, Individual reviews with the experimenter followed until the students met the criterion.

**Small-group response card instruction.** The first and the third sessions in each instruction phase were the small-group response card instruction sessions. The response card sessions were scripted (see Appendix G). At the beginning of each response card session, the target group of students was asked to sit in a semi-circle in the corner of their classroom. They were given response cards, dry erase markers, and erasers. Each of the story problems being taught was displayed on 8½ x 11-inch paper using a 36-point font so that all students in the group could see them.

The students were taught target problems in three stages: (1) teacher-modeling, (2) teacher-directed practice, and (3) independent practice (see Figure 3.2). These three stages were repeated for each of the three problem subtypes targeted for a given session. A script of Session 1 for the MCMP group can be found in Appendix G. For example, Combination 3, Comparison 3, and Change 4 were taught in Session 1 of MCMP instruction. Combination 3 was taught through teacher modeling, teacher-directed practice, and independent practice using response cards. In each stage, different variations of a Combination 3 problem (i.e., same structure, but different subject name and numbers) was taught. After the completion of all three stages for Combination 3,
Comparison 3 and Change 4 were taught through the same three stages. Therefore, during any given response card session, students solved a total of 9 problems. Figure 3.2 summarizes the sequence of small-group response card instruction sessions.

At the teacher-modeling stage, the experimenter modeled solving each problem using a response card. First, the experimenter showed a target problem written on 8 ½ x 11-inch paper (e.g., "Tom has 5 apples. Mary has some apples. They have 8 apples in all. How many does Mary have?") and read the problem. Next, she read the first sentence ("Tom has 5 apples") and wrote 5 over the yellow line on her response card in such a way so that all the target students could see it. The second sentence ("Mary has some apples") was read next. The experimenter wrote an empty box over the pink line on her response card. She explained that she wrote a box because the sentence did not say how many apples Mary had. The third sentence ("They have 8 apples in all") was read, and the experimenter wrote 8 over the green line on her board. Then she wrote "+" signs in the circle on her response card, and said, "Tom has 5, Mary has some, and they have 8 in all. So it is plus." At this point, the correct mystery box equation, 5 + □ = 8, was on the experimenter’s response card. Then, the experimenter wrote the answer, 3, in the mystery box. In addition, she wrote the answer above the answer line on her response card.

At the teacher-directed practice stage, the experimenter presented the problem on a piece of 8 ½ x 11-inch paper, and then the students practiced a new problem with the experimenter. The sequence of activities was the same as in the teacher-modeling stage (i.e., read the whole problem, read the first sentence, write a number or box on the response card). The students wrote the required numbers or operation signs on their response cards and showed their cards to the experimenter. The experimenter always
1. Teacher Modeling
   a. Teacher reads the target problem
   b. Teacher reads the first sentence
   c. Teacher writes an element of the first sentence on her response card
   d. Teacher reads the second sentence
   e. Teacher writes an element of the second sentence on her response card
   f. Teacher reads the third sentence
   g. Teacher writes an element of the third sentence on her response card
   h. Teacher writes an operation sign in the circle on her response card
   i. Teacher writes an appropriate number in the mystery box
   j. Teacher writes an answer over the answer line

2. Teacher-Directed Practice
   a. Teacher reads the target problem
   b. Teacher reads the first sentence
   c. Students write an element of the first sentence on their response cards by following the teacher's model and show their response cards to the teacher
   d. Teacher reads the second sentence
   e. Students write an element of the second sentence on their response cards following the teacher's model and show their response cards to the teacher
   f. Teacher reads the third sentence
   g. Students write an element of the third sentence on their response cards following the teacher's model and show their response cards to the teacher
   h. Students write an operation sign in the circle on their response cards following the teacher's model and show their response cards to the teacher
   i. Students write an appropriate number in the mystery box following the teacher's model and show their response cards to the teacher
   j. Students write an answer over the answer line following the teacher's model and show their response cards to the teacher

3. Independent Practice
   a. Teacher reads the target problem
   b. Teacher reads the first sentence
   c. Students write an element of the first sentence on their response cards and show their response cards to the teacher
   d. Teacher reads the second sentence
   e. Students write an element of the second sentence on their response cards and show their response cards to the teacher
   f. Teacher reads the third sentence
   g. Students write an element of the third sentence on their response cards and show their response cards to the teacher
   h. Students write an operation sign in the circle on their response cards and show their response cards to the teacher
   i. Students write an appropriate number in the mystery box and show their response cards to the teacher
   j. Students write an answer over the answer line and show their response cards to the teacher

Stages 1, 2, and 3 are repeated for three taught problems.

4. Practice Problem Worksheet
   a. Teacher reads the problems on a Practice Problem Worksheet, and students complete the worksheets independently.

Figure 3.2: Sequence of instructional activities during response card instruction sessions
modeled the correct response before the students produced their own responses. For example, the experimenter wrote the number in the first sentence on her response card and showed it to students. Then she asked the students to write the same thing on their response cards. The students held up their response cards to display their responses to the experimenter. If the students’ responses were correct, the experimenter gave them praise. Whenever the students’ responses were incorrect, the experimenter stated what the correct answer was and had students correct their responses. Thus, the experimenter provided praise and/or corrective feedback on all of the students’ responses, and the mistakes that students made were corrected before proceeding to the next step.

At the independent practice stage, the students followed the same activities as in the teacher-directed practice stage but without the preceding teacher models. The experimenter frequently provided praise and the corrective feedback on the students’ response in the same manner as during the teacher-directed practice stage.

At the end of each small-group response card instruction session, the students were required to complete a Practice Problems Worksheet.

During the response card activity, the experimenter used marbles as conditioned reinforcers. When the students followed teacher directions, correctly responded to teacher questions with “big voices,” wrote correct answers, and showed quick transitions, the experimenter put marbles in the marble jar. The jar had a line on the top, and the students were told that they would have a pizza party if the marbles were filled up to the line. The same marble jar was used across three groups of students. Therefore, the pizza party rewarded the whole class.
Small-group worksheet instruction. The second and fourth sessions in each instruction phase were the worksheet instruction sessions. During the worksheet instruction, the independent practice stage described above was repeated for the target problems. However, instead of using response cards, the students wrote their answers on instructed problem worksheets.

At the beginning of the worksheet instruction, the experimenter passed out the instructed problem worksheets and pencils. On the instructed problem worksheets, there were two examples of each of the three problems taught on the previous day. The students followed the independent practice stage, but they wrote their equations and answers on the worksheets instead of on their response cards. The experimenter checked the students' responses on their worksheets as they made each response and delivered praise and corrective feedback in the same manner as during teacher-directed practice stage.

At the end of each small-group worksheet instruction session, the students were required to complete a Practice Problems Worksheet.

Marbles and the marble jar were used during the small-group worksheet instruction sessions in same manner as during the small-group response card instruction sessions.

Individual review sessions. Students who did not meet the 80% accuracy criterion after four sessions of small group instruction participated in individual review sessions with the experimenter. The individual review sessions were conducted in the same corner of the classroom as the small group instruction. The problems that students did not answer correctly on the previous day’s worksheet were practiced through teacher modeling, teacher-directed practice, and independent practice. The response card was not
used in the individual review sessions, but the instructed problem worksheets were prepared for the students. The individual review session was conducted approximately 5 minutes for each student at a time.

At the end of each individual review session, the students were required to complete a Practice Problems Worksheet. The individual review sessions continued until the students met the criterion of the termination of instruction phase (i.e., two consecutive Practice Problems Worksheets independently with more than 80% correct on both equations and answers).

**Generalization Assessment**

Following each instruction phase, the generalization was assessed. During the generalization phase, the students answered questions on the Generalization Test. The test contained 2 sets of 18 story problems subtypes (see Table 3.4), so that 1 test provided 2 assessment data. Six problems were on a worksheet and the students answered 2 worksheets a day. It took 3 days for students to complete 1 generalization assessment test.

A total of 6 generalization assessment phases were conducted (i.e., each of the three groups had 2 generalization assessment phases, generalization assessment 1 and generalization assessment 2). The experimenter delivered two of them and the assistants delivered the rest. When the assistants conducted the generalization assessment, the experimenter delivered instruction sessions to one of the other groups of students.

The students who participated in the generalization assessment were the ones who finished their instruction phase on the previous day. The group of students targeted was
called, and they came to the art table that was placed in another corner of their classroom. The experimenter or the assistants passed out the generalization test and pencils to the students, and the assessment began.

The experimenter or the assistant read each problem on the first worksheet of the test two times and paused approximately 15 seconds for the students to have time to write the equation and answer the problems. When the students completed the first worksheet, they were instructed to turn the page so that the second worksheet of the generalization test was revealed. In the same manner, the second worksheet was completed. When the students had completed the second worksheet, the generalization tests were collected by the experimenter or the assistant. The collected tests were scored and returned to the students in the next session with lottery tickets in same manner described in the general procedure section. These procedures were repeated until the students finished 6 worksheets in the generalization test.

Out of 18 problems, 6 problems were taught and 12 were untaught as of the first generalization assessment. The students’ results on the taught problems served as a maintenance measure, and their results on the untaught problems were a generalization measure. Generalization assessment was also conducted after the second instruction phase. In that second generalization assessment, the MCSP group (who experienced MCSP instruction first, then received MCMP instruction next) had 11 taught and 7 untaught problems out of 18 problems. Similarly, the SCMP group had 10 taught and 8 untaught problems. For the MCMP group, the number of taught problems for the second generalization assessment was 6 and the untaught problems were 12.
Follow-up

Follow-up was conducted for the MCSP and SCMP groups. When the MCMP group was in the second generalization assessment phase, the other two groups that had finished their second generalization phases 1–2 weeks before participated in the same generalization test with the students in the MCMP group. The results of this assessment served to provide follow-up data. The follow-up was done 1 week after the termination of instruction for the SCMP group and 2 weeks after termination of instruction for the MCSP group. The MCMP group did not have follow-up.

The follow-up was conducted as a whole-class activity. Otherwise, the procedures used to obtain follow-up data were the same as the ones described in the generalization assessment section above.
CHAPTER 4

RESULTS

This chapter presents the results of this study. Data were collected for a total of 27 to 29 sessions for each student, showing the comparative effects of three sets of teaching examples on generalized story problem solving by the 15 first grade students who participated in the study. The results of the accuracy checks are presented in this chapter followed by baseline, instruction, generalization, and follow-up data for each student and the group averages. The data for a student who did not show more than 60% acquisition during the two instruction phases are not included in the group averages.

Accuracy of Measurements

Accuracy checks were carried out by the assistants for equations and answers on 31% of the worksheets that the students completed in each session. The results were calculated by dividing the number of agreements by the total number of problems on the worksheet and then multiplying by 100. Table 4.1 shows the results of the accuracy checks for each student. More than 95% agreement was reached for all students. Table 4.2 shows the accuracy of the measurement summary across the three groups. More than 98% agreement was reached for all groups on the average.
<table>
<thead>
<tr>
<th></th>
<th>BL (18)</th>
<th>Inst. 1 (12)</th>
<th>GA 1 (12)</th>
<th>Inst. 2 (12)</th>
<th>GA 2 (12)</th>
<th>Total (66)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>Answer</td>
<td>Equation</td>
<td>Answer</td>
<td>Equation</td>
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<tr>
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<td>100</td>
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<td>83</td>
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<td>99</td>
<td>96</td>
<td>99</td>
<td>100</td>
</tr>
</tbody>
</table>

a Number of problems checked.

Table 4.1: Percentage agreement between experimenter's and assistant's scoring of students' answers and equations on worksheets.
Table 4.2: Group average percentage agreement between experimenter’s and assistants’ scoring of students’ answers and equations on worksheets

<table>
<thead>
<tr>
<th></th>
<th>BL</th>
<th>Inst. 1</th>
<th>GA 1</th>
<th>Inst. 2</th>
<th>GA2</th>
<th>Average</th>
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<tbody>
<tr>
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<td>99</td>
<td>96</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td></td>
<td>(92-100)</td>
<td>(100-100)</td>
<td>(83-100)</td>
<td>(92-100)</td>
<td>(100-100)</td>
<td></td>
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<td>SCMP Group</td>
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<td></td>
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<td>(92-100)</td>
<td>(92-100)</td>
<td>(92-100)</td>
<td>(92-100)</td>
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<td>MCMP Group</td>
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<td>97</td>
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<td>100</td>
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<td>98</td>
</tr>
<tr>
<td></td>
<td>(75-100)</td>
<td>(83-100)</td>
<td>(83-100)</td>
<td>(100-100)</td>
<td>(92-100)</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>98</td>
<td>98</td>
<td>99</td>
<td>98</td>
<td>99</td>
<td>98</td>
</tr>
</tbody>
</table>

Disagreements were found to be due to the following two reasons: (1) some students wrote “6” reversed and it looked like “2” and (2) When students wrote “+” first and then changed it to “−”, it was hard to identify if it was “+” or “−” on the photocopied worksheets.

Multiple-Category/Single-Position (MCSP) Group

The results for both answers and equations for each student in the MCSP group are presented in this section. The results are described by taught and untaught problems and by experimental phases. Each student’s results are followed by a group summary.

Four students, Andy, Ed, Alice, and Amber, were in this group. They experienced baseline phase, followed by the MCSP instruction phase—in which Combination 1, Change 2, Comparison 2, Combination 5, Change 1 and Comparison 3 were taught—as their first instruction phase for the 6 sessions. The term “taught” problems thus refers to those 6 problems during baseline, instruction 1, and generalization assessment 1. The “untaught” problems during those three phases included 12 problems other than the 6
MCSP problems. The total number of problems and problem subtypes during each phase is summarized in Table 4.3.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Taught/Untaught</th>
<th>Total Number of Problems</th>
<th>Problem Subtypes Included</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>Taught</td>
<td>6</td>
<td>Combination 1, Change 2, Comparison 2, Combination 5, Change 1, Comparison 3</td>
</tr>
<tr>
<td></td>
<td>Un-taught</td>
<td>12</td>
<td>Other than above 6 subtypes</td>
</tr>
<tr>
<td>Instruction 1 - MCSP</td>
<td>Taught</td>
<td>6</td>
<td>Combination 1, Change 2, Comparison 2, Combination 5, Change 1, Comparison 3</td>
</tr>
<tr>
<td></td>
<td>Un-taught</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Generalization assessment 1</td>
<td>Taught</td>
<td>6</td>
<td>Combination 1, Change 2, Comparison 2, Combination 5, Change 1, Comparison 3</td>
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<tr>
<td></td>
<td>Un-taught</td>
<td>12</td>
<td>Other than above 6 subtypes</td>
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<td>Instruction 2 - MCMP</td>
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<td>Combination 3, Comparison 3, Change 4, Combination 4, Comparison 5, Change 6</td>
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<td>Un-taught</td>
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<td>Taught</td>
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<td>Combination 1, Change 2, Comparison 2, Combination 5, Change 1, Comparison 3</td>
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<tr>
<td>Follow-up</td>
<td></td>
<td></td>
<td>Combination 3, Change 4, Combination 4, Combination 5, Change 6</td>
</tr>
<tr>
<td></td>
<td>Un-taught</td>
<td>7</td>
<td>Other than above 11 subtypes</td>
</tr>
</tbody>
</table>

Table 4.3: Total number and subtypes of taught and untaught problems for the MCSP group during baseline, instruction 1, generalization assessment 1, instruction 2, generalization assessment 2, and follow-up.

After the first generalization assessment, the MCMP instruction phase, in which Combination 3, Comparison 3, Change 4, Combination 4, Comparison 5, and Change 6 were taught, was conducted for 8 sessions as the students' second instruction phase. The taught problems during the second instruction included the 6 MCMP problems. The
taught problems at the second generalization assessment and at the follow-up phase included MCSP problems that had been taught during the first instruction and MCMP problems that had been taught during the second instruction. There was one overlap problem between the MCSP and MCMP problems, so the total number of taught problems during the second generalization assessment and the follow-up phases were 11. Thus, the total number of untaught problems for generalization assessment 2 and the follow-up was 7. The follow-up phase was conducted 2 weeks after the second generalization assessment.

Andy

Figure 4.1 shows the percentage of correct answers and equations on taught and untaught problems for Andy throughout the study. A graph representing Andy’s number of correct answers and equations across three different sets of teaching examples is presented as Figure 4.1 in Appendix P.

Taught Problems

The results of the answers and equations on taught problems for Andy are described by experimental phases below.

Baseline. During baseline, Andy had an average score of 61% correct on answers for the MCSP problems. His average percentage correct on equations was 39% during baseline.

Instruction 1- MCSP. Andy experienced the MCSP instruction phase. He reached 100% correct in four probes for both answers and equations. For his last two probes during instruction 1, his average percentage of correct answers was 92%, and his average percentage of correct equations was 100%.
Figure 4.1: Percentage of correct answers and equations on taught and untaught story problems for Andy during baseline, instruction, generalization assessment, and follow-up. “A” above horizontal axis indicates student absences.
Generalization assessment 1. During the first generalization assessment, Andy had an average percentage of 83% correct answers and 83% correct equations.

Instruction 2 — MCMP. Andy experienced the MCMP instruction phase. He reached 100% correct in six probes for both answers and equations. His average percentage of correct problems for his last two probes during instruction 2 was 83% on answers and 100% on equations.

Generalization assessment 2. During the second generalization assessment, Andy’s average percentage of correct answers was 83% and his average percentage of correct equations was 100%.

Follow-up. Follow-up sessions were conducted 2 weeks after the second generalization assessment for Andy. Andy’s average percentage of correct answers was 73%, and his average percentage of correct equations was 73% as well.

Summary of Taught Problems. Andy’s percentage of correct answers and equations on taught problems improved through the first and the second instructions. Although his performance during the first and the second generalization assessment and during the follow-up decreased from his performance during instruction, his performance level during those phases was higher than baseline level.

Untaught problems

The results of answers and equations on untaught problems for Andy are described by experimental phases below.

Baseline. Andy had an average score of 14% correct on answers for untaught problems. The average percentage correct on equations was 14% as well.
Generalization assessment 1. For untaught problems during the first generalization assessment, Andy had an average percentage correct of 25% on answers and 33% on equations.

Generalization assessment 2. During the second generalization assessment, Andy’s average percentage of correct answers was 43%, and his average percentage of correct equations was also 43%.

Follow-up. Follow-up sessions were conducted 2 weeks after the second generalization assessment. Andy’s average percentage of correct answers was 43%, and his average percentage of correct equations was 36%.

Summary of Untaught Problems. Andy’s percentage of correct answers and equations on untaught problems was slightly improved after the first instruction, and it improved more after the second instruction. In sum, his performance on untaught problems became much higher than baseline level by the end of the study.

Ed

Figure 4.2 shows the percentage of correct answers and equations on taught and untaught problems for Ed throughout the study. A graph representing Ed’s number of correct answers and equations across three different sets of teaching examples is presented as Figure P.2 in Appendix P.

Taught Problems

The results of the answers and equations on taught problems for Ed are described by experimental phases below.

Baseline. During baseline, Ed had an average score of 94% correct on answers for the MCSP problems. His average percentage correct on equations was 67% during baseline.
Figure 4.2: Percentage of correct answers and equations on taught and untaught story problems for Ed during baseline, instruction, generalization assessment, and follow-up. "A" above horizontal axis indicates student absences.
**Instruction 1 - MCSP.** Ed experienced the MCSP instruction phase. He reached 100% correct in three probes for both answers and equations. On his last two probes during instruction 1, his average percentage of correct answers was 100%, and his average percentage of correct equations was 100%.

**Generalization assessment 1.** During the first generalization assessment, Ed had an average percentage of 92% correct answers and 100% correct equations.

**Instruction 2 – MCMP.** Ed experienced the MCMP instruction phase. He reached 100% correct in six probes for answers and in three probes for equations. His average percentage of correct problems for his last two probes during instruction 2 was 83% on answers and 92% on equations.

**Generalization assessment 2.** During the second generalization assessment, Ed’s average percentage of correct answers was 77% and his average percentage of correct equations was 82%.

**Follow-up.** Follow-up sessions were conducted 2 weeks after the second generalization assessment for Ed. His average percentage of correct answers was 91% and his average percentage of correct equations was 95%.

**Summary of Taught Problems.** Ed’s percentage of correct answers and equations on taught problems improved through the first and the second instructions. Although his performance during the first and the second generalization assessment and during the follow-up decreased from his performance during instruction, his performance level during those phases was higher than baseline level on equations.
Untaught Problems

The results of the answers and equations on untaught problems for Ed are described by experimental phases below.

Baseline. Ed had an average score of 69% correct on answers for untaught problems. His average percentage correct on equations was 33%.

Generalization assessment 1. For untaught problems during the first generalization assessment, Ed had an average percentage correct of 50% on answers and 50% on equations as well.

Generalization assessment 2. During the second generalization assessment, Ed’s average percentage of correct answers was 71%, and his average percentage of correct equations was 64%.

Follow-up. Follow-up sessions were conducted 2 weeks after the second generalization assessment. Ed’s average percentage of correct answers was 86% and his average percentage of correct equations was also 86%.

Summary of Unhtaught Problems. Ed’s percentage of correct answers on untaught problems was not improved after the first instruction, but his percentage of correct equations was improved. The percentage correct on both answers and equations on generalization assessment 2 were higher than at baseline and generalization assessment 1. In sum, his performance on untaught problems became higher than baseline level by the end of the study, especially on equations.

Alice

Figure 4.3 shows the percentage of correct answers and equations on taught and untaught problems for Alice throughout the study. A graph representing Alice’s number 105
Figure 4.3: Percentage of correct answers and equations on taught and untaught story problems for Alice during baseline, instruction, generalization assessment, and follow-up. “A” above horizontal axis indicates student absences.
of correct answers and equations across three different sets of teaching examples is presented as Figure P.3 in Appendix P.

**Taught Problems**

The results of the answers and equations on taught problems for Alice are described by experimental phases below.

**Baseline.** During baseline, Alice had an average score of 72% correct on answers for the MCSP problems. Her average percentage correct on equations was 61% during baseline.

**Instruction 1 — MCSP.** Alice experienced the MCSP instruction phase. She reached 100% correct in four probes for answers and in six probes for equations. Her average percentage correct on answers for her last two probes during instruction 1 was 92%, and it was 92% on equations as well.

**Generalization assessment 1.** During the first generalization assessment, Alice had an average percentage of 33% correct answers and 50% correct equations.

**Instruction 2 — MCMP.** Alice experienced the MCMP instruction phase. Alice did not reach 100% correct for either answers or equations. Her average percentage of correct problems for her last two probes during instruction 2 was 67% on answers and 75% on equations.

**Generalization assessment 2.** During the second generalization assessment, Alice’s average percentage of correct answers was 64%, and her average percentage of correct equations was 68%.
Follow-up. Follow-up sessions were conducted 2 weeks after the second generalization assessment for Alice. Alice’s average percentage of correct answers was 45%, and her average percentage of correct equations was 55%.

Summary of Taught Problems. Alice’s percentage of correct answers and equations on taught problems improved through the first and the second instruction. However, her scores during generalization assessment 1 and 2 and follow-up were low.

Untaught Problems

The results of answers and equations on untaught problems for Alice are described by experimental phases below.

Baseline. Alice had an average score of 47% correct on answers for untaught problems. Her average percentage correct on equations was 25%.

Generalization assessment 1. For untaught problems during the first generalization assessment, Alice had an average percentage correct of 17% on answers and 21% on equations.

Generalization assessment 2. During the second generalization assessment, Alice’s average percentage of correct answers was 21%, and her average percentage of correct equations was 29%.

Follow-up. Follow-up sessions were conducted 2 weeks after the second generalization assessment. Alice’s average percentage of correct answers was 29%, and her average percentage of correct equations was 43%.

Summary of Untaught Problems. Alice’s percentage of correct answers and equations on untaught problems was not improved after the first instruction or after the second instruction.
Amber

Figure 4.4 shows the percentage of correct answers and equations on taught and untaught problems for Amber throughout the study. A graph representing Amber’s number of correct answers and equations across three different sets of teaching examples is presented as Figure P.4 in Appendix P.

Taught Problems

The results of the answers and equations on taught problems for Amber are described by experimental phases below.

Baseline. During baseline, Amber had an average score of 75% correct on answers for the MCSP problems. Her average percentage correct on equations was 58% during baseline.

Instruction 1 - MCSP. Amber experienced the MCSP instruction phase. She reached 100% correct in four probes for both answers and equations. Her average percentage correct on answers for her last two probes during instruction 1 was 92%, and her average percentage correct for equations was 92%.

Generalization assessment 1. During the first generalization assessment, Amber had an average percentage of 92% correct answers and 92% correct equations as well.

Instruction 2 – MCMP. Amber experienced the MCMP instruction phase. She reached 100% correct in six probes for answers and in five probes for equations. Her average percentage of correct problems for her last two probes during instruction 2 was 83% on answers and 83% on equations as well.
Figure 4.4: Percentage of correct answers and equations on taught and untaught story problems for Amber during baseline, instruction, generalization assessment, and follow-up. “A” above horizontal axis indicates student absences.
Generalization assessment 2. During the second generalization assessment, Amber's average percentage of correct answers was 73%, and her average percentage of correct equations was 77%.

Follow-up. Follow-up sessions were conducted 2 weeks after the second generalization assessment for Amber. Amber's average percentage of correct answers was 68%, and her percentage of correct equations was 77%.

Summary of Taught Problems. Amber's percentage of correct answers and equations on taught problems improved through the first and the second instructions. Although it became lower during the second generalization assessment and during the follow-up, her performance level on equations during those phases was higher than at baseline level.

Untaught Problems

The results of answers and equations on untaught problems for Amber are described by experimental phases below.

Baseline. Amber had an average score of 46% correct on answers for untaught problems. Her average percentage correct on equations was 33%.

Generalization assessment 1. For untaught problems during the first generalization assessment, Amber had an average percentage correct of 50% on answers and of 50% on equations as well.

Generalization assessment 2. During the second generalization assessment, Amber's average percentage of correct answers was 64%, and her average percentage of correct equations was 71%.
**Follow-up.** Follow-up sessions were conducted 2 weeks after the second generalization assessment. Amber’s average percentage of correct answers was 36%, and her average percentage of correct equations was 64%.

**Summary of Untaught Problems.** Amber’s percentage of correct answers and equations on untaught problems was slightly improved after the first instruction, and it improved more after the second instruction. In sum, her performance on untaught problems became much higher than baseline level by the end of the study.

**MCSP Group Summary**

In the section below, the results from the students in the MCSP group are summarized.

**Summary of Performance by Individual Students**

Table 4.4 and Figure 4.5 show the average percentage of correct answers and equations on taught and untaught story problems across the experimental phases (except follow-up) for each student in the MCSP group.

**Taught Problems.** As can be seen in Figure 4.5, 3 students in this group exhibited more than 80% correct answers and equations on taught problems during the two instruction phases. However, during generalization assessments, they scored lower. In other words, the acquired skills were not greatly maintained.

**Untaught Problems.** As can be seen in Figure 4.5, Andy and Amber exhibited slightly higher scores on answers for untaught problems on generalization assessment 1. However, Ed and Alice scored lower compared with their baseline performance. All four students showed an improved average percentage of correct answers on second generalization assessment. Three students exhibited a higher percentage of correct
<table>
<thead>
<tr>
<th>Student</th>
<th>Condition</th>
<th>Answer Taught</th>
<th>Answer Untaught</th>
<th>Equation Taught</th>
<th>Equation Untaught</th>
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<td>83</td>
<td>33</td>
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<td>Inst. 2-MCMP</td>
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<td>100</td>
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<td></td>
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<td>43</td>
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<td>43</td>
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<td>GA2</td>
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<td>21</td>
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<td>Amber</td>
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Table 4.4: Average percentage of correct answers and equations on taught and untaught story problems by each student in the MCSP group
Figure 4.5: Average percentage of correct answers and equations on taught and untaught story problems by each student in MCSP group during baseline, instruction, and generalization assessment.
equations at generalization assessment 1. All of them showed improved scores on equations at their generalization assessment 2. In sum, the generalization that occurred after instruction 1 was minimal for the students in the MCSP group. However after the second instruction, which was the MCMP instruction phase, the students showed better generalization.

**MCSP Group Summary**

Table 4.5 and Figure 4.6 show the MCSP group average percentage of correct answers and equations across the experimental phases (except follow-up) by taught and untaught problems. All students in this group showed more than 60% correct answers and equations during their two instruction phases, and all four students' data were used to calculate the group averages.

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<tr>
<th>Condition</th>
<th>Answer</th>
<th>Equation</th>
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<td>Inst. 1-MCSP</td>
<td>94</td>
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<td>GA1</td>
<td>75</td>
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<td>50</td>
</tr>
<tr>
<td>GA2</td>
<td>72</td>
<td>50</td>
</tr>
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</table>

Table 4.5: MCSP group mean percentage of correct answers and equations on taught and untaught story problems

**Taught Problems.** As can be seen in Table 4.5 and Figure 4.6, the MCSP group reached about 95% correct answers and equations (94% on answers, 96% on equations) on taught problems on the average. However, this level of performance was not maintained on first generalization assessment. By the end of instruction 2, the group had
Figure 4.6: MCSP group mean percent correct answers and equations on taught and untaught story problem during baseline, instruction and generalization assessment.
reached 79% correct on answers and 88% correct on equations on the average. The score on generalization assessment 2 was slightly lower compared with the one for instruction 2. In sum, it can be said that the acquisition of taught problems for this group was good on the average, but maintenance was not shown. **Untaught Problems.** As a group average, the MCSP group exhibited slightly lower scores on answers for untaught problems on generalization assessment 1. However, an improved average percentage of correct answers was shown on second generalization assessment. This group exhibited a higher percentage of correct equations on generalization assessment 1, and their correct equation scores became higher at their generalization assessment 2. In sum, the generalization occurred after instruction 1 on equations but not on answers for the MCSP group. However, after the second instruction, which was the MCMP instruction phase, generalization on both answers and equations resulted.

**Single-Category/Multiple-Position (SCMP) Group**

The results on answers and equations for each student in the SCMP group are presented in this section. The results are described by taught and untaught problems and by experimental phases. Each student's results are followed by a group summary.

Five students, Matthew, Theresa, Willy, Jason, and Sam, were in this group. They experienced baseline phase, followed by the SCMP instruction phase—in which Changes 1, 2, 3, 4, 5, and 6 were taught—as their first instruction phase for 6 sessions. "Taught" problems refer to those 6 problems, for baseline, instruction 1, and generalization assessment 1. The problems called "untaught" problems during the three phases include 12 problems other than the 6 SCMP problems. The total number of problems and problems subtypes during each phase are summarized in Table 4.6.
<table>
<thead>
<tr>
<th>Condition</th>
<th>Taught/Untaught</th>
<th>Total Number of Problems</th>
<th>Problem Subtypes Included</th>
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<td>Baseline</td>
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<td>Change 1, 2, 3, 4, 5, 6</td>
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<tr>
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<td>Other than above 11 subtypes</td>
</tr>
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</table>

Table 4.6: Total number and subtypes of taught and untaught problems for the SCMP group during baseline, instruction 1, generalization assessment 1, instruction 2, generalization assessment 2, and follow-up.

After the first generalization assessment, the MCMP instruction phase, in which Combination 3, Comparison 3, Change 4, Combination 4, Comparison 5, and Change 6 were taught, was conducted for 5 sessions as the students' second instruction phase. The taught problems during the second instruction included the 6 MCMP problems. The taught problems at the second generalization assessment and at the follow-up phase included the MCSP problems that had been taught during the first instruction and the MCMP problems that had been taught during the second instruction. There were two overlap problems between the MCSP and MCMP problems, so the total number of taught problems during the second generalization assessment and the follow-up phases was 10. Thus, the total number of untaught problems for generalization assessment 2 and the
follow-up was 8. The follow-up phase was conducted 2 weeks after the second generalization assessment.

Matthew

Figure 4.7 shows the percentage of correct answers and equations on taught and untaught problems for Matthew throughout the study. A graph representing Matthew’s number of correct answers and equations across three different sets of teaching examples is presented in Figure P.5 in Appendix P.

Taught Problems

The results of answers and equations on taught problems for Matthew are described by experimental phases below.

Baseline. During baseline, Matthew had an average score of 33% correct on answers for the SCMP problems. His average percentage correct on equations was 39% during baseline.

Instruction 1 - MCSP. Matthew experienced the SCMP instruction phase. He reached 100% correct in two probes for both answers and equations. His average percentage correct for his last two probes during instruction 1 was 92% on answers and 100% on equations.

Generalization assessment 1. During the first generalization assessment, Matthew had an average percentage of 92% correct on answers and 92% correct on equations as well.

Instruction 2 – MCMP. Matthew experienced the MCMP instruction phase. He did not reach 100% correct in five probes for either answers or equations. His average percentage of correct problems for his last two probes during instruction 2 was 83% on answers and 75% on equations.
Figure 4.7: Percentage of correct answers and equations on taught and untaught story problems for Matthew during baseline, instruction, generalization assessment, and follow-up. "A" above horizontal axis indicates student absences.
Generalization assessment 2. During the second generalization assessment, Matthew's average percentage of correct answers was 80%, and his average percentage of correct equations was 90%.

Follow-up. Follow-up sessions were conducted 1 week after the second generalization assessment for Matthew. Matthew’s average percentage of correct answers was 90%, and his average percentage of correct equations was 90% as well.

Summary of Taught Problems. Matthew’s percentage of correct answers and equations on taught problems improved through the first and the second instruction phases. Although it became lower during the second generalization assessment, his performance level after the second instruction was higher than baseline level.

Untaught Problems

The results of answers and equations on untaught problems for Matthew are described by experimental phases below.

Baseline. Matthew had an average score of 33% correct on answers for untaught problems. His average percentage correct on equations was 17%.

Generalization assessment 1. For untaught problems during the first generalization assessment, Matthew had an average percentage correct of 67% on answers and 46% on equations.

Generalization assessment 2. During the second generalization assessment, Matthew’s average percentage of correct answers was 50%, and his average percentage of correct equations was 38%.
Follow-up. Follow-up sessions were conducted 1 week after the second generalization assessment. Matthew’s average percentage of correct answers was 25%, and his average percentage of correct equations was 30%.

Summary of Untaught Problems. Matthew’s percentage of correct answers and equations on untaught problems improved after the first instruction, but they were not high on second generalization assessment. However, his performance on untaught problems became much higher than at baseline level by the end of the study.

Theresa

Figure 4.8 shows the percentage of correct answers and equations on taught and untaught problems for Theresa throughout the study. A graph representing Theresa’s number of correct answers and equations across three different sets of teaching examples is presented as Figure P. 6 in Appendix P.

Taught Problems

The results of answers and equations on taught problems for Theresa are described by experimental phases below.

Baseline. During baseline, Theresa had an average score of 28% correct on answers for the SCMP problems. Her average percentage correct on equations was 17% during baseline.

Instruction 1- MCSP. Theresa experienced the SCMP instruction phase. She showed 100% correct on first probe on equations and reached 100% correct in six probes on answers. For her last two probes during instruction 1, her average percentage of correct answers was 92%, and her average percentage of correct equations was 92% as well.

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Figure 4.8: Percentage of correct answers and equations on taught and untaught story problems for Theresa during baseline, instruction, generalization assessment, and follow-up. "A" above horizontal axis indicates student absences.
Generalization assessment 1. During the first generalization assessment, Theresa had an average percentage of 92% correct answers and 83% correct equations.

Instruction 2 – MCMP. Theresa experienced the MCMP instruction phase. Theresa did not reach 100% correct in four probes for both answers and equations. For her last two probes during instruction 2, her average percentage of correct answers was 83%, and her average percentage of correct equations was 83% as well.

Generalization assessment 2. During the second generalization assessment, Theresa’s average percentage of correct answers was 60%, and her average percentage of correct equations was 50%.

Follow-up. Follow-up sessions were conducted 1 week after the second generalization assessment for Theresa. Theresa’s average percentage of correct answers was 70%, and her average percentage of correct equations was 70% as well.

Summary of Taught Problems. Theresa’s percentage of correct answers and equations on taught problems improved through the first and the second instructions. Although it became lower during the second generalization assessment, her performance level by the end of the study was higher than baseline level.

Untaught Problems

The results of answers and equations on untaught problems for Theresa are described by experimental phases below.

Baseline. Theresa had an average score of 31% correct on answers for untaught problems. Her average percentage correct on equations was 22%.
Generalization assessment 1. For untaught problems during the first generalization assessment, Theresa had an average percentage correct of 54% on answers and 58% on equations.

Generalization assessment 2. During the second generalization assessment, Theresa’s average percentage of correct answers was 63%, and her average percentage of correct equations was 63% as well.

Follow-up. Follow-up sessions were conducted 1 week after the second generalization assessment. Theresa’s average percentage of correct answers was 20%, and her average percentage of correct equations was 10%.

Summary of Untaught Problems. Theresa’s percentage of correct answers and equations on untaught problems improved after the first instruction, and it was higher on second generalization assessment. As a result, her performance on untaught problems became much higher than baseline level on second generalization assessment.

Willy

Figure 4.9 shows the percentage of correct answers and equations on taught and untaught problems for Willy throughout the study. A graph representing Willy’s number of correct answers and equations across three different sets of teaching examples is presented as Figure P.7 in Appendix P.

Taught Problems

The results of answers and equations on taught problems for Willy are described by experimental phases below.
Figure 4.9: Percentage of correct answers and equations on taught and untaught story problems for Willy during baseline, instruction, generalization assessment, and follow-up. “A” above horizontal axis indicates student absences.
**Baseline.** During baseline, Willy had an average score of 33% correct on answers for the SCMP problems. His average percentage correct on equations was 28% during baseline.

**Instruction 1- MCSP.** Willy experienced the SCMP instruction phase. He reached 100% correct in six probes for both answers and equations. For his last two probes during instruction 1, his average percentage correct was 75% on answers and 75% on equations as well.

**Generalization assessment 1.** During the first generalization assessment, Willy had an average percentage of 75% correct answers and 83% correct equations.

**Instruction 2 - MCMP.** Willy experienced the MCMP instruction phase. Willy reached 100% correct in five probes for answers and in four probes for equations. His average percentage of correct problems for his last two probes during instruction 2 was 92% on answers and 100% on equations.

**Generalization assessment 2.** During the second generalization assessment, Willy’s average percentage of correct answers was 90%, and his average percentage of correct equations was 90% as well.

**Follow-up.** Follow-up sessions were conducted 1 week after the second generalization assessment for Willy. Willy’s average percentage of correct answers was 75%, and his average percentage of correct equations was 85%.

**Summary of Taught Problems.** Willy’s percentage of correct answers and equations on taught problems improved through the first and the second instructions. Although it became slightly lower during the second generalization assessment, his performance level by the end of the study was higher than baseline level.
Untaught Problems

The results of answers and equations on untaught problems for Willy are described by experimental phases below.

**Baseline.** Willy had an average score of 25% correct on answers for untaught problems. His average percentage correct on equations was 17%.

**Generalization assessment 1.** For untaught problems during the first generalization assessment, Willy had an average percentage correct of 33% on answers and 38% on equations.

**Generalization assessment 2.** During the second generalization assessment, Willy’s average percentage of correct answers was 25%, and his average percentage of correct equations was 25%.

**Follow-up.** Follow-up sessions were conducted 1 week after the second generalization assessment. Willy’s average percentage of correct answers was 25%, and his average percentage of correct equations was 20%.

**Summary of Untaught Problems.** Willy’s percentage of correct answers and equations on untaught problems improved after the first instruction, but they were not high on second generalization assessment. His performance on untaught problems after the second instruction was at the same level as his baseline level.

Jason

Figure 4.10 shows the percentage of correct answers and equations on taught and untaught problems for Jason throughout the study. A graph representing Jason’s number of correct answers and equations across three different sets of teaching examples is presented as Figure P.8 in Appendix P.
Figure 4.10: Percentage of correct answers and equations on taught and untaught story problems for Jason during baseline, instruction, generalization assessment, and follow-up. “A” above horizontal axis indicates student absences.
Taught Problems

The results of answers and equations on taught problems for Jason are described by experimental phases below.

Baseline. During baseline, Jason had an average score of 33% correct on answers for the SCMP problems. His average percentage correct on equations was 22% during baseline.

Instruction 1 - MCSP. Jason experienced the SCMP instruction phase. Although he did not reach 100% correct on answers during instruction 1, his correct equations did reach 100% on fourth probe. For his last two probes during instruction 1, his average percentage correct was 58% on answers and 92% on equations.

Generalization assessment 1. During the first generalization assessment, Jason had an average percentage of 67% correct answers and 83% correct equations.

Instruction 2 - MCMP. Jason experienced the MCMP instruction phase. Jason showed 100% correct on answers on first probe and reached 100% correct in four probes for equations. His average percentage of correct problems for his last two probes during instruction 2 was 92% on answers and 92% on equations as well.

Generalization assessment 2. During the second generalization assessment, Jason’s average percentage of correct answers was 75%, and his average percentage of correct equations was 95%.

Follow-up. Follow-up sessions were conducted 1 week after the second generalization assessment for Jason. Jason’s average percentage of correct answers was 65%, and his average percentage of correct equations was 80.
**Summary of Taught Problems.** Jason's percentage of correct answers and equations on taught problems improved through the first and the second instructions. Although it became slightly lower during the second generalization assessment and the follow-up, his performance level by the end of the study was higher than baseline level.

**Untaught Problems**

The results of answers and equations on untaught problems for Jason are described by experimental phases below.

**Baseline.** Jason had an average score of 36% correct on answers for untaught problems. His average percentage correct on equations was 25%.

**Generalization assessment 1.** For untaught problems during the first generalization assessment, Jason had an average percentage correct of 58% on answers and 58% on equations.

**Generalization assessment 2.** During the second generalization assessment, Jason's average percentage of correct answers was 38%, and his average percentage of correct equations was 38%.

**Follow-up.** Follow-up sessions were conducted 1 week after the second generalization assessment. Jason's average percentage of correct answers was 15%, and his average percentage of correct equations was 10%.

**Summary of Untaught Problems.** Jason's percentage of correct answers and equations on untaught problems improved after the first instruction, but they were not high on second generalization assessment. His performance on untaught problems after the second instruction was slightly higher than at his baseline level.
Sam

Figure 4.11 shows the percentage of correct answers and equations on taught and untaught problems for Sam throughout the study. A graph representing Sam's number of correct answers and equations across three different sets of teaching examples is presented as Figure P.9 in Appendix P.

Taught Problems

The results of answers and equations on taught problems for Sam are described by experimental phases below.

Baseline. During baseline, Sam had an average score of 61% correct on answers for the SCMP problems. His average percentage correct on equations was 22% during baseline.

Instruction 1 - MCSP. Sam experienced the SCMP instruction phase. He reached 100% correct in three probes for both answers and equations. For his last two probes during instruction 1, his average percentage correct was 100% on answers and 100% on equations.

Generalization assessment 1. During the first generalization assessment, Sam had an average percentage of 67% correct answers and 67% correct equations as well.

Instruction 2 - MCMP. Sam experienced the MCMP instruction phase. Sam did not reach 100% correct in five probes for either answers or equations. For his last two probes during instruction 2, his average percentage correct was 75% on answers and 67% on equations.
Figure 4.11: Percentage of correct answers and equations on taught and untaught story problems for Sam during baseline, instruction, generalization assessment, and follow-up. “A” above horizontal axis indicates student absences.
Generalization assessment 2. During the second generalization assessment, Sam’s average percentage of correct answers was 75%, and his average percentage of correct equations was 85%.

Follow-up. Follow-up sessions were conducted 1 week after the second generalization assessment for Sam. His average percentage of correct answers was 50%, and his average percentage of correct equations was 40% as well.

Summary of Taught Problems. Sam’s percentage of correct answers and equations on taught problems improved through the first instruction but were not improved very much through the second instruction. Although his first generalization assessment score was lower than his instruction 1 score, generalization assessment 2 score was higher than his instruction 2 score. In sum, his performance level at the end of the second generalization assessment was higher than baseline level.

Untaught Problems

The results of answers and equations on untaught problems for Sam are described by experimental phases below.

Baseline. Sam had an average score of 64% correct on answers for untaught problems. His average percentage correct on equations was 8%.

Generalization assessment 1. For untaught problems during the first generalization assessment, Sam had an average percentage correct of 29% on answers and 33% on equations.

Generalization assessment 2. During the second generalization assessment, Sam’s average percentage of correct answers was 50%, and his average percentage of correct equations was 44%.
Follow-up. Follow-up sessions were conducted 1 week after the second generalization assessment. Sam's average percentage of correct answers was 30%, and his average percentage of correct equations was 20%.

Summary of Untaught Problems. Since Sam's baseline scores were relatively high, he did not show any improvement for answers on untaught problems. However, his percentage of correct equations was improved after the first and the second instruction. His performance on equations for untaught problems became much higher than baseline level on generalization assessment 2.

SCMP Group Summary

In the section below, the results from the students in the SCMP group are summarized.

Summary of Performance by Individual Students

Table 4.7 and Figure 4.12 show the average percentage of correct answers and equations on taught and untaught story problems across experimental phases (except follow-up) for each student in the SCMP group.

Taught Problems. As can be seen in Figure 4.12, 3 students in this group exhibited more than 80% correct answers and equations on taught problems during the first and the second instruction phase, and their scores were maintained during the first and the second generalization assessment. In sum, for most of the students in this group, the skills taught were acquired and maintained well enough.

Untaught Problems. As can be seen in Figure 4.12, four of the five students in this group exhibited higher scores on answers for untaught problems on generalization assessment 1. However, their scores on answers of generalization assessment 1 were not
<table>
<thead>
<tr>
<th>Students</th>
<th>Condition</th>
<th>Answer</th>
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<td>75</td>
<td></td>
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<tr>
<td></td>
<td>Inst. 2-MCMP</td>
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<td>50</td>
<td>90</td>
<td>38</td>
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<td>GA2</td>
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Table 4.7: Average percentage of correct answers and equations on taught and untaught story problems by each student in the SCMP group
Figure 4.12: Average percentage of correct answers and equations on taught and untaught story problems by each student in SCMP group during baseline, instruction, and generalization assessment.
high enough. All five students exhibited a higher percentage of correct equations on generalization assessment 1. Although Theresa and Sam showed more improved scores on equations at their generalization assessment 2, the others exhibited lower scores on equations at their second generalization assessment. In sum, it can be said that generalization occurred after instruction 1 for the students in the MCSP group. However, after the second instruction, which was the MCMP instruction phase, the students showed less generalization.

SCMP Group Summary

Table 4.8 and Figure 4.13 show the SCMP group average percentage of correct answers and equations across experimental phases (except follow-up) by taught and untaught problems. All students in this group showed more than 60% correct during their two instruction phases, and all five students' data were used to calculate the group averages.

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<td>38</td>
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<td>Inst. 1-SCMP</td>
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<td>83</td>
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<tr>
<td>GA2</td>
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<td>47</td>
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Table 4.8: SCSP group mean percentage of correct answers and equations on taught and untaught story problems
Figure 4.13: SCMP group mean percent correct answers and equations on taught and untaught story problem during baseline, instruction and generalization assessment.
Taught Problems. As can be seen in Table 4.8 and Figure 4.13, the SCMP group reached about 90% correct answers and equations (88% on answers, 90% on equations) on taught problems on the average at their first instruction. However, the level of performance was slightly lower on first generalization assessment. At the end of instruction 2, the group reached 85% correct on answers and 83% on equations on the average. The score on generalization assessment 2 was lower compared with the one for instruction 2. In sum, it can be said that the acquisition of taught problems through SCMP instruction was good, but the maintenance and the acquisition through MCMP instruction was lower than that.

Untaught Problems. On the average, the SCMP group exhibited slightly higher scores on answers for untaught problems on generalization assessment 1. A more improved average percentage of correct answers was shown on second generalization assessment. This group exhibited a much higher percentage of correct equations on generalization assessment 1 compared with baseline, and the scores on equations become slightly higher at their generalization assessment 2. In sum, the generalization occurred after instruction 1 on equations but not much on answers for the MCSP group. After the second instruction, which was the MCMP instruction phase, a little generalization both on answers and on equations resulted.

Multiple-Category/Multiple-Position (MCMP) Group

The results on answers and equations for each student in the MCMP group are presented in this section. The results are described by taught and untaught problems and by experimental phases. Each student's results are followed by a group summary.
Six students, Chuck, Debbie, Al, Amy, Tim, and Ali, were in this group. They experienced baseline phase followed by the MCMP instruction phase—in which Combination 3, Comparison 3, Change 4, Combination 4, Comparison 5, and Change 6 were taught—as their first instruction phase for 11 sessions. “Taught” problems refer to those 6 problems, for baseline, instruction 1, and generalization assessment 1. “Untaught” problems during the three phases include 12 problems other than the 6 MCMP problems. The total number of problems and problem subtypes during each phase are summarized in Table 4.9.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Taught/Untaught</th>
<th>Total Number of Problems</th>
<th>Problem Subtypes Included</th>
</tr>
</thead>
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<td>Baseline</td>
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<td>Combination 3, Comparison 3, Change 4, Combination 4, Comparison 5, Change 6</td>
</tr>
<tr>
<td></td>
<td>Untaught</td>
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<td>Other than above 6 subtypes</td>
</tr>
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<td>Instruction 1 - MCMP</td>
<td>Taught</td>
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<td>Combination 3, Comparison 3, Change 4, Combination 4, Comparison 5, Change 6</td>
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<td>Untaught</td>
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<td>Combination 3, Comparison 3, Change 4, Combination 4, Comparison 5, Change 6</td>
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<td></td>
<td>Untaught</td>
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<td>Other than above 6 subtypes</td>
</tr>
<tr>
<td>Instruction 2 - MCMP</td>
<td>Taught</td>
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<td>Combination 3, Comparison 3, Change 4, Combination 4, Comparison 5, Change 6</td>
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<td>Generalization assessment 2</td>
<td>Taught</td>
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<td>Combination 3, Comparison 3, Change 4, Combination 4, Comparison 5, Change 6</td>
</tr>
<tr>
<td></td>
<td>Untaught</td>
<td>12</td>
<td>Other than above 11 subtypes</td>
</tr>
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</table>

Table 4.9: Total number and subtypes of taught and untaught problems for the MCMP group during baseline, instruction 1, generalization assessment 1, instruction 2, and generalization assessment 2
After the first generalization assessment, the MCMP instruction phase was repeated for 5 sessions as the students' second instruction phase. The taught problems during the second instruction and the second generalization assessment included the same 6 MCMP problems. The untaught problems for generalization assessment 2 were the same 12 problems as their baseline and generalization assessment 1. The follow-up phase was not conducted for this group because their school year ended before follow-up data could be collected.

Chuck

Figure 4.14 shows the percentage of correct answers and equations on taught and untaught problems for Chuck throughout the study. A graph representing Chuck's number of correct answers and equations across three different sets of teaching examples is presented as Figure P.10 in Appendix P.

Taught Problems

The results of answers and equations on taught problems for Chuck are described by experimental phases below.

Baseline. During baseline, Chuck had an average score of 17% correct on answers for the MCMP problems. His average percentage correct on equations was 22%.

Instruction 1- MCSP. Chuck experienced the MCMP instruction phase. He reached 100% correct in nine probes for answers but did not reach 100% for equations. His average percentage correct on his last two probes during instruction 1 was 75% on answers and 75% on equations.

Generalization assessment 1. During the first generalization assessment, Chuck had an average percentage of 75% correct answers and 83% correct equations.
Figure 4.14: Percentage of correct answers and equations on taught and untaught story problems for Chuck during baseline, instruction, generalization assessment, and follow-up. “A” above horizontal axis indicates student absences.
Instruction 2 – MCMP. Chuck repeated the MCMP instruction phase. He reached 100% correct in four probes for both answers and equations. For his last two probes during instruction 2, his average percentage was 92% correct on answers and 100% correct on equations.

Generalization assessment 2. During the second generalization assessment, Chuck’s average percentage of correct answers was 83%, and his average percentage of correct equations was 75%.

Summary of Taught Problems. Chuck’s percentage of correct answers and equations on taught problems improved through the first and the second instruction phases. Although it became lower during the second generalization assessment, his performance level was much improved compared with his baseline level.

Untaught Problems

The results of answers and equations on untaught problems for Chuck are described by experimental phases below.

Baseline. Chuck had an average score of 28% correct on answers for untaught problems. His average percentage correct on equations was 31%.

Generalization assessment 1. For untaught problems during the first generalization assessment, Chuck had an average percentage correct of 63% on answers and 79% on equations.

Generalization assessment 2. During the second generalization assessment, Chuck’s average percentage of correct answers was 67%, and his average percentage of correct equations was 67%.
Summary of Untaught Problems. Chuck’s percentage of correct answers and equations on untaught problems improved after the first instruction, although they were not high as well on second generalization assessment. However, his performance on untaught problems became much higher than baseline level by the end of the study.

Debbie

Figure 4.15 shows the percentage of correct answers and equations on taught and untaught problems for Debbie throughout the study. A graph representing Debbie’s number of correct answers and equations across three different sets of teaching examples is presented as Figure P.11 in Appendix P.

Taught Problems

The results of answers and equations on taught problems for Debbie are described by experimental phases below.

Baseline. During baseline, Debbie had an average score of 44% correct on answers for the MCMP problems. Her average percentage correct on equations was 17% during baseline.

Instruction 1- MCSP. Debbie experienced the MCMP instruction phase. She reached 100% correct in three probes for answers and in two probes for equations. For her last two probes during instruction 1, her average percentage correct was 83% on answers and 83% on equations as well.

Generalization assessment 1. During the first generalization assessment, Debbie had an average percentage of 83% correct answers and 83% correct equations.
Figure 4.15: Percentage of correct answers and equations on taught and untaught story problems for Debbie during baseline, instruction, generalization assessment, and follow-up. "A" above horizontal axis indicates student absences.
Instruction 2 – MCMP. Debbie repeated the MCMP instruction phase. She reached 100% correct in four probes for both answers and equations. For her last two probes during instruction 2, her average percentage correct was 75% on answers and 83% on equations.

Generalization assessment 2. During the second generalization assessment, Debbie’s average percentage of correct answers was 100%, and her average percentage of correct equations was 100%.

Summary of Taught Problems. Debbie’s percentage of correct answers and equations on taught problems improved through the first and the second instructions. Although it became slightly lower during the second generalization assessment, her performance level was much improved compared with her baseline level.

Untaught Problems

The results of answers and equations on untaught problems for Debbie are described by experimental phases below.

Baseline. Debbie had an average score of 44% correct on answers for untaught problems. Her average percentage correct on equations was 33%.

Generalization assessment 1. For untaught problems during the first generalization assessment, Debbie had an average percentage correct of 63% on answers and 79% on equations.

Generalization assessment 2. During the second generalization assessment, Debbie’s average percentage of correct answers was 63%, and her average percentage of correct equations was 71%.
Summary of Untaught Problems. Debbie’s percentage of correct answers and equations on untaught problems improved after the first instruction, although they were slightly lower on second generalization assessment. However, her performance on untaught problems became much higher than baseline level by the end of the study.

Al

Figure 4.16 shows the percentage of correct answers and equations on taught and untaught problems for Al throughout the study. A graph representing Al’s number of correct answers and equations across three different sets of teaching examples is presented as Figure P.12 in Appendix P.

Taught Problems

The results of answers and equations on taught problems for Al are described by experimental phases below.

Baseline. During baseline, Al had an average score of 28% correct on answers for the MCMP problems. His average percentage correct on equations was 22% during baseline.

Instruction 1- MCSP. Al experienced the MCMP instruction phase. He reached 100% correct in nine probes for answers but did not reach 100% for equations. For his last two probes during instruction 1, his average percentage correct was 83% on answers and 92% on equations.

Generalization assessment 1. During the first generalization assessment, Al had an average percentage of 50% correct answers and 75% correct equations.
Figure 4.16: Percentage of correct answers and equations on taught and untaught story problems for Al during baseline, instruction, generalization assessment, and follow-up. “A” above horizontal axis indicates student absences.
Instruction 2 — MCMP. Al repeated the MCMP instruction phase. He reached 100% correct in two probes for answers, and he showed 100% correct for equations at this first probe. For his last two probes during instruction 2, his average percentage correct was 83% on answers and 67% on equations.

Generalization assessment 2. During the second generalization assessment, Al’s average percentage of correct answers was 67%, and his average percentage of correct equations was 75%.

Summary of Taught Problems. Al’s percentage of correct answers and equations on taught problems improved through the first instruction. However, he showed a decreasing trend toward correct equations during the second instruction phase. Al’s scores on generalization assessments were lower than the ones at the end of instruction. However, his performance level was much improved compared with his baseline level.

Untaught Problems

Baseline. Al had an average score of 17% correct on answers for untaught problems. His average percentage correct on equations was 28%.

Generalization assessment 1. For untaught problems during the first generalization assessment, Al had an average percentage correct of 63% on answers and 46% on equations.

Generalization assessment 2. During the second generalization assessment, Al’s average percentage of correct answers was 54%, and his average percentage of correct equations was 54%.

Summary of Untaught Problems. Al’s percentage of correct answers and equations on untaught problems improved after the first instruction, although they became lower on
second generalization assessment. However, his performance on untaught problems became much higher than baseline level by the end of the study.

Amy

Figure 4.17 shows the percentage of correct answers and equations on taught and untaught problems for Amy throughout the study. A graph representing Amy’s number of correct answers and equations across three different sets of teaching examples is presented as Figure P.13 in Appendix P.

Taught Problems

The results of answers and equations on taught problems for Amy are described by experimental phases below.

Baseline. During baseline, Amy had an average score of 22% correct on answers for the MCMP problems. Her average percentage correct on equations was 17% during baseline.

Instruction 1 - MCSP. Amy experienced the MCMP instruction phase. She reached 100% correct in nine probes for answers but she did not reach the 100% level for equations.

For her last two probes during instruction 1, her average percentage correct was 83% on answers and 83% on equations.

Generalization assessment 1. During the first generalization assessment, Amy had an average percentage of 42% correct answers and 83% correct equations.
Figure 4.17: Percentage of correct answers and equations on taught and untaught story problems for Amy during baseline, instruction, generalization assessment, and follow-up. "A" above horizontal axis indicates student absences.
**Instruction 2 — MCMP.** Amy repeated the MCMP instruction phase. She reached 100% correct in three probes for answers but she did not show 100% correct for equations. For her last two probes during instruction 2, her average percentage correct was 50% on answers and 50% on equations as well.

**Generalization assessment 2.** During the second generalization assessment, Amy’s average percentage of correct answers was 100%, and her average percentage of correct equations was 100% as well.

**Summary of Taught Problems.** Amy’s percentage of correct answers and equations on taught problems improved through the first instruction. Only her performance on equations was maintained on generalization assessment 1. Although she showed very unstable performance during instruction 2, her score on generalization assessment 2 was high. Her performance level was much improved compared with her baseline level.

**Untaught Problems**

The results of answers and equations on untaught problems for Amy are described by experimental phases below.

**Baseline.** Amy had an average score of 31% correct on answers for untaught problems. Her average percentage correct on equations was 28%.

**Generalization assessment 1.** For untaught problems during the first generalization assessment, Amy had an average percentage correct of 71% on answers and 50% on equations.

**Generalization assessment 2.** During the second generalization assessment, Amy’s average percentage of correct answers was 58%, and her average percentage of correct equations was 54%.
Summary of Untaught Problems. Amy’s percentage of correct answers and equations on untaught problems improved after the first instruction, although they were slightly lower on second generalization assessment. However, her performance on untaught problems became much higher than baseline level by the end of the study.

Tim

Figure 4.18 shows the percentage of correct answers and equations on taught and untaught problems for Tim throughout the study. A graph representing Tim’s number of correct answers and equations across three different sets of teaching examples is presented as Figure P.14 in Appendix P.

Taught Problems

The results of answers and equations on taught problems for Tim are described by experimental phases below.

Baseline. During baseline, Tim had an average score of 50% correct on answers for the MCMP problems. His average percentage correct on equations was 25% during baseline.

Instruction 1- MCSP. Tim experienced the MCMP instruction phase. He reached 100% correct in nine probes for answers and in seven probes for equations. For his last two probes during instruction 1, his average percentage correct was 67% on answers and 92% on equations.

Generalization assessment 1. During the first generalization assessment, Tim had an average percentage of 92% correct answers and 100% correct equations.
Figure 4.18: Percentage of correct answers and equations on taught and untaught story problems for Tim during baseline, instruction, generalization assessment, and follow-up. "A" above horizontal axis indicates student absences.
Instruction 2 — MCMP. Tim repeated the MCMP instruction phase. Tim did not reach the 100% level for answers but he showed 100% correct in two probes for equations. For his last two probes during instruction 2, his average percentage correct was 83% on answers and 100% on equations.

Generalization assessment 2. During the second generalization assessment, Tim’s average percentage of correct answers was 83%, and his average percentage of correct equations was 100%.

Summary of Taught Problems. Tim’s percentage of correct answers and equations on taught problems improved through the first and the second instructions. Although it became slightly lower during the second generalization assessment, his performance level was much improved compared with his baseline level.

Untaught Problems

The results of answers and equations on untaught problems for Tim are described by experimental phases below.

Baseline. Tim had an average score of 63% correct on answers for untaught problems. His average percentage correct on equations was 25%.

Generalization assessment 1. For untaught problems during the first generalization assessment, Tim had an average percentage correct of 42% on answers and 58% on equations.

Generalization assessment 2. During the second generalization assessment, Tim’s average percentage of correct answers was 63%, and his average percentage of correct equations was 67%.
Summary of Untaught Problems. Tim’s percentage of correct problems on untaught problems improved after the first and the second instruction only for equations. His performance on untaught problems became higher than baseline level by the end of the study regarding equations, but it did not change for answers.

Ali

Figure 4.19 shows the percentage of correct answers and equations on taught and untaught problems for Ali throughout the study. A graph representing Ali’s number of correct answers and equations across three different sets of teaching examples is presented as Figure P.15 in Appendix P.

Taught Problems

The results of answers and equations on taught problems for Ali are described by experimental phases below.

Baseline. During baseline, Ali had an average score of 17% correct on answers for the MCMP problems. Her average percentage correct on equations was 17% during baseline.

Instruction 1- MCSP. Ali experienced the MCMP instruction phase. She reached 100% correct in four probes for both answers and equations. For her last two probes during instruction 1, her average percentage correct was 83% on answers and 83% on equations as well.

Generalization assessment 1. During the first generalization assessment, Ali had an average percentage of 75% correct answers and 58 correct equations.
Figure 4.19: Percentage of correct answers and equations on taught and untaught story problems for Ali during baseline, instruction, generalization assessment, and follow-up. "A" above horizontal axis indicates student absences.
Instruction 2 — MCMP. Ali repeated the MCMP instruction phase. She reached 100% correct in five probes for answers and in four probes for equations. For her last two probes during instruction 2, her average percentage correct was 92% on answers and 92% on equations.

Generalization assessment 2. During the second generalization assessment, Ali’s average percentage of correct answers was 100%, and her average percentage of correct equations was 100%.

Summary of Taught Problems. Ali’s percentage of correct answers and equations on taught problems improved through the first and the second instructions. Although it was lower during the first generalization assessment, her performance level was much improved compared with her baseline level.

Untaught Problems

The results of answers and equations on untaught problems for Ali are described by experimental phases below.

Baseline. Ali had an average score of 36% correct on answers for untaught problems. Her average percentage correct on equations was 28%.

Generalization assessment 1. For untaught problems during the first generalization assessment, Ali had an average percentage correct of 29% on answers and 42% on equations.

Generalization assessment 2. During the second generalization assessment, Ali’s average percentage of correct answers was 46%, and her average percentage of correct equations was 50%.
Summary of Untaught Problems. Ali’s percentage of correctness on untaught problems improved after the first instruction only for equations. However, she showed improved levels of performance for both answers and equations on generalization assessment 2. Her performance on untaught problems became much higher than baseline level by the end of the study.

MCMP Group Summary

In the section below, the results from students in the MCMP group are summarized.

Summary of Performance by Individual Students

Table 4.10 and Figure 4.20 show the average percentage of correct answers and equations on taught and untaught story problems across experimental phases for each student in the MCMP group.

Taught Problems. As can be seen in Figure 4.20, four students in this group exhibited more than 80% correct answers and equations on taught problems during the two instruction phases. Chuck, Debbie, and Tim showed a maintained level of performance during generalization assessment 1 on answers and equations. In addition, Chuck and Ali scored high during generalization assessment 2.

Untaught Problems. As can be seen in Figure 4.20, four students in this group exhibited much higher scores on answers for untaught problems on generalization assessment 1. All students showed higher scores on equations at the same time. For generalization assessment 2, three students showed scores as high as or higher than their generalization assessment 1 scores. In sum, they showed generalization after the first and the second instructions, and this tendency was stronger on equations than on answers.
<table>
<thead>
<tr>
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Table 4.10: Average percentage of correct answers and equations on taught and untaught story problems by each student in the MCMP group
Figure 4.20: Average percentage of correct answers and equations on taught and untaught story problems by each student in MCMP group during baseline, instruction, and generalization assessment.
MCSP Group Summary

Table 4.11 and Figure 4.21 show the MCMP group average percentage of correct answers and equations across experimental phases by taught and untaught problems. Since Amy did not show more than 60% correctness during her second instruction phase, her data was not used to calculate the group averages.

Taught Problems. As can be seen in Table 4.11 and Figure 4.21, the MCMP group reached about 80% correct answers and equations (78% on answers, 85% on equations) on taught problems on the average. However, the level of performance was slightly lower on first generalization assessment. At the end of instruction 2, the group reached 85% correct on answers and 88% on equations on the average. The score on generalization assessment 2 was slightly higher compared with the one for instruction 2. In sum, it can be said that the acquisition of taught problems, as a average of this group, was good. Although a high enough level of maintenance was not shown on first generalization assessment, the maintenance score after the second instruction was high.

Untaught Problems. As a group average, the MCMP group exhibited much higher scores on answers and on equations for untaught problems on generalization assessment 1 (from 38% to 52% on answers, from 29% to 61% on equations). Moreover, the average percentage of correct answers and equations on second generalization assessment was higher (58% on answers and 62% on equations). In sum, it can be said that the generalization occurred after instruction 1 and 2 for the MCMP group.
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<th>Answer Untaught</th>
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Table 4.11: MCMP group mean percentage of correct answers and equations on taught and untaught story problems
Figure 4.21: MCMP group mean percent correct answers and equations on taught and untaught story problem during baseline, instruction and generalization assessment.
CHAPTER 5

DISCUSSION

This study was designed to evaluate the comparative effects of three subsets of teaching examples of story problems—Multiple-Category/Single-Position, Single-Category/Multiple-Position, and Multiple-Category/Single-Position—on generalized arithmetic story problem solving by elementary students. This chapter discusses limitations of the study, offers an interpretation of the results relative to the two research questions and previous research, suggests implications for curriculum design and classroom practice, and recommends directions for future research.

Limitations of the Study

In this section, limitations of the study are discussed regarding curriculum content, design, measurement, students, and setting.

Curriculum Content Limitations

Riley and Greeno's (1988) taxonomy of 18 subtypes of basic arithmetic story problems was used to provide tasks for instruction and assessment in this study. Riley and Greeno classified arithmetic story problems according to two characteristics: which of three categories (Combination, Change, and Comparison) they fell into and what kind of unknown values they had (see Table 2.1 in Chapter 2). As a result, they suggested 18 subtypes as prototypes of basic story problems. Although previous studies have used
Riley and Greeno's categorization, there is no scientific evidence that their taxonomy is the best way to organize basic arithmetic story problems. Therefore, we may have a better way to categorize story problems. Also, we may be able to find more effective instructional strategies if studies are conducted based on another way of categorizing story problems.

Since the story problems used in this study were based on Riley and Greeno's (1988) categorization, they had three mathematical key words—"in all" for Combination, "gave" for Change, and "more" and "less" for Comparison problems. However, story problems can be stated with different key words. For example, "altogether" can be exchanged with "in all" in a story problem (e.g., "Mary has 4 apples. Bob has 3 apples. How many apples do they have in all?"). Also, all the Change problems used in this study used the word "gave" (e.g., "Mary had 4 apples. Bob gave her 3 apples. How many apples does Mary have now?"). However, this problem can be stated as "Mary had 4 apples. Mary receives 3 apples from Bob. How many apples does Mary have now?"

Moreover, the words "sell" and "buy" or "get" and "lost" can be exchanged with "give" and "given." Similarly, the words "more" and "less" in Comparison problems such as "Mary has 3 apples. Bob has 3 more apples than Mary. How many apples does Bob have?" can be changed into "older" and "younger" or "taller" and "shorter." Thus, this study targeted story problems written with a limited vocabulary of key words. If the story problems had been written with different mathematical key words, that might have affected the results of the study.

In addition to the mathematical key words, several other story problem elements could be dealt with in ways different from this study. By design, all 6 story problems used in this study included only single digit numbers, solving problems did not require
regrouping of addition or subtraction, and no extraneous information beyond the numbers was included. Authors of previous studies have argued that story problems with extraneous information are more difficult than ones without extraneous information (Cawley et al., 2001; Parmer et al., 1996). For example, consider the following: "Tom has 5 apples. Lisa has 3 apples and 2 oranges. How many apples do they have in all?" In this case, "Lisa has ... 3 oranges" is extraneous information that only makes the problem more difficult to solve. The instruction used in the study did not include teaching students to identify extraneous information in the story, if any. Students were taught to write the element (number or a mystery box) of the first sentence at the beginning position of the equation, to write the element (number or a mystery box) of the second sentence in the middle position of the equation, and to write the element (number or a mystery box) of the third sentence at the end position of the equation. It can be expected that students would have been confused if a problem had extraneous information between, for example, the first and the second sentences of the story. Therefore, the results from this study may not apply to more complex story problems.

As discussed above, story problems can have various characteristics (e.g., category, subtype, type of equation used, key words, numbers, extraneous information). Since the story problems used for this study were based on Riley and Greeno’s (1988) taxonomy, they did not include a possible variation of factors. At present, we do not even know if Riley and Greeno’s categorization describes the nature of story problems in the best way. Therefore, it might be necessary to evaluate the categorization of story problems in the future.
Design Limitations

This study was designed to compare the effects of three subsets of teaching examples, MCSP, SCMP, and MCMP, on generalized story problem solving. To investigate generalized effects, it was necessary to assess students’ acquisition and maintenance of solving taught story problems, which was a prerequisite condition for analyzing generalization effects. The experimental design, therefore, had to be very complex with several unavoidable limitations. In this section, design limitations are discussed with respect to assessment of the generalization effects and assessment of the acquisition and maintenance effects.

Assessment of Generalization Effects

Students in the MCSP group experienced MCSP instruction followed by MCMP instruction. The SCMP group experienced SCMP instruction followed by MCMP instruction. Students in the MCMP group experienced MCMP instruction twice.

All three groups received instruction on MCMP problems, and MCMP instruction had the greatest effect on generalization for all three groups. However, the relative size of those generalization effects achieved by MCMP instruction cannot be compared across groups. Strictly speaking, sequence effects must be considered because each group received instruction on a different subset of problems preceding MCMP instruction. Since sequence effects could not be eliminated when instruction on two or more subsets of problems had to be introduced, it needed to be controlled.

Since this study was designed to compare three types of instruction, the sequence of instruction introduced to each group was considered carefully. Although only three groups of students participated in this study, 6 groups or 12 groups would have been
needed to control sequence effects. Working with 6 groups of students would have enabled examination of all possible sequences of instruction created by the three different subsets of problems. With 12 groups of students, those 6 sequences would be replicated at least once. Thus, if a larger-scale study of 12 groups of students had occurred, the effects of three different subsets of teaching examples could have been compared strictly and the sequential effects could also have been controlled.

To assess the generalization effects, this study used 18 subtypes of story problems. Some problems were used as taught problems and students were introduced to those taught problems, then the rest of the 18 subtypes were used for assessing the generalization effects as untaught problems. As of the end of the first instruction phase, each of the groups had 12 untaught problems remaining for generalization assessment. This was fine because all groups had the same number of problems to be assessed on for the generalization. However, after the second phase of instruction, only 5 untaught problems remained for the MCSP group and 6 untaught problems for the SCMP group while the MCMP group still had 12 untaught problems. Therefore, a different number of untaught problems remained for the second generalization assessment for each group of students. In addition, the number of untaught problems remaining for the second generalization assessment for students in the MCSP group (5) and the SCMP group (6) was small. A more ideal design could include a larger number of untaught problems for each group. This limitation, however, was unavoidable because there were only 18 subtypes of story problems in the categorization used in this study.

After the first and the second phase of instruction, generalization assessments were conducted. At each generalization assessment, the 18 problem subtypes were assessed
twice. The performance of some students on the two generalization assessment was inconsistent. For example, one student solved 100% correct on first generalization probe but only 60% on second generalization assessment. While more frequent generalization assessments might have been conducted to yield stable data, doing so might have confounded the results with practice effects.

Assessment of Acquisition and Maintenance Effects

Analyzing the effects of instruction on acquisition and maintenance of taught problems was not the primary purpose of this study. However, to investigate the comparative generalization effects of teaching the three subsets of story problems, it was necessary to obtain evidence that students initially learned and maintained the taught problems. Although most of the students showed high levels of acquisition and maintenance in this study, the study’s design entailed some limitations regarding the assessment of such acquisition and maintenance effects.

Although the students showed high acquisition and maintenance scores, they were not 100%. If the students had been able to show higher scores on acquisition and maintenance, the generalization scores might have been higher.

The sequence of conditions in the study functioned as a reversal design or as a multiple baseline across subsets of teaching example design. The students in the MCSP group experienced instruction on MCSP problems and MCMP problems in the manner of a multiple baseline design, and the students in the SCMP group experienced instruction on SCMP problems and MCMP problems in the manner of a multiple baseline design as well. Students in the MCMP group, on the other hand, had a reversal design to assess the effects of instruction on MCMP problems. However, these designs did not enable an
experimental assessment in the study because of irreversibility of instruction and overlap of teaching examples across problem subsets.

Story problem solving behavior is irreversible (Sidman, 1960). Once students have been taught how to solve a certain type of story problem, they are likely to be able to solve that type of problem in the future. Therefore, the reversal design does not fit to assess the functional relations between instruction and story problem solving behavior. The MCMP group experienced instruction on MCMP problems twice. Because their acquisition and maintenance scores for the first MCMP instruction were relatively low, they scored higher on second instruction. However, it cannot be said from this result that the functional relation between instruction and the target behavior was replicated through a reversal design. Instead, it showed that a longer duration of instruction resulted in a higher performance without replications. Therefore, the replication of the effects of instruction on acquisition and maintenance needed to be replicated using designs other than a reversal design.

Students in the MCSP and the SCMP groups received instruction on two different subsets of story problem examples in different sequences. Although students in both groups achieved relatively high acquisition and maintenance scores for all instruction, it cannot be said that there is a functional relation between instruction and the target skills. MCSP problems and MCMP problems had 1 overlap problem in 6 problems in each subset. SCMP and MCMP problems had 2 overlap problems in 6 problems in each subset. For these overlaps, the combined effects of the first instruction and the second instruction could sequentially affect the target skills. Therefore, the overlap of problem subtypes
across subsets of teaching examples should have been eliminated to make the multiple baseline across problem subset design work to assess the effect of instruction on acquisition and maintenance.

Having acknowledged these limitations, it is important to restate that determining the presence and extent of a functional relation between instruction and the students' acquisition and maintenance of taught problems was not the purpose of this study.

**Measurement Limitations**

Three limitations related to the experimental procedures and the measurement are described below.

First, the experimenter or assistants read the story problems when students completed worksheets for the purpose of assessment of baseline, acquisition, maintenance, and generalization. Because the pre-experiment assessment revealed that the students had various levels of reading fluency and reading comprehension, the experimenter needed to read the problems to the students to control the effects of their reading skills. This procedure was kept consistent throughout the study, and it is not a large limitation. However, students are usually required to read story problems by themselves and then to solve them. Therefore, the results from this study may not be able to be generalized to a situation that requires students to read the problems by themselves.

Second, baseline and generalization assessments were conducted by the experimenter and the assistants. This may be a limitation because all instruction was delivered by only the experimenter. However, because no differences were found in the students’ performances between generalization probes conducted by the experimenter and those conducted by the assistants, this does not appear to be a limitation.
Third, the number of worksheets that students were required to complete was not consistent throughout the study. During baseline, students completed one or two worksheets a day. During instruction phases, they completed one worksheet a day. On generalization assessment, students completed two worksheets a day. Although the data suggest that performance was not affected by this aspect of the procedures, it is possible that students might have experienced, for example, fatigue during the probes with two worksheets.

Student Limitations

A total of 19 students participated in the study at the beginning, and they were divided into three groups. Because 4 students had a high rate of absence or moved from the district, the study ended up with 15 students. At the end of the study, the MCSP, SCMP, and MCMP groups included 4, 5, and 6 students, respectively. The small number of students in each group is a considerable limitation.

It may be also a limitation that all participants were selected from one classroom. Although it was good that all students had relatively the same history effects regarding previous math instruction, such history effects might have affected the results of this study unknowingly.

The pre-experiment assessment was conducted for all students to assess their computation skills and story problem solving skills before the experiment. All students participated in the study regardless of the level of their skills, and there was almost no difference in the results between low and high performers. However, the relation between the students' previous skills and the results of the study were not evaluated using scientific methods.
The study required students to participate in sessions that lasted for approximately 30 minutes for more than 20 days. Since it was expected that students might get bored of attending the sessions, several strategies were built into the study to keep students’ motivation high. However, on a couple of occasions one or two students expressed that they were tired, which may have affected their performance on solving story problems.

**Setting Limitations**

Several limitations regarding the experimental settings deserve mention.

First, the study began in early March and continued to the end of the school year. Because the study needed to be finished by the end of the school year, an optimum number of instructional sessions could not be delivered for the SCMP and MCMP groups, and there was no time to collect follow-up data for students in the MCMP group. In addition, a week-long spring break occurred in the middle of the study, which may have affected the students’ performance.

The instruction and the assessment were delivered for one group at a time. Students in the group receiving instruction were called on, and they worked with the experimenter in one corner of their classroom. The remaining students in the class worked on other activities prepared by their classroom teacher. On several occasions when the experimenter delivered instruction, the classroom became very noisy. Such a setting factor might have affected the results of the study.

The experimenter talked with the teacher of the classroom in which the study was conducted and checked that the students had not been taught story problems previously. However, it was observed that the materials for students’ regular math class began to introduce basic story problems (e.g., Combination 1 and 2, Change 1 and 2) while the
study was going on. The teacher reported that she had not provided any explicit
instruction on those story problems. However, it might be possible that instructional
activities going on in the regular classes affected the results of the study.

Research Question One

How will students’ accuracy of writing answers and equations to basic arithmetic story
problems during and after instruction featuring the mystery box strategy, choral
responding, and response cards compare to their pre-instruction performance on such
problems?

Research Question 1 is not directed toward the primary purpose of this study, which is to
investigate the comparative effects of three sets of teaching examples on generalized
story problems. However, assessing generalization of skills toward untaught problems
requires evidence of students’ acquisition and maintenance of taught problems. Without
evidence of the acquisition and the maintenance of the taught story problems, the
generalization effects cannot be compared across the three groups.

The Acquisition and Maintenance Effects of Instruction

Table 5.1 and Figure 5.1 show a comparison of the average percentage of correct
answers and equations on taught problems by students in each group during each
experimental phase. The scores of the acquisition (i.e., instruction 1 and instruction 2)
and the maintenance compared with the scores of baseline are discussed below within
each group, followed by a group comparison.
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</tr>
<tr>
<td></td>
<td></td>
<td>MCMP</td>
<td>85 (6)</td>
</tr>
<tr>
<td>GA2 (2)</td>
<td>McSP Group</td>
<td>SCMP</td>
<td>72 (11)</td>
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<tr>
<td></td>
<td></td>
<td>MCMP</td>
<td>81 (10)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SCM P Group</td>
<td>87 (6)</td>
</tr>
</tbody>
</table>

a: number in parentheses shows the number of probes in phase  
b: number in parentheses shows the number of problems assessed in a probe

Table 5.1: Mean percentage of correct answers and equations on taught story problems by three groups during baseline, instruction, and generalization assessment
Figure 5.1: Mean percentage of correct answers and equations on taught story problems for three groups during baseline, instruction, and generalization assessment.
MCSP Group

A comparison of the MCSP group's the average scores at baseline and after instruction 1 lends support to the effectiveness of the instruction featuring the mystery box strategy, choral responding, and use of response cards on acquisition of MCSP problems. Students in the MCSP group showed relatively high scores during baseline, averaging 76% correct answers and 56% correct equations. After instruction 1 on MCSP problems, the mean performance by this group was 94% correct answers and 96% correct equations.

At generalization assessment 1, which assessed the maintenance effects on taught problems, 3 out of 4 students kept their acquired high level of scores, and the group's average percentage of correct answers was 75% and of correct equations was 81%. Those scores were lower than their scores at the end of instruction 1, showing less than 100% maintenance. However, the group's average percentage of correct equations was higher than at baseline, suggesting that the students maintained some parts of the skills they acquired through instruction. The group average percentage on correct answers during generalization assessment 1 was at the same high level as during baseline.

At the end of instruction 2, in which the students received MCMP instruction, the group average percentage of correct answers was 79% and of correct equations was 88%. The MCSP average group percentage of correct MCMP problems during baseline was 46% and 30% for answers and equations, respectively. Looking at the before and after instruction data individually, all four students showed a drastic increase in their percentage of correct answers and equations for MCMP problems. Since the students in this group experienced MCSP instruction before instruction on MCMP problems, the
score after MCMP instruction cannot be attributed to MCMP instruction only. However, with regard to the students’ learning of MCMP problems, these data do provide support for the effectiveness of the instruction featuring the mystery box strategy, choral responding, and response cards when it follows instruction on MCSP problems.

The group average percentage of correct answers and equations was 72% and 77% on generalization assessment 2, respectively. These scores were computed based on the students’ correct answers and equations on MCSP problems and on MCMP problems. Therefore, these scores represent the combined scores of the maintenance of MCSP instruction and the maintenance of MCMP instruction. The scores were lower compared with the ones in instruction 1, in generalization assessment 1, and in instruction 2. Therefore, it can be said that perfect maintenance failed to be shown. However, the average percentage of correct equations on generalization assessment 2 was higher than that at baseline.

In sum, comparing the MCSP group’s performance on taught problems before and after instruction lends credibility to the effects of the instruction featuring the mystery box strategy, choral responding, and response cards on initial acquisition of MCSP problems and MCMP problems. However, maintenance scores by student in this group were somewhat disappointing.

SCMP Group

A comparison of the SCMP group’s average scores at baseline and after instruction 1 lends support to the effectiveness of the instruction featuring the mystery box strategy, choral responding, and response cards on acquisition of SCMP problems. Students in the SCMP group showed relatively high scores during baseline, averaging 34% correct
answers and 24% correct equations. After instruction 1 on MCSP problems, the mean performance by this group was 88% correct answers and 90% correct equations.

On generalization assessment 1, which assessed the maintenance effects on taught problems, 5 out of 6 students kept their acquired high level of scores, and the group’s average percentage of correct answers was 80% and of correct equations was 77%. Those scores were lower than their scores at the end of instruction 1, showing less than 100% maintenance. However, the group’s average percentage of correct answers and equations was higher than at baseline, suggesting that the students maintained some parts of the skills they acquired through instruction.

At the end of instruction 2, in which the students received MCMP instruction, the group average percentage of correct answers was 85% and of correct equations was 83%. The SCMP group average percentage of correct MCMP problems during baseline was 25% and 12% for answers and equations, respectively. Looking at the before and after instruction data individually, all four students showed a drastic increase on their percentage of correct answers and equations for MCMP problems. Since the students in this group experienced SCMP instruction before instruction on MCMP problems, the score after MCMP instruction cannot be attributed to MCMP instruction only. However, with regard to students’ learning MCMP problems, these data do provide support for the effectiveness of the instruction featuring the mystery box strategy, choral responding, and response cards when it follows instruction on SCMP problems.

The group average percentage of correct answers and equations was 81% and 83% on generalization assessment 2, respectively. These scores were computed based on the students’ correct answers and equations on SCMP problems and on MCMP problems.
Therefore, these scores represent the combined scores of the maintenance of SCMP instruction and the maintenance of MCMP instruction. The scores were lower compared with the ones in instruction 1, in generalization assessment 1, and in instruction 2. Therefore, it can be said that perfect maintenance failed to be shown. However, the average percentage of correct equations on generalization assessment 2 was higher than at baseline.

In sum, comparing the SCMP group’s performance on taught problems before and after instruction lends credibility to the effects of the instruction featuring the mystery box strategy, choral responding, and response cards on initial acquisition of SCMP problems and MCMP problems. However, the maintenance scores by students in this group were somewhat disappointing.

MCMP Group

A comparison of the MCMP group’s average scores at baseline and after instruction 1 lends support to the effectiveness of the instruction featuring the mystery box strategy, choral responding, and response cards on acquisition of MCMP problems. Students in the SCMP group showed relatively high scores during baseline, averaging 31% correct answers and 21% correct equations. After instruction 1 on MCSP problems, the mean performance by this group was 78% correct answers and 85% correct equations.

On generalization assessment 1, which assessed the maintenance effects on taught problems, 3 out of 6 students kept their acquired high level of scores, and the group’s average percentage of correct answers was 75% and of correct equations was 80%. Those scores were lower than their scores at the end of instruction 1, showing less than 100%
maintenance. However, the group’s average percentage of correct answers and equations was higher than at baseline, suggesting that the students maintained some parts of the skills they acquired through instruction.

At the end of instruction 2, in which the students received MCMP instruction, the group average percentage of correct answers was 85% and of correct equations was 88%. These scores were higher than the scores at baseline, instruction 1, and generalization assessment 1. The data do provide support for the effectiveness of the instruction featuring the mystery box strategy, choral responding, and response cards following instruction on MCMP problems.

The group average percentage of correct answers and equations was 87% and 90% on generalization assessment 2, respectively. The scores were higher compared with the ones at baseline, in instruction 1, in generalization assessment 1, and in instruction 2. Therefore, it can be said that the additional instruction on MCMP problems was effective in creating good maintenance scores.

In sum, comparing the MCMP group’s performance on taught problems before and after instruction lends credibility to the effects of the instruction featuring the mystery box strategy, choral responding, and response cards on initial acquisition of MCMP problems. Although only one MCMP instruction did not show effects on the maintenance scores, the additional instruction on MCMP problems resulted in good maintenance.

Comparison of Acquisition and Maintenance Data Across Groups

Baseline. During baseline, although the MCSP group had high scores on answers and equations, the other two groups, the SCMP and MCMP groups, showed low scores. The three groups’ average percentage of correct answers were MCSP group, 76%, SCMP
group, 34%, and MCMP group, 31% (see Table 5.1 and Figure 5.1 on pages 177 to 178). The MCSP group’s baseline scores for taught problems were higher compared with the other two groups because most of the students answered MCSP problems with a high percentage of correctness. The average percentage of correct equations was 56% for the MCSP group, 24% for the SCMP group, and 21% for the MCMP group.

Instruction 1. Comparing the data at the end of instruction 1 across the three groups, it can be said that the instruction featuring the mystery box strategy, choral responding, and response cards was effective for the purposes of acquisition of each of the MCSP, SCMP, and MCMP problems. The average percentage of correct answers was 94% for the MCSP group, 88% for the SCMP group, and 78% for the MCMP group. Although the MCSP group showed the highest score compared with the other two groups, this may be because the MCMP group had high baseline scores on MCSP problems. It can be said that all three groups showed relatively the same effects from instruction in terms of the acquisition of problems assigned to each group. However, the difference between the highest and the lowest score was 16%. Perhaps the MCMP problems are more difficult to acquire compared with the MCSP and SCMP problems. The average percentage of correct equations was 96% for the MCSP group, 90% for the SCMP group, and 85% for the MCMP group. Although the MCSP group showed the highest score compared with the other two groups, all three groups showed fairly high scores. The difference between the highest and the lowest score was 11%.

Generalization assessment 1. Comparing the data during generalization assessment 1 across three groups, it can be said that the instruction featuring the mystery box strategy, choral responding, and response cards resulted in the same level of maintenance for all
three groups. On generalization assessment 1, the average percentage of correct answers on taught problems was 75% for the MCSP group, 80% for the SCMP group, and 75% for the MCMP group. The difference between the highest and the lowest score was only 5%. This indicates that all three groups showed relatively the same level of maintenance scores on correct answers. The average percentage of correct equations was 81% for the MCSP group, 77% for the SCMP group, and 80% for the MCMP group. The difference between the highest and the lowest score was only 4%. Again, all three groups showed relatively the same level of maintenance scores on correct equations. Thus, although all the groups showed lower scores on answers and equations on generalization assessment 1 compared with instruction 1, it can be said that the instruction featuring the mystery box strategy, choral responding, and use of response cards resulted in the same level of maintenance for all three groups.

Instruction 2. Comparing the data at the end of instruction 2 across the three groups, it can be said that all three groups showed the effects of the instruction featuring the mystery box strategy, choral responding, and use of response cards on acquisition of MCMP problems. At the end of instruction 2 in which all three groups were taught MCMP problems, the average percentage of correct answers was 79% for the MCSP group, 85% for the SCMP group, and 85% for the MCMP group. Although the MCSP group showed a lower score compared with the other two groups, the difference between the highest and the lowest score was only 6%. Therefore, it can be said that all three groups showed relatively the same level of effects of instruction on acquisition of MCMP problems. The average percentage of correct equations was 88% for the MCSP group, 83% for the SCMP group, and 88% for the MCMP group. Although the SCMP group
showed a lower score compared with the other two groups, all three groups showed high scores. The difference between the highest and the lowest score was only 5%. Thus, it can be said that all three groups showed the effects of the instruction featuring the mystery box strategy, choral responding, and response cards on acquisition of MCMP problems.

**Generalization assessment 2.** Comparing the data during generalization assessment 1 across the three groups, it can be said that the instruction featuring the mystery box strategy, choral responding, and use of response cards resulted in the highest level of maintenance for the MCMP group and a high enough level of maintenance for the other two groups. During generalization assessment 2, the average percentage of correct answers on taught problems was 72% for the MCSP group, 81% for the SCMP group, and 87% for the MCMP group. The difference between the highest and the lowest score was 15%. The MCMP group showed the highest scores among the three groups, and only the MCMP group showed the higher scores on generalization assessment 2 compared with their scores on instruction 1 and 2. However, the other two groups’ scores were high enough compared with their baseline level. The average percentage of correct equations was 77% for the MCSP group, 83% for the SCMP group, and 90% for the MCMP group. The difference between the highest and the lowest score was 13%.

Again, the MCMP group showed the highest scores among the three groups, and only the MCMP group showed higher scores on generalization assessment 2 compared with their scores on instructions 1 and 2. However, the other two groups’ scores were high enough compared with their baseline level. Thus, the MCMP group showed the highest scores on generalization assessment 2 which assessed the maintenance of all the
taught problems. The scores of generalization assessment 2 represent the average scores of the 11 taught problems for the MCSP group (MCSP problems and MCMP problems), the 10 taught problems for the SCMP group (SCMP problems and MCMP problems), and the 6 taught problems for the MCMP group (MCMP problems only). In other words, the MCMP group received instruction on only 6 problems but the other groups received instruction on more problems. This difference in total number of taught problems might have affected the result of the highest maintenance scores for the MCMP group.

**Summary of Results for Research Question One**

The students’ accuracy in terms of writing answers and equations to basic arithmetic story problems during and after the instruction featuring the mystery box strategy, choral responding, and response cards was improved compared to their pre-instruction performance. Although the maintenance score for the MCMP group was the highest during generalization assessment 2, all the groups showed relatively the same levels of high acquisition and maintenance.

Response card and choral responding have served as effective instructional strategies for teaching various subject matters (e.g., Cavanaugh, Heward, & Donelson, 1996; Dugan, Leonard, & Daoust, 1994; Endo, 2000; Heward, Courson, & Narayan, 1989; Kamps, Rindfuss, Al-Attrash, Morrison, & Heward, 1998). The results of this study lend additional support for and provide another example of successful use of response cards and choral responding as teaching methods.

The mystery box strategy was created based on the number family strategy. The results of the study support previous studies in that the number family strategy is effective for students’ acquisition of story problem solving skills (e.g., Carnine, 1997;
Endo, 2000; Harper et al., 1993; Neef, 2001; Stein et al., 1997). In addition, it was exhibited that the mystery box strategy had a maintenance effect on story problem solving skills.

Harper et al. (1993) also used the Direct Instruction's number family strategy, on which the mystery box strategy was based, to teach story problem solving, and they reported that the students could find answers without using the number family strategy. Further, the students in their study did not use the strategy called a diagram in their study very well. However, the students in this study learned how to use the correct strategy (i.e., mystery box equation) as well as to find the correct answers.

The MCSP group showed higher scores during MCSP instruction and MCMP instruction compared with their baseline. The SCMP group showed higher scores during SCMP instruction and MCMP instruction compared with their baseline. The MCMP group showed higher scores during MCMP instruction. Therefore, it can be said that the instruction featuring the mystery box strategy, choral responding, and response cards was effective for acquisition of all the three sets of teaching examples.

The story problem solving skills acquired through instruction were maintained high enough compared with baseline level. Therefore, it can be said that the instruction featuring the mystery box strategy, choral responding, and response cards was effective for maintenance of all the three sets of teaching examples. However, each student's maintenance scores were lower than they were at the end of instruction. The effects of instruction on better maintenance need to be investigated further in the future.

All 15 students who participated in the study showed a high percentage of correct answers and equations on instruction and on generalization assessments. At the pre-
experiment assessment conducted before the study, they showed a wide range of computation skills and reading skills. In other words, the students’ performance of acquisition and maintenance of taught problems did not correlate with difference in the pre-assessment scores. This gives general support for the effectiveness of the instruction used in this study.

Research Question Two

What are the differential effects of three subsets of teaching examples selected regarding problem categories and types of positions of the mystery box on students’ generalization of writing answers and equations to untaught story problems?

This study compared the effects of teaching three different subsets of story problems on students’ ability to solve untaught problems. One of the three subsets, MCSP problems, consisted of 6 teaching examples that sampled all three of Riley and Greeno’s (1988) categories (Combination, Change, and Comparison) but had only one position of the unknown value in their mystery box equations. In other words, during MCSP instruction, students were presented with problems from all three categories and practiced producing only one type of equation that had a mystery box at the end. SCMP problems contained 6 teaching examples that sampled only one category (Change) but that sampled all 6 types of mystery box equations, including having the mystery box at the beginning, in the middle, or at the end. During SCMP instruction, the students were presented with problems from only one category but practiced producing all 6 types of mystery box equations. MCMP problems contained 6 teaching examples that sampled all 3 categories and all 6 types of mystery box equations. During MCMP instruction, students were presented with problems from all 3 categories and practiced them producing all 6 types of
mystery box equations. Investigating the comparative effects of instruction for three subsets of story problems on generalization to untaught problems was the primary purpose of this study.

In the following sections, the relative generalization effects of each phase of instruction on each subset of story problems are discussed within groups followed by a group comparison. A discussion of the efficiency of instructions and an analysis of non-generalized problem subtypes follow.

The Generalization Effects of Instruction

Table 5.2 and Figure 5.2 show a comparison of the average percentage of correct answers and equations on untaught problems by students in each group during each experimental phase. The generalization effects of each instruction on untaught problems are discussed within groups followed by a group comparison below.

MCSP group

Comparing the MCSP group’s average score at generalization assessment 1 with their baseline, it shows that MCSP instruction resulted in no generalization to answers of untaught problems and a small degree of generalization on equations of untaught problems. Students in the MCSP group showed scores averaging 44% correct answers and 26% correct equations during baseline. At generalization assessment 1, the mean performance by this group was 35% correct answers and 39% correct equations.

At generalization assessment 2, which was conducted after their instruction 2 and in which the students received MCMP instruction, the group’s average percentage on correct answers was 50% and on correct equations was 52%. These scores were higher than at baseline and at generalization assessment 1. Therefore, it can be said that MCMP
<table>
<thead>
<tr>
<th>Phase</th>
<th>Group</th>
<th>Type of Instructional Problems</th>
<th>Untaught Story Problems</th>
<th>Answers</th>
<th>Equations</th>
</tr>
</thead>
<tbody>
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<td>Baseline (3)*</td>
<td>MCSP Group</td>
<td>44 (12)</td>
<td>26 (12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SCMP Group</td>
<td>38 (12)</td>
<td>18 (12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MCMP Group</td>
<td>38 (12)</td>
<td>29 (12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inst.1 (2)</td>
<td>MCSP Group</td>
<td>MCSP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SCMP Group</td>
<td>SCMP</td>
<td></td>
<td></td>
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</tr>
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<td></td>
<td>MCMP Group</td>
<td>MCMP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GA1 (2)</td>
<td>MCSP Group</td>
<td>35 (12)</td>
<td>39 (12)</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>SCMP Group</td>
<td>43 (12)</td>
<td>43 (12)</td>
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<td></td>
</tr>
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<td>MCMP Group</td>
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<td>61 (12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inst.2 (2)</td>
<td>MCSP Group</td>
<td>MCMP</td>
<td></td>
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<td></td>
<td>SCMP Group</td>
<td>MCMP</td>
<td></td>
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<td></td>
<td>MCMP Group</td>
<td>MCMP</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>GA2 (2)</td>
<td>MCSP Group</td>
<td>50 (7)</td>
<td>52 (7)</td>
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<td></td>
</tr>
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<td></td>
<td>SCMP Group</td>
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<td></td>
<td>MCMP Group</td>
<td>58 (12)</td>
<td>62 (12)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a: number in parentheses shows the number of probes in phase
b: number in parentheses shows the number of problems assessed in a probe

Table 5.2: Mean percentage of correct answers and equations on untaught story problems by three groups during baseline and generalization assessment
Figure 5.2: Mean percentage of correct answers and equations on untaught story problems for three groups during baseline and generalization assessment
instruction in addition to MCSP instruction produced more generalization on answers and equations of untaught problems.

In sum, the level of generalization that resulted after MCSP instruction was minimal. However, an increased level of generalization was exhibited after MCMP instruction.

**SCMP group**

Comparing the SCMP group’s average score on generalization assessment 1 with their baseline, it shows that SCMP instruction resulted in a slight generalization effect on answers and equations of untaught problems. Students in the SCMP group showed scores averaging 38% correct answers and 18% correct equations during baseline. On generalization assessment 1, the mean performance by this group was 43% correct answers and 43% correct equations.

On generalization assessment 2, which was conducted after their instruction 2 and in which the students received MCMP instruction, the group average percentage on correct answers was 47% and on correct equations was 44%. These scores were much higher than at baseline and slightly higher than at generalization assessment 1. Therefore, it can be said that MCMP instruction in addition to SCMP instruction produced more generalization on answers and equations of untaught problems.

In sum, some generalization occurred after SCMP instruction. Moreover, an increased level of generalization was exhibited after MCMP instruction.

**MCMP group**

Comparing the MCMP group’s average score on generalization assessment 1 with their baseline, it shows that MCMP instruction resulted in generalization effects for answers and equations of untaught problems. Students in the MCMP group showed
scores averaging 38% correct answers and 29% correct equations during baseline. On
generalization assessment 1, the mean performance by this group was 52% correct
answers and 61% correct equations.

On generalization assessment 2, which was conducted after their instruction 2 and in
which the students received the second MCMP instruction, the group average percentage
on correct answers was 58% and on correct equations was 62%. These scores were higher
than at baseline and at generalization assessment 1. Therefore, it can be said that
additional MCMP instruction produced more generalization on answers and equations of
untaught problems.

In sum, MCMP instruction resulted in a high level of generalization. Moreover, an
increased level of generalization was exhibited after additional MCMP instruction.

Comparison of Generalization Data Across Groups

Baseline. During baseline, all three groups showed relatively the same level of low
scores on untaught problems. The average percentage of correct answers was 44% for the
MCSP group, 38% for the SCMP group, and 38% for the MCMP group (see Table 5.2
and Figure 5.2 on pages 191 to 192). Although the MCSP group showed a higher score
compared with the other two groups, the difference between the highest and the lowest
score was only 6%. In other words, all three groups showed relatively the same level of
percentage correct on answers during baseline. The average percentage of correct
equations was 26% for the MCSP group, 18% for the SCMP group, and 29% for the
MCMP group. Although the SCMP group showed a lower score compared with the other
two groups, the difference between the highest and the lowest score was only 11%. It can
be said that all three groups showed relatively the same level of low scores during baseline on equations. Thus, the difference of scores as seen across groups was minimal, and all three groups showed the same level of low scores on baseline.

**Generalization assessment 1.** The first generalization assessment was conducted after instruction 1. During instruction 1, the MCSP, the SCMP, and the MCMP groups experienced MCSP instruction, SCMP instruction, and MCMP instruction, respectively. As a result, MCMP instruction produced the most generalization on untaught equations among the three groups.

The average percentage of correct answers on taught problems on generalization assessment 1 was 35% for the MCSP group, 43% for the SCMP group, and 52% for the MCMP group. The difference between the highest and the lowest score was 17%. This indicates that the MCMP group showed the highest level of generalization and that the MCSP group showed the lowest level of generalization for answers of untaught problems. The average percentage of correct equations was 39% for the MCSP group, 43% for the SCMP group, and 61% for the MCMP group. Again, the MCMP group showed the highest level of generalization and the MCSP group showed the lowest level of generalization for answers of untaught problems. The difference between the highest and the lowest score was 22%. Thus, it can be said that MCMP instruction produced the most generalization on untaught equations among the three groups.

**Generalization assessment 2.** The second generalization assessment was conducted after instruction 2. During instruction 2, all three groups experienced MCMP instruction. All the groups exhibited the highest percentage of correct answers and equations on generalization assessment 2 as compared with baseline and generalization assessment 1.
The average percentage of correct answers on taught problems on generalization assessment 1 was 50% for the MCSP group, 47% for the SCMP group, and 58% for the MCMP group. The difference between the highest and the lowest score was 11%.

Although the MCMP group showed the highest level of generalization, the other two groups also showed good generalization on answers of untaught problems. The average percentage of correct equations was 52% for the MCSP group, 44% for the SCMP group, and 62% for the MCMP group. Again, the MCMP group showed the highest level of generalization, and the SCMP group showed the lowest level of generalization for answers of untaught problems. The difference between the highest and the lowest score was 18%.

Overall, all the groups exhibited the highest percentage of correct answers and equations on generalization assessment 2 as compared with baseline and generalization assessment 1. This indicates that MCMP instruction had the biggest effect on generalized story problem solving for untaught problems. Also, the MCMP group showed the most generalization on answers and equations of untaught problems on generalization assessment 2, and the MCSP group and the SCMP group followed in order. Although this is discussed in the later section, the amount of instruction on MCMP problems was different across the three groups. The MCMP group had the longest period of instruction on MCMP problems and the SCMP group had the shortest instruction on MCMP problems. Thus, the correlation between the scores on generalization assessment 2 and the amount of instruction on MCMP problems is shown.

In addition, the difference of scores during generalization assessment 1 and 2 was larger for equations than for answers. The difference of scores between the MCMP group
and the other two groups was bigger on equations than on answers. From this, it may be said that teaching MCMP problems promotes more generalization on equations. However, at the same time this result suggests that the students may need additional instruction on answers.

In sum, the results of generalization assessment 1 showed that the MCMP group, which experienced MCMP instruction as their instruction 1, produced the most generalization of story problem solving on answers and equations of untaught problems. From the results of generalization assessment 2, the other two groups (i.e., MCSP and SCMP) showed more generalization after they had received MCMP instruction. Overall, the results show that teaching students the MCMP problems had the largest effect on students’ generalization of writing answers and equations to untaught story problems.

The Efficiency of Instruction

Although MCMP instruction had the greatest effect on generalization, MCMP problems were more difficult for students to acquire and a greater amount of instructional time was needed. Table 5.3 shows the total amount of instructional time for students in each of the three groups.

As can be seen in Table 5.3, MCMP problems required longer instructional time for acquisition as compared with the other two groups. The total number of minutes for instruction 1 was 130 minutes for the MCSP group, 130 minutes for the SCMP groups and 155 minutes for the MCMP group. On generalization assessment 1, which was conducted right after instruction 1, the MCMP group showed the highest percentage of correct answers and equations on untaught problems. However, it took a longer period of time for the students to acquire MCMP problems.
Table 5.3: Total minutes of instruction for each student of the three groups. Numbers in parenthesis show sessions devoted to teach teaching format.

Interestingly, the percentage of correct answers and equations on generalization assessment 2 correlated with the total amount of instructional time for MCMP problems. Because they received instruction on MCMP problems twice, students in the MCMP group received the most instruction on MCMP problems (280 minutes). This group showed the highest scores on generalization assessment 2. On the other hand, the SCMP group, which had the least amount of instruction on MCMP problems (125 minutes) showed the lowest score on generalization assessment 2. Although additional research is needed for confirmation, these data suggest a relationship between the amount of instruction on MCMP problems and generalization to untaught problems.
In addition, students in the MCSP and MCMP groups received a similar amount of instruction as the total of instructions 1 and 2 (MCSP group had 270 min., and MCMP group had 280 min.). Thus, the MCSP group received instruction on a total of 11 problems (MCSP problems and MCMP problems) and the MCMP group had instruction on 6 problems (MCMP problems only) for almost the same amount of time. Then, the MCMP group showed a higher percentage of correct answers and equations on generalization assessment 2. Given these results, it may be possible to say that intensively teaching only 6 problem subtypes from MCMP problems within a certain amount of instructional time yields more generalization than does teaching students to solve a greater number of problem subtypes within the same amount of instructional time.

In sum, MCMP problems required more instructional time compared to instruction of MCSP or SCMP problems. However, students only achieved more than 50% correct on answers and equations on untaught problems after instruction of MCMP problems. Moreover, more instruction on MCMP problems may yield greater generalization to untaught problems. Also, better generalization was shown after instruction on only MCMP problems rather than after instruction on MCSP problems and MCMP problems even though the total amount time of instruction was almost the same. From these points, it can be concluded that MCMP instruction is the most efficient to promote generalized effects to untaught story problems.

**Analysis of Generalization by Subtype**

Although students in the MCMP group showed the greatest extent of generalization to untaught story problems, their highest levels of accuracy on untaught problems were 58% on answers and 62% on equations. Thus, generalization did not occur to all untaught
problems, which suggests that an analysis of generalization across problem subtypes might be of interest. Table 5.4 shows each group’s average percentage of correct answers and equations on untaught problems by problem categories. Tables representing each group’s average percentage of correct answers and equations on taught and untaught story problems by problem subtypes can be found in Appendix Q.

<table>
<thead>
<tr>
<th>Group</th>
<th>Problem Category</th>
<th>Untaught Answers</th>
<th>Untaught Equations</th>
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</thead>
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<td></td>
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<td>GA1</td>
</tr>
<tr>
<td>MCSP Group</td>
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Table 5.4: Average percentage of correct answers and equations on three categories of untaught story problems during baseline and generalization assessments for the three groups of students. Students in the SCMP group received instruction on all 6 problem subtypes of the Change problem category.

As can be seen in Table 5.4, the MCSP group showed the most generalization on both answers and equations for untaught Comparison problems. However, it cannot be said that MCSP instruction produces the most generalization on Comparison problems.
because students in the MCSP group had a high baseline score on Comparison problems. On the other hand, the MCSP group had the most generalization on Change problems and the least generalization on Comparison problems on generalization assessment 2 that was conducted after MCMP instruction.

On generalization assessment 1, the SCMP group showed greater generalization on both answers and equations for Combination problems as compared with Comparison problems. The same tendency was shown for the data from the second generalization assessment. Since students in the SCMP group had SCMP instruction in which all the Change problems were taught, the level of generalization to Change problems could not be analyzed for this group.

Students in the MCMP group exhibited the most generalization on answers to untaught Combination problems and less generalization on answers of Change and Comparison problems on generalization assessment 1. For generalization to equations on generalization assessment 1, this group showed more generalization on Combination and Change and least generalization on Comparison. On generalization assessment 2, the MCMP group showed a high percentage of correct answers and equations on untaught Combination and Change problems and a low percentage of correct answers and equations on Comparison problems.

Since the percentage of correct answers and equations across three problems categories on baseline were different, the percentages on generalization assessment 1 and 2 cannot be compared differently. However, two tendencies can be seen. First, with no exceptions, all the groups achieved their lowest scores on generalization assessment 2 for Comparison problems, compared with those on generalization assessment 1, even though
the scores for the other two categories were increased from generalization assessment 1 to 2. This indicates that the students failed to show a stable level of performance on answers and equations for Comparison problems. In other words, the generalized story problem solving for Comparison problems may not have been strong enough to be produced consistently. Second, except for generalization assessment 1 for the MCSP group, the scores on Comparison problems were the lowest among the three categories. Looking at the results for the MCMP group, which received the most efficient instruction, it can be said that the generalization was quite good to Combination (correct answers, 75%; correct equations, 75%) and Change problems (correct answers, 80%; correct equations, 88%), but the generalization to Comparison problems was low (correct answers, 23%; correct equations, 23%). The average percentage correct on untaught answers and equations shown by the MCMP group on generalization assessment 2 for all three problem categories combined was 58% and 62%, respectively. However, this group’s performance on untaught Combination and Change problems was only 77% correct on answers and 82% correct on equations.

Thus, it may be said that Comparison is a category to which generalization is not likely to occur. Although this should be investigated further in the future, I would like to suggest that students might require extra instruction on Comparison problems in order to solve them.

Summary of Results for Research Question Two

Overall, the results of this study show that teaching MCMP problems to students produced the most generalization of story problem solving on untaught problems. Comparing the three groups’ average performance on generalization assessments, the
MCMP group scored the highest percentage correct on untaught problems. Additionally, students in the other two groups showed more generalization after receiving the MCMP instruction that followed their instruction on the other two subsets. These results support the conclusion that teaching MCMP problems has the greatest effects on students' generalization of writing answers and equations to untaught story problems.

The three different subsets of teaching examples were selected based on the framework of the general case strategy. Previous studies have shown the effects of general case strategy—in which target skills are taught through examples sampled from a variety of characteristics of problems—on generalization of taught skills (Ducharme & Feldman, 1991; Frederick-Dugan et al., 1991; Hughes et al., 1995; Hughes & Rusch, 1989; Neef et al., 1990; Sprague & Horner, 1984). In this study, teaching MCMP problems that sampled all three categories and all types of mystery box equations resulted in the greatest generalization. The results support previous studies that have shown the effectiveness of the general case strategy for students' generalization on untaught problems.

It is important to note that teaching MCMP problems required more instructional time as compared with MCSP and SCMP problems. However, only after the MCMP instruction were students able to produce more than 50% correct answers and equations on untaught problems. Moreover, the results support a positive correlation between the amount of instruction on MCMP problems and the level of generalization. Also, students achieved better generalization after instruction on only MCMP problems rather than after instruction on MCSP problems and MCMP problems even though the total amount time
for instruction for both groups was similar. From these points, it can be concluded that MCMP instruction is the most efficient instruction regarding the generalized effects on untaught story problems.

However, no students in the study could answer correctly on all untaught problems. An analysis of generalization by problem categories revealed that generalization to problems in the Comparison was least likely. Although additional research is needed to explore this relationship, these results of this study suggest that Comparison problems require explicit instruction.

Implications for Curriculum Design and Classroom Practice

Teaching arithmetic story problems is an important element of mathematics education and an area with which many students have difficulty. A recent study showed that significant numbers of general education students and those with mild disabilities do not demonstrate proficiency on story problems in many of the topics introduced or expected to be mastered at a specific grade level (Cawley et al., 2001).

Early elementary students are expected to solve a wide variety of story problems. Riley and Greeno (1988) have developed one classification system of addition/subtraction story problems. Various instructional strategies have been suggested for teaching story problems (e.g., using manipulatives, using diagrams, emphasizing mathematical key words, teaching explicit number family concepts, teaching cognitive and metacognitive strategies, etc.). Although several published studies have found one or more teaching methods effective for some story problems, no research has shown that a certain strategy is effective for all students to learn all 18 subtypes of story problems by
Riley and Greeno's taxonomy. In addition, at present, the research literature does not have a clear view on which types of story problems should be taught.

This study was designed as an initial investigation of an efficient way of teaching story problems. The purpose of the study was to explore if there were any differential effects of selected teaching examples on generalization of story problem solving skills, and, if so, what kind of teaching examples would best promote generalization. In this study, three sets of teaching examples were selected from Riley and Greeno's (1988) 18 subtypes of addition and subtraction story problems. Which subset of story problems yielded the most generalization to untaught problems was studied. In addition, the effects of instruction in the mystery box strategy with scripted lessons featuring choral responding and response card on the acquisition of story problem solving was investigated.

Maximizing Generalization to Untaught Problems

It would require a tremendous amount of instructional time to teach all students how to solve every type of story problem. However, it could happen that students will automatically solve untaught problems after instruction on some particular problem subtypes.

Several studies have suggested that teaching examples should be carefully selected to maximize the extent of generalization to untaught tasks (Ducharme & Feldman, 1991; Frederick-Dugan et al., 1991; Hughes et al., 1995; Hughes & Rusch, 1989; Neef et al., 1990; Sprague & Horner, 1984). The corrective results of previous research has shown that it is important to use teaching examples that sample a variety of characteristics of untaught tasks as widely as possible.
In this study, the two characteristics of story problems were sampled in different ways, and three subsets of teaching examples were created. One of the characteristics that distinguish story problems is category, which represents the problem situations dealt with in the story. According to Riley and Greeno (1988), there are three categories, Combination, Change, and Comparison. Another characteristic of story problems is that they also use equations used to solve the problems. In this study, mystery box equations that represented the unknown value in the problem with an empty box were used as the equations. Sampling these two characteristics, three different teaching examples were created: Multiple-Category/Single-Position (MCSP), Single-Category/Multiple-Position (SCMP), and Multiple-Category/Multiple-Position (MCMP).

MCSP problems contained 6 teaching examples that sampled all three categories (Combination, Change, and Comparison) but sampled only one position of the mystery box in the mystery box equation. In other words, during MCSP instruction, students were presented problems from all 3 categories and practiced producing only one type of equation that had a mystery box at the end. SCMP problems contained 6 teaching examples that sampled only one category (Change) but that sampled all 6 types of mystery box equations with a mystery box at the beginning, in the middle, or at the end. During SCMP instruction, students were presented problems from only one category but practiced producing all 6 types of mystery box equations. MCMP problems contained 6 teaching examples that sampled all 3 categories and all 6 types of mystery box equations. During MCMP instruction, students were presented problems from all 3 categories and practiced producing all 6 types of mystery box equations.
Instruction on MCMP problems produced the most generalization of story problem solving on answers and equations of untaught problems. Comparing the group averages on generalization assessments, the MCMP group scored the highest percentage of correct answers and equations on untaught problems. Not only was this the group that experienced MCMP instruction, but also the other two groups that were introduced to MCMP instruction following the other two types of instruction showed more generalization after the MCMP instruction. Therefore, teaching MCMP problems to students can be recommended to promote the greatest generalization of story problem solving.

Because MCMP problems are the most complicated, students required more instructional time to learn those problems as compared with MCSP and SCMP problems. However, students obtained more than 50% correct on answers and equations on untaught problems only after they had experienced MCMP instruction. Moreover, the more instruction they received on MCMP problems, the more generalization students exhibited. Also, better generalization was shown after instruction on only MCMP problems rather than after instruction on MCSP problems and MCMP problems even though the total amount time for instruction was the same. From these points, it can be concluded that MCMP instruction is the most efficient instruction regarding the generalized effects on untaught story problems. Therefore, it is highly recommended to use a certain amount of instructional time to teach MCMP problems until the students show a high and stable performance on solving those problems.

Students could relatively easily solve SCMP problems with mystery box equations that had an empty box at the end. For example, the problem “Mary has 3 apples. Bob has
4 apples. How many apples do they have in all?” or the problem “Mary had 3 apples. Bob gave her 4 apples. How many apples does Mary have now?” can be solved by the equation, 3+4=□, which has a mystery box at the end position of the equation. Students have little difficulty solving these types of problems. Therefore, many textbooks tend to introduce these problems first. However, teaching these problems does not produce generalization effects. In other words, after being taught these problems, students cannot automatically solve other problems such as “Mary has 3 apples. Bob has some apples. They have 7 apples in all. How many apples does Bob have?” Therefore, teachers should know that additional instruction will be needed for those problems, if they taught MCSP problems to students first.

SCMP problems, which included all types of equations with the mystery box in all different positions but which sampled only the Change situation, could be taught easily, too. However, the results of this study indicate that instruction on SCMP problems yielded little generalization to other untaught problems. Most students were not able to solve problems in the Combination and Comparison categories after SCMP instruction even though those problems could be solved by mystery box equations that had the same structures as the ones the students had been taught.

On the other hand, if students are taught MCMP problems, which include problems from all three categories and which include all types of mystery box equations, they are more likely to solve untaught problems without any additional instruction. Although it is harder to teach MCMP problems compared with MCSP problems, teaching MCMP problems is the most efficient instruction, since it ultimately results in higher performance on story problems in general and less instructional time totally.
Thus, teaching MCMP problems is highly recommended based on the results of this study. However, this study does not tell us how much instruction on MCMP problems produced enough generalization. After 5 days of lessons on MCMP problems, some students may begin to solve other untaught problems with 100% accuracy, while others may need 10 or 15 days of instruction to achieve 100% correct. From this study, the duration of instruction needed could not be identified. Therefore, at this point, it is recommended for teachers to frequently assess the extent of generalization during MCMP instruction. That would reduce the amount of unneeded instruction on MCMP problems for students who have already shown generalization effects on untaught problems. As a result, the instructional time could be kept minimal.

From the study, it was found out that MCMP instruction yielded very little generalization effects for Comparison problems. Comparison problems are the most difficult category among the three (Riley & Greeno, 1988). Therefore, in addition to MCMP instruction, some extra sessions may be needed for Comparison problems.

**Teaching Mystery Box Equations**

The results of this study suggest that teachers can use the mystery box strategy for teaching all the 18 subtypes of story problems. The mystery box strategy was created based on the explicit number family concept strategy described by Stein et al. (1997). The mystery box strategy is a method that teaches students to represent unknown value (i.e., answer) of the problem by a mystery box (□). For example, the problem “Bob has 3 apples. Mary has 5 apples. How many do they have in all?” can be described by the equation, 3+5=□. The problem, “Bob has 3 apples. Mary has some apples. They have 8
in all. How many does Mary have?” is represented by $3 + □ = 8$. The students are taught to produce these types of equations that contain a mystery box in the appropriate position.

This mystery box strategy requires three steps: (1) writing the numbers and the mystery box in the equation in the order of the story, (2) deciding the operation sign (plus or minus), and (3) performing the arithmetic.

For step 1, students write the number, if any, of the first sentence at the left of the equation, and the number of the second sentence, if any, in the middle, and the number of the next sentence, if any, at the end of the equation. If the sentence does not show any numbers and says “some” or asks a question (“How many...?”), students write an empty box instead of a number. For example, for the story problem “Mary has 3 candies. Bob has 5 candies. How many candies do they have in all?” students would write “3” (i.e., number in the first sentence) at the left part of the equation and “5” (i.e., number in the second sentence) in the middle. The last sentence is a question and does not have any number, so the students would write a mystery box at the right part of the equation. For a story problem like “Mary had some pencils. Then she gave 5 pencils to Karen. Now Mary has 3 pencils. How many pencils did Mary have at the beginning?” students would write a mystery box first because the first sentence does not have any number but says “some.” Then they would write “5” from the second sentence in the middle and “3” in the third sentence at the end. At the end of step 1, students have two numbers and one mystery box in various orders based on the type of the story problem.

For step 2 (i.e., identification of operation sign), students read the whole story problem again and think if it was plus or minus. Since there is no simple rule for identification of operation sign, rules are not given to the students. The students are
expected to learn what the correct operation is through repeated practice. They then write
the correct operation sign between the first and second object of the equation (number or
mystery box), and write an equal sign between the second and third objects. At the end of
step 2, students have a complete mystery box equation such as 3+5=□ or □−5=3.

Then students solve the mystery box equation to discover the number that goes into
the box.

All students who participated in the study learned the mystery box strategy and
applied it for all 18 subtypes of story problems. Although the strategy needs to be
researched to make it function more efficiently, the mystery box strategy is recommended
for teaching story problems to early elementary students.

Suggestions for Future Research

Questions raised by this study may provide the basis of ideas for future research to
advance the knowledge of teaching story problems. Several of the limitations identified
in the beginning of this chapter provide impetus for discussing areas of future research.

Research Design

This study had several limitations regarding design. Future research that eliminates
those limitations is needed. Ideally, this study should have been done with more than 6
groups of students, although only the 3 groups did actually participate. In addition, each
group should have had at least 20 students. Students who participate the study need to be
selected from various environments, and students’ skills preceding the study need to be
experimentally controlled. The schedule of this study was tight and ideal amount of data
could not be obtained. Also, since only 18 problem subtypes were assessed as one probe, there was not enough room for assessing generalization. A systematic replication of the study that controls for the points above is necessary.

**Increasing Level of Generalization**

Students in the MCMP group exhibited 58% correct on answers and 62% on equations of untaught problems. Although the MCMP group’s performance on untaught problems was better than other two groups’ performance, they did not achieve 100% generalization. Research that investigates ways of instruction that would result in more generalization is needed in the future.

The results of this study found that students had the most difficulty solving untaught Comparison problems. Research designed to find instructional strategies to promote generalization to Comparison problems needs to be pursued so that overall generalization effects can increase.

**Generalization to Other Types of Story Problems**

Riley and Greeno’s (1988) taxonomy of story problems does not include various types of story problems beyond their categorization. For example, story problems can be written with different key words, with different numbers that require higher computation demands, and with the inclusion of extraneous information. Since this study dealt with only 18 subtypes of story problems based on the Riley and Greeno taxonomy, the acquisition, maintenance, and generalization effects of the procedure of the study on different types of story problems need to be examined in the future.

This study showed that MCMP instruction yielded some generalization effects to untaught problems that were in Riley and Greeno’s (1988) 18 subtypes. However, the
extent of generalization to problems not represented by the 18 subtypes could not be assessed. In the future, the possibility of generalizing the effects of MCMP instruction to other story problems such as ones written with different mathematical key words and ones with different numbers that require high computation demands (e.g., regrouping) should be investigated.

**Mystery Box Strategy**

Mystery box equations were used as a teaching strategy in this study. Because the primary purpose of the study was to investigate the functional relations between subsets of teaching examples and generalization to solving untaught problems, the effects of the mystery box strategy on the acquisition and maintenance of story problems was not investigated. However, it appears that the mystery box strategy may be an effective and efficient way to teach story problems. In particular, the mystery box strategy seemed to help students use correct equations more frequently. Therefore, future research evaluating and improving upon the mystery box strategy as a method for teaching story problems may be warranted.

**Curriculum Design**

This study used Riley and Greeno's (1988) categorization of basic story problems. However, we do not know if their categorization is the only and the best way to organize the nature of story problems solved by one-step addition or subtraction. In the future, the organization of story problems may need to be assessed and reproduced. Riley and Greeno (1988) organized story problems according to two major characteristics: category (Combination, Change, and Comparison) and subtypes (1 to 6 in each category). However, from the results of this study, it is suggested that selecting teaching examples
based on category or subtypes is not enough to promote generalization to untaught problems. Instead, this study indicates that teaching examples need to sample the categories and the mystery box equations that the students produced to solve each problem. In other words, the type of mystery box equations can be presented as a new key for the organization of story problems.

Although Riley and Greeno (1988) did not make the categorization for the purpose of efficient curriculum design, several textbooks and studies have been designed based on their categorization (e.g., Jitendra & Hoff, 1996; Stein et al., 1997). To make the curriculum more efficient, other organizations of story problems need to be considered in the future.

Summary

Learning to solve arithmetic story problems is an important element of mathematics education. A recent study has shown that significant numbers of general education students and those with mild disabilities do not demonstrate proficiency on story problems in many of the topics introduced or expected to be mastered at a specific grade level (Cawley et al., 2001). However, there is not much experimental research available to guide classroom teachers in the selection of effective instructional materials and methods for story problems.

The purpose of this study was to explore if there were any differential effects of selected teaching examples on the generalization of story problem solving skills, and, if so, what kind of teaching examples would promote the most generalization. Three sets of teaching examples were selected from 18 subtypes of addition and subtraction story problems. Instruction in the mystery box strategy with scripted lessons featuring choral
responding and use of response cards was delivered for teaching those three sets of examples. Which set affected the generalization of story problem skills most positively was studied.

Fifteen students in the first grade were divided into three groups, MCSP, SCMP, and MCMP groups. Students in the MCSP group were taught MCSP problems that contained 6 teaching examples that sampled all 3 categories (Combination, Change, and Comparison) but that sampled only one position of the mystery box in the mystery box equation. Students in the SCMP group were taught SCMP problems that contained 6 teaching examples that sampled only one category (Change) but that sampled all 6 types of mystery box equations with the mystery box at the beginning, at the middle, or at the end. Students in the MCMP group were taught MCMP problems that contained 6 teaching examples that sampled all 3 categories and all 6 types of mystery box equations. All students experienced MCMP instruction as the best practice in the second instruction phase. The three subsets of teaching examples were taught through the instruction featuring the mystery box strategy, choral responding, and response cards. The comparative effects of the three subsets of teaching examples on generalized story problem solving were assessed using worksheets.

As results of the study, MCMP problems produced the most generalization of story problem solving on answers and equations of untaught problems. Comparing the group average of generalization assessments, the MCMP group scored the highest percentage of correct answers and equations on untaught problems. Not only was this the group that experienced MCMP instruction, but also the other two groups that were introduced to MCMP instruction following the other two types of instruction showed more
generalization after the MCMP instruction. Because MCMP problems were complicated, the students needed more instructional time for acquisition of those problems as compared with MCSP and SCMP problems. However, students were able to achieve more than 50% correct on answers and equations on untaught problems only after they received MCMP instruction. Moreover, the more instruction students received on MCMP problems, the more generalization to untaught problems they exhibited. Also, better generalization was shown after instruction on only MCMP problems rather than after instruction on MCSP problems and MCMP problems even though the total amount time for instruction was the same. From these points, it can be concluded that MCMP instruction is the most efficient instruction to produce generalized effects on untaught story problems.

The generalization effects of selection of teaching examples for story problem instruction are worthy of future research. Further research examining better generalization effects of selection of teaching examples and stronger acquisition and maintenance effects of mystery box equations may promote a more efficient curriculum design in the field of math education, which has began to shift direction from strengthening basic computation skills to enhancing problem solving skills.
LIST OF REFERENCES


Endo, S. (2000). Teaching arithmetic word problems to elementary students. Unpublished second year research, The Ohio State University, Columbus.


Frederick-Dugan, A., Test, D. W., & Varn, L. (1991). Acquisition and generalization of purchasing skills using a calculator by students who are mentally retarded. Education and Training in Mental Retardation, 26, 381-387


APPENDIX A:

Parent/Guardian Letter from the Experimenter

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February 1, 2001

Dear Parent:

We are writing to request consent for your child to participate in a research study we hope to conduct in Ms. Zeppemick’s classroom. Learning to solve arithmetic story problems is an important element of mathematics education. After students have learned the basic addition and subtraction facts (e.g., 4+5=9), they are expected to apply those skills to story problems (e.g., Joe has 5 marbles. Tom has 8 marbles. How many marbles does Tom have more than Joe?). Many students have difficulty with story problems, yet there is little research available to guide classroom teachers in the selection of effective instructional materials and methods for story problems. We hope this study will shed some light on how to more effectively teach story problems to young children.

Ms. Sayaka Endo, a doctoral student in the College of Education at the Ohio State University will be using response cards to teaching story problems to 6 to 7 students in Ms. Zeppemick’s classroom. Response cards—cards, signs, or other items that are held up by each student in the class to signal his/her answer to teacher-posed questions or problems—are used by elementary teachers across many curriculum areas, including math. Children who participate in the study will take part in five small-group lessons taught by Ms. Endo each week. We expect each lesson to last about 30 to 40 minutes. During the lessons, each child will have numerous opportunities to actively participate by responding chorally (with their voices) and by writing answers (on their response cards) to step-by-step questions posed by Ms. Endo (e.g., Teacher: “Class, how many marbles does Tom have?” Students: “Eight”). Following each lesson, students will be asked to solve story problems in order to evaluate the effectiveness of the instruction.

Because your child can already answer single-digit addition and subtraction facts with a high degree of accuracy, we believe he/she would benefit from participating in this study. Since this teaching program will be part of a formal research study, we need your consent for your son or daughter to participate. Enclosed you will find two copies of a Parent/Guardian Consent Form. One copy must be signed by you and returned in the enclosed envelope for your child to participate. You may keep the other copy for your records. If you have any questions or concerns whatsoever about this project, please do not hesitate to call Ms. Endo (262-5240), Dr. Heward (292-3348), or Ms. Zeppemick (365-6013). Thank you for your prompt attention to this request.

Sincerely,

Sayaka Endo
Doctoral Student

William L. Heward
Professor/Faculty Advisor

c: Ms. Susan Zeppemick, CLASSROOM TEACHER
   Ms. Patricia D. Brown, PRINCIPAL

Enclosure: 2 copies of Parent/Guardian Consent Form
Return envelope
APPENDIX B:

Parent/Guardian Letter from the Classroom Teacher
February 1, 2001

Dear Parent:

Teaching students to solve story problems is an important element of mathematics education. After they have learned the basic addition and subtraction facts (e.g., $4 + 5 = 9$), students are expected to apply those skills to solve word problems (e.g., Joe has 5 marbles. Tom has 8 marbles. How many marbles does Tom have more than Joe?). Many children have difficulty learning word problems, and there is little research available to guide classroom teachers in the selection of effective instructional methods for word problems. I am writing you to because I and my students have an opportunity to participate in a research study that may shed light on how to teach word problems to young children.

Ms. Sayaka Endo, a doctoral student in the College of Education at Ohio State University will be evaluating the effects of a using response cards to teaching word problems to a select group of students in my classroom. Response cards—cards, signs, or other items that are held up by each student in the class to signal his/her answer to teacher-posed questions or problems—are used by teachers across many curriculum areas, including math. Children who participate in the study will take part in three or four small-group lessons each week, each lesson lasting about approximate 30 to 40 minutes. During the lessons, each child will have numerous opportunities to actively participate by responding chorally (with their voices) and in writing (on their response cards) to step-by-step questions posed by Ms. Endo (e.g., Teacher: “Class, how many marbles does Tom have?” Students: “Eight.”)

Because your child can already answer single-digit addition and subtraction facts with a high degree of accuracy, I believe he/she would benefit from participating in this study. Since this teaching program will be part of a formal research study, we need your consent for your son or daughter to participate. You will receive two copies of a Parent/Guardian Consent Form from Ms. Endo. One copy must be signed by you and returned in the enclosed envelope for your child to participate. You may keep the other copy for your records. If you have any questions or concerns whatsoever about this program, please do not hesitate to contact Ms. Endo (262-5240) or me at school (365-6013). Thank you for your prompt attention to this request.

Sincerely,

Susan Zeppernick
Classroom Teacher

C: Ms. Patricia D. Brown, Principal
    Ms. Sayaka Endo, OSU Researcher
    Dr. William L. Heward, OSU Faculty Advisor
APPENDIX C:

Parent/Guardian Consent Form
Parent/Guardian Consent Form For Participation in Educational Research

I agree to allow my child to participate in a research study investigating response cards as a method of math instruction. The purpose of the study and procedures have been explained to me. This research will be conducted during normal school hours by the classroom teacher (NAME) and Ms. Sayaka Endo, under the supervision of Professor William L. Heward. I understand that the math lessons sessions will require approximately 30 to 40 minutes per school day, 5 days per week. The daily lessons will last for 10 to 12 weeks with periodic follow-up assessments.

I understand that my child's identity will not be revealed to anyone not directly involved in conducting the research, nor will his/her identity be revealed by means of publication, document, computer storage, or any other form of report developed from this research. Additionally, I understand that I may withdraw my consent for my child's participation at any time.

______________________________
Child's Name

______________________________
Signature of Parent or Guardian Date

______________________________
Susan Zeppernick, Classroom Teacher Date

______________________________
Sayaka Endo, Graduate Student Date
The Ohio State University

______________________________
William L. Heward, Faculty Advisor Date
The Ohio State University
APPENDIX D:

Principal Consent Form
Dear Ms. Endo:

Ms. Susan Zeppernick has discussed with me the study you wish to do in her classroom investigating the use of response cards to teach students how to solve word problems. You have my permission and support to conduct this research, contingent upon your obtaining parental consent for each child who participates.

Sincerely,

Patricia D. Brown
Principal

c: Ms. Susan Zeppernick
APPENDIX E:

Pre-experiment Assessment Test
Pre-experiment Assessment

A. Addition Facts without Regrouping
   A.1. x+y=□
   A.2. x+□=z
   A.3. □+y=z

B. Subtraction Facts without Regrouping
   B.1. x-y=□
   B.2. x-□=z
   B.3. □-y=z

C. Story Problems
   C.1. 18 story problems solved without regrouping

D. Comprehension
   D.1. 3 reading comprehension problems

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Mary has 2 candies. Ann has 6 candies. How many candies do they have in all?

Equation

Amy had 8 crayons. Then Chuck gave her 2 crayons. How many crayons does Amy have now?

Equation

Chuck has 5 apples. Bob has 4 apples. How many apples does Bob have less than Chuck?

Equation

Tom and Lisa have some cookies. Tom has 4 cookies. Lisa has 3 cookies. How many cookies do they have in all?

Equation

Rick has 8 apples. He has 2 more apples than Jenny. How many apples does Jenny have?

Equation

Matt has some stickers. Amy has 3 stickers. They have 9 stickers in all. How many stickers does Matt have?

Equation
Cl-2
Sam and Ken have 9 pens in all. Sam has 8 pens. How many pens does Ken have?

Equation Answer

David has 5 candies. Matt has 3 candies. How many candies does David have more than Matt?

Equation Answer

Julie has 3 candies. Bill has 3 more candies than Julie. How many candies does Bill have?

Equation Answer

Shelly had some pens. Then she gave 4 pens to Rick. Now Shelly has 4 pens. How many pens did Shelly have at the beginning?

Equation Answer

Bill had 5 crayons. Then he gave some crayons to Shelly. Now Bill has 1 crayon. How many crayons did Bill give to Shelly?

Equation Answer

Becky has 2 pens. She has 8 pens less than Sara. How many pens does Sara have?

Equation Answer
C1–3

Rose and Joe have 10 stickers in all. Rose has some stickers. Joe has 7 stickers. How many stickers does Rose have?

Equation

Jenny has 8 cookies. Rose has 1 cookie less than Jenny. How many cookies does Rose have?

Equation

Sara had 2 apples. Then Julie gave her some apples. Now Sara has 7 apples. How many apples did Julie give Sara?

Equation

Bob had 7 stickers. Then he gave 4 stickers to David. How many stickers does Bob have now?

Equation

Joe has 4 cookies. Becky has some cookies. They have 8 cookies in all. How many cookies does Becky have?

Equation

Ann had some crayons. Then Mary gave her 3 crayons. Now Ann has 7 crayons. How many crayons did Ann have at the beginning?

Equation
Tom likes peaches. Mary likes grapes. Who likes peaches?

Answer

Katy wanted to go outside. But it is raining. Does Katy need an umbrella or swimsuit?

Answer

John has crayons. Betty has markers. What John has?

Answer
APPENDIX F:

Results of Pre-experiment Assessment
### Table F: Results of pre-experiment assessment

"Corr." represents number of problems answered correctly in 1 minute and "Incorr." represents number of problems answered incorrectly in 1 minute. "\%Corr." represents percentage of correct answers. CB, CH, CP represents Combination problems, Change problems, and Comparison problems respectively.

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APPENDIX G:

Example of Lesson Script
TEACHER MODEL
T: We are going to learn story problems. Look at the question here. Let’s read the question together.
T&S: “Joe has 5 cookies. Becky has some cookies. They have 8 cookies in all. How many cookies does Becky have?”
T: I’m going to show you how to use a response card to solve problems like this. The first sentence tells us “Joe has 5 cookies.” So, I’ll write 5 over the yellow line on the response card. (Write 5 on the response card.)
T: Next sentence says “Becky has some cookies.” We do not know how many cookies does Becky have. Do we know how many cookies does Becky have, yes or no? (signal)
S: NO.
T: When we do not know the number, I will write an empty box here. (Write □ on the response card.) We call this box as a Mystery Box. What do we call this box? (signal)
S: A mystery box.
T: A mystery box. This empty box is called Mystery Box? What do we call this? (signal)
S: A mystery box.
T: When we do not know the number, we are going to write a mystery box. When we donot know the number, what do we write? (signal)
S: A mystery box.
T: A mystery box. When we do not know the number, we will write a mystery box. What do we write? (signal)
S: A mystery box.
T: Good. We do not know how many cookies does Becky have, so I wrote a mystery box over the pink line. (Write □ on the response card.)
T: What do we call this box? (signal)
S: Mystery box.
T: That’s right. The next sentence says, “They have 8 cookies in all.” So I will write 8 over the green line. (Write 8.)
T: Now I have 5 box and 8 on the board. This is going to be the equation. In the equation, this side and this side suppose to be equal. In the equation, this side and this side suppose to be what? (signal)
S: equal.
T: equal. In the equation, this side and this side suppose to be equal. In the equation, this side and this side suppose to be what? (signal)
S: equal.
T: What do we have to do to 5, to make this side of the equation
and this side of the equation equal? 8 is bigger than 5. So, we need to add something. Is 8 bigger than 5, yes or no? (signal)
S: Yes.
T: Yes. Is 8 bigger than five, yes or no? (signal)
S: Yes.
T: That’s right. So, to make this side of equation and this side of equation equal, do we need to add something to 5 or minus something from 5? Add or minus, get ready? (signal)
S: Add.
T: Add. 8 is bigger than 5, so we need add something to 5 to make this side and this side equal. To make this side of equation and this side of equation equal, do we need to add something to 5 or minus something from 5? Add or minus, get ready? (signal)
S: Add. Add. So, I will write (Write +.)
T: And the number coming into the box is 3, because five plus 3 equals 8. 5 plus what number equals 8? Get ready? (signal)
S: 3.
T: Good, So I will write 3 in the box. Then, the last sentence asks us, “How many cookies does Becky have?” The number in the box is always the answer. So the answer is 3. What’s the answer? Get ready? (signal)
S: 3.
T: I will write the answer over the answer line. (Writes “3” over the line)
T: Now I solved this question. The correct equation is five plus box equals 8, and the answer is 3.

TEACHER & STUDENT TOGETHER

T: (Pass out Instructed Problems Worksheets and RC to the students. Put the first questions on the board.) Let’s practice together. Look at the question here. The first sentence tells us “Mary has 2 candies.” Read the first sentence together.
Get ready? (Signal)
S: “Mary has 2 candies.”
T: You will write 2 over the yellow line on the response card. (Write “2” on the response card.) Do it. (pause) Show me your RC. Get ready? Cards up!
S: (Write 2 on the response card. And show their RC to the teacher with a cue.)
T: (praise / correction + repetition until firm.)
T: Next sentence says “Ann has some candies.” Read the second sentence together.
Get ready? (Signal)
S: “Ann has some candies.”
T: Ann has some candies. We do not know how many does Ann have. Do we know how many candies does Ann have, yes or no?
S: NO.
T: When we don’t know how many does Ann have, we’re going to write a mystery box. When we don’t know how many does Ann have, what are we going to write? Get ready? (signal)
S: Mystery Box.
T: So I will write a mystery box over the pink line on the response card. (Write box on the response card.) Do it. (Pause). Show me your RC. Get ready? Cards up!
S: (Write a box on the pink line. And show their RC to the teacher with a cue.)
T: What do we call this empty box? Get ready? (signal)
S: Mystery Box.
T: That’s right. The next sentence says “They have 6 candies in all.” Read that sentence together? Get ready? (Signal)
S: “They have 6 candies in all.”
T: You will write 6 over the green line (Write 6.) Do it. (Pause). Show me your RC. Get ready? Cards up!
S: (Write 6 on the green line. And show their RC to the teacher with a cue.)
T: (praise / correction + repetition until firm.)
T: Now we have 2 box and 6. This side of equation and this side of equation suppose to be equal. This side of equation and this side of equation suppose to be what?
Get ready? (signal)
S: equal.
T: Good. 6 is bigger than 2. Is 6 bigger than two, yes or no? Get ready? (signal)
S: yes.
T: Good. So, to make this side of equation and this side of equation equal, we need to add something to 2. To make this side of equation and this side of equation equal, do we need to add something to 2 or minus something from 2? Add or minus? Get ready? (signal)
S: add.
T: Good. So, we’ll write plus sign in the circle. (Write +.) Do it. (Pause). Show me your RC. Get ready? Cards up!
S: (Write + in the circle. And show their RC to the teacher with a cue.)
T: (praise / correction + repetition until firm.)
T: Now we have the equation, 2 +box = 6. What kind of equations is on your board?
Get ready? (Signal)
S: Two plus box equals 6.
T: (praise / correction + repetition until firm.)
T: And the number coming into the box is 4, because two plus 4 equals six. 2 plus what number equals 6? Get ready? (Signal)
S: 4.
T: (praise / correction + repetition until firm.)
T: Good. So We will write 4 in the box. (Writes “4” in the box) Do it. (Pause). Show me your RC. Get ready? Cards up!
S: (Write 4 in the mystery box. And show their RC to the teacher with a cue.)
T: Then, the last sentence asks us, "How many candies does Ann have?" The number in the box is always the answer. So the answer is 4. What is the answer? Get ready? (Signal)
S: 4.
T: (praise/correction + repetition until firm.)
T: You will write the answer over the answer line. (Writes "4" over the line) Do it. (Pause). Show me your RC. Get ready? Cards up!
S: Write 4 over the answer line. And show their RC to the teacher with a cue.
T: (praise/correction + repetition until firm.)
T: Now you solved this question. We used the equation, two plus box equals 6, and the answer is 4. Good job, guys. Erase the board.

STUDENTS ONLY

T: Let's try another problem. Look at this question. The first sentence says, Sara has 6 apples. Read the sentence together. Get ready? (Signal)
S: Sara has 6 apples.
T: (praise/correction + repetition until firm.)
T: Write how many does Sara have over the yellow line on your board. (pause) Show me your RC. Get ready? Cards up!
S: (Write 6 on the response card, And show their RC to the teacher with a cue.)
T: Next sentence says, Julie has some apples. Read the sentence together. Get ready? (Signal)
S: "Julie has some apples."
T: Does the sentence says how many apples does Julie have? Yes or no? Get ready? (Signal)
S: No.
T: When we don't know how many apples does Julie have, what are we going to write? Get ready? (Signal)
S: Mystery Box.
T: Good. Write it over the pink line. (Pause). Show me your RC. Get ready? Cards up!
S: (Write a box on the yellow line. And show their RC to the teacher with a cue.)
T: (praise/correction + repetition until firm.)
T: The next sentence says, They have 9 apples in all. Read the sentence together. Get ready? (Signal)
S: "They have 9 apples in all."
T: So, write the number over the green line. (Pause). Show me your RC. Get ready? Cards up!
S: (Write 9 on the green line. And show their RC to the teacher with a cue.)
T: (praise/correction + repetition until firm.)
T: Is 9 bigger than 6? Yes or no. Get ready? (Signal)
S: Yes.
T: Good. So, to make this side of equation and this side of equation equal, do we need to add or minus? Get ready? (Signal)

S: Add.

T: That's right. Write it in the circle.

S: Write in the circle. And show their RC to the teacher with a cue.

T: Now, what kind of equations is on your board? Get ready? (Signal)

S: Six plus box equals 9.

T: (praise / correction + repetition until firm.)

T: And six plus what number equals 9? Get ready? (Signal)

S: 3.

T: (praise / correction + repetition until firm.)

T: Write it in the box. (Pause). Show me your RC. Get ready? Cards up!

S: (Write 3 in the box. And show their RC to the teacher with a cue.)

T: Then, the last sentence asks us, “How many apples does Julie have?” The number in the box is always the answer. So what is the answer? Get ready? (Signal)

S: 3.

T: (praise / correction + repetition until firm.)

T: You will write the answer over the line answer line. Do it. (Pause). Show me your RC. Get ready? Cards up!

S: (Write 3 over the answer line. And show their RC to the teacher with a cue.)

T: (praise / correction + repetition until firm.)

Now you solved this question. We used the equation, six plus box equals 9, and the answer is 3. Erase your board.

Comparison 3

TEACHER MODEL

T: (Put the next question on the board.) Put your RC away and look at me. We are going to learn new questions. Here is the question. “Bill has 4 crayons. Shelly has 5 more crayons than Bill. How many crayons does Shelly have?” The first sentence tells us “Bill has 4 crayons.” So, I’ll write 4 over the yellow line on the response card. (Write 4 on the response card.), and this is Bill. (Write Bill over the 4).

T: Next sentence says “Shelly has 5 more crayons than Bill” So, I’ll write 5 on the pink line. (Write 5 on the response card)

T: The next sentence says, “How many crayons does Shelly have?” The sentence does not say how many crayons does Shelly have. Does the sentence says how many crayons does Shelly have? Get Ready? (Signal)

S: NO.

T: So I’ll write a mystery box over the green line. (Write a mystery box.)And this is Shelly. (Write Shelly over the box.)

T: What do you call this box?

S: Mystery Box.
T: Now I have 4 and box on the board. This is Bill and this is Shelly. Shelly has 5 more crayons than Bill. Shelly has more than Bill. (Write <.) Does Shelly have more than Bill or less than Bill? More or Less? Get Ready? (Signal)
S: More.
T: Shelly has 5 more than Bill. Does Shelly have more than Bill or less than Bill? More or Less? Get Ready? (Signal)
S: More.
Shelly has more, and to make this side and this side of equation equal, you need add something to Bill. To make this side and this side of equation equal, do you need to add or minus? Get Ready? (Signal)
S: add.
T: That's right! So I will write plus sign in the circle. (Write +.) Now we have the equation, 4+5 =box.
T: And the number coming into the box is 9, because 4+5=9. 4+5 equals what? Get Ready? (Signal)
S: 9.
T: The number in the box is always the answer. So the answer is 9. I will write the answer over the answer line. (Writes "9" over the line)
T: Now I solved the question.

TEACHER & STUDENT TOGETHER

T: Let's practice together. Look at this question. The first sentence tells us “Tom had 4 cookies.” Read the first sentence together? Get ready? (Signal)
S: “Tom had 4 cookies.”
T: You will write 4 over the yellow line on the response card. (Write “4” on the response card.) Do it. (pause) Show me your RC. Get ready? Cards up!
S: (Write 4 on the response card. And show their RC to the teacher with a cue.)
T: (praise / correction + repetition until firm.)
T: Next sentence says “Lisa has 3 more cookies than Tom.” Read the sentence together. Get ready? (Signal)
S: “Lisa has 3 more cookies than Tom.”
T: You will write 3 over the pink line on the response card. (Write 3 on the response card.) Do it. (Pause). Show me your RC. Get ready? Cards up!
S: (Write 3 on the pink line. And show their RC to the teacher with a cue.)
T: (praise / correction + repetition until firm.)
T: The next sentence says “How many cookies does Lisa have?” Read it together. Get ready? (Signal)
S: “How many cookies does Lisa have?”
T: The sentence does not say how many does Lisa have. Does the sentence say how many does Lisa have? Get ready? (Signal)
S: No.
T: So you will write a mystery box over the green line. When we don't know the number, what are we going to write? Get ready? (Signal)
S: Mystery Box.
T: So I will write a mystery box over the green line. (Write a mystery box.) Do it. (Pause). Show me your RC. Get ready? Cards up!
S: (Write a mystery box over the green line. And show their RC to the teacher with a cue.)
T: This is Tom and this is Lisa. (Write Tom and Lisa) Lisa has 3 more cookies than Tom. Does Lisa have more than Tom or Less? More or Less? Get ready? (Signal)
S: More.
T: More. Lisa has 3 more cookies than Tom. Does Lisa have more than Tom or Less? More or Less? Get ready? (Signal)
S: More.
T: Good! Lisa has more. So we need to add something to Tom. Do we have to add or minus, to make this side of equation and this side of equation equal? Get ready? (Signal)
S: add.
T: add. Lisa has more. So we need to add something to Tom. Do we have to add or minus, to make this side of equation and this side of equation equal? Get ready? (Signal)
S: add.
T: Good. So I will write plus sign in the circle. (Write +.) Do it. (Pause). Show me your RC. Get ready? Cards up!
S: (Write + in the circle. And show their RC to the teacher with a cue.)
T: (praise / correction + repetition until firm.)
T: Now we have the equation, 4 +3=box.
T: And the number coming into the box is 7, because 4+3=7. 4+3=what? Get ready? (Signal)
S: 7.
T: (praise / correction + repetition until firm.)
T: Write 7 in the box. (Pause). Show me your RC. Get ready? Cards up!
S: (Write 7 in the box. And show their RC to the teacher with a cue.)
T: The number in the box is always the answer. So the answer is 7. What is the answer? Get ready? (Signal)
S: 7.
T: (praise / correction + repetition until firm.)
T: You will write the answer over the answer line. (Writes “7” over the line) Do it. (Pause). Show me your RC. Get ready? Cards up!
S: (Write 7 over the answer line. And show their RC to the teacher with a cue.)
T: (praise / correction + repetition until firm.)
T: Now you solved the problem. Did you get it? We'll have some more practice. Erase the board.
T: Let's try another problem. Look at this new question. Ann had 8 crayons. Read the sentence together. Ready? (Signal)
S: Ann had 8 crayons.
T: (praise/correction + repetition until firm.)
T: Write the number over the yellow line on your board. (pause) Show me your RC. Get ready? Cards up!
S: (Write 8 on the response card. And show their RC to the teacher with a cue.)
T: (praise/correction + repetition until firm.)
T: The next sentence is Mary has 1 more crayon than Ann. Read it together. Get ready? (Signal)
S: "Mary has 1 more crayon than Ann."
T: Write the number over the pink line. (Pause). Show me your RC. Get ready?
Cards up!
S: (Write 1 over the pink line. And show their RC to the teacher with a cue.)
T: (praise/correction + repetition until firm.)
T: The last sentence is How many crayons does Mary have? Read it together. Get ready? (Signal)
S: "How many crayons does Mary have?"
T: Do we know how many crayons does Mary have? Yes or no? Get ready? (Signal)
S: No.
T: Good. So, what are we going to write? Get ready? (Signal)
S: Mystery Box.
T: Good. Write it over the green line. Show me your RC. Get ready? Cards up!
S: (Write 0 in the box on the green line. And show their RC to the teacher with a cue.)
T: (praise/correction + repetition until firm.)
T: This is Ann and This is Mary. Does Mary have more crayons than Ann or less? More or less? Get ready? (Signal)
S: More.
T: Good, so do we need to add something to Ann or minus, to make this side and this side make equal? Add or Minus, Get ready? (Signal)
S: Add.
T: Good. So write it in the circle. (Pause). Show me your RC. Get ready? Cards up!
S: (Write + in the circle. And show their RC to the teacher with a cue.)
T: And 8 plus 1 = what number? Get ready? (Signal)
S: 9.
T: (praise/correction + repetition until firm.)
T: Write the number in the box. (Pause). Show me your RC. Get ready? Cards up!
S: (Write 9 in the box. And show their RC to the teacher with a cue.)
T: (praise/correction + repetition until firm.)
T: The number in the box is always the answer. So what is the answer? Get ready? (Signal)
T: (praise/correction + repetition until firm.)

T: You will write the answer over the answer line. Do it. (Pause). Show me your RC.

Get ready? Cards up!

S: Write 5 over the answer line. And show the RC to the teacher with a card.

T: (praise/correction + repetition until firm.)

T: Now you solved the question perfectly. Great job. Erase the board.

TEACHER MODEL

T: Put your RC away and look at me. We are going to learn new questions. Look at the problem. The first sentence tells us "Julie had 5 candies." So, I'll write 5 over the yellow line on the response card. (Write 5 on the response card.)

T: Next sentence says "She gave some candies to Cindy." We do not know how many candies did Julie give to Cindy. Do we know, how many candies did Julie give to Cindy? Get ready? (Signal)

S: No.

T: Right. So, what am I going to write? Get ready? (Signal)

S: Mystery Box.

T: That's right. (Write a mystery box on the response card)

T: The next sentence says "Now Julie has 3 candies." So I will write 3 over the green line. (Write 3 on the response card).

T: Now I have 5 box 3. This side of equation and this side of equation has to be equal. 3 is smaller than 5. Is 3 bigger or smaller than 5? Bigger or smaller? Get ready? (Signal)

S: smaller.

T: smaller. 3 is smaller than 5. Is 3 bigger or smaller than 5? Bigger or smaller? Get ready? (Signal)

S: smaller.

T: That's right. Because 3 is smaller than 5. To make this side and this side equal, I have to minus something from 5. Do I have to add something to 5 or minus from 5 to make this side of equation and this side of equation equal? Add of minus? Get ready? (Signal)

S: minus.

T: Minus. Because 3 is smaller than 5. To make this side and this side equal, I have to minus something from 5. Do I have to add something to 5 or minus from 5 to make this side of equation and this side of equation equal? Add of minus? Get ready? (Signal)

S: minus.

T: So, I'll write minus sign in the circle. (Write -.) Now we have the equation, 5-box = 3.

T: And the number coming into the box is 2, because 5 take away 2 equals 3. 5 take away what number equals 3? Get ready? (Signal)

S: 2.
T: Good, The number in the box is always the answer. So the answer is 2. I will write the answer over the answer line. *(Write “2” over the line)*

T: Now I solved the question.

**TEACHER & STUDENT TOGETHER**

T: Let’s practice together. Look at this question. The first sentence tells us “Sam had 9 pens.” Read it together? Get ready? *(Signal)*

S: “Sam had 9 pens.”

T: You will write 9 over the yellow line on the response card. *(Write “9” on the response card. Do it. (pause) Show me your RC. Get ready? Cards up!)*

S: Write 9 on the response card. And show their RC to the teacher with a cue.

T: *(praise / correction + repetition until firm.)*

T: Next sentence says “Then he gave some pens to Ken.” Read it together. Get ready? *(Signal)*

S: “Then he gave some pens to Ken.”

**[Comment: We do not know how many pens did Sam give to Ken. Do we know how many pens did Sam give to Ken? Get ready? (Signal)]**

S: NO.

T: So you’ll write a mystery box on the pink line. What are you going to write? Get ready? *(Signal)*

S: Mystery box.

T: *(Write a box on the response card.) Wright it. (Pause). Show me your RC. Get ready? Cards up!*

S: *(Write a box on the pink line. And show their RC to the teacher with a cue.)*

T: *(praise / correction + repetition until firm.)*

T: The next sentence says “Now Sam has 5 pens.” Read it together? Get ready? *(Signal)*

S: “Now Sam has 5 pens.”

T: So you’ll write 5 on the green line. *(Write 5.) Do it. (Pause). Show me your RC. Get ready? Cards up!*

S: *(Write 5 on the green line. And show their RC to the teacher with a cue.)*

T: *(praise / correction + repetition until firm.)*

T: Now we have 9 box and 5. 5 is smaller than 9. Is 5 bigger or smaller than 9? Get ready? *(Signal)*

S: Smaller.

T: Good! So we need to minus something from 9 to make this side and this side equal. Do we add or minus? Get ready? *(Signal)*

S: minus.

T: Good!! So we’ll write - sign in the circle. *(Write -.) Do it. (Pause). Show me your RC. Get ready? Cards up!*

S: *(Write - in the circle. And show their RC to the teacher with a cue.)*

**[Comment: We now have the equation, 9-box=5. And the number coming into the box is 4, because 9-4=5. 9 take away what number equals 5? Get ready? (Signal)]**
S: 4.
T: (praise / correction + repetition until firm.)
T: The number in the box is always the answer. So the answer is 4. What is the
answer? Get ready? (Signal)
S: 4.
T: (praise / correction + repetition until firm.)
T: Write the number in the box. (Pause). Show me your RC. Get ready? Cards up!
S: (Write 4 in the box. And show their RC to the teacher with a cue.)
T: (praise / correction + repetition until firm.)
T: You will write the answer over the answer line. (Writes “4” over the line) Do it.
(Pause). Show me your RC. Get ready? Cards up!
S: (Write 4 over the answer line. And show their RC to the teacher with a cue.)
T: (praise / correction + repetition until firm.)
T: Now you solved the question. Erase the board.

STUDENTS ONLY

T: Let’s try another problem. Look at the question. The first sentence is “David had
6 candies. Read it together. Get ready? (Signal)
S: David had 6 candies.
T: (praise / correction + repetition until firm.)
T: Write how many did David have over the yellow line on your board. (pause)
Show me your RC. Get ready? Cards up!
S: (Write 6 on the response card. And show their RC to the teacher with a cue.)
T: (praise / correction + repetition until firm.)
T: Next sentence is Then he gave some candies to Matt. Read it together. Get ready?
(Signal)
S: “Then he gave some candies to Matt.”
T: Do we know how many did he give to Matt? Yes or No, Get ready? (Signal)
S: No.
T: Right. So, what are we going to write? Get ready? (Signal)
S: Mystery Box.
T: Good. Write it. (Pause). Show me your RC. Get ready? Cards up!
S: (Write a box on the pink line. And show their RC to the teacher with a cue.)
T: (praise / correction + repetition until firm.)
T: The next sentence says, Now David has 2 candies. Get ready? (Signal)
S: “Now David has 2 candies.”
T: Write the number. (Pause). Show me your RC. Get ready? Cards up!
S: (Write 2 on the green line. And show their RC to the teacher with a cue.)
T: (praise / correction + repetition until firm.)
T: Now we have 6 box and 2. Is 2 bigger or smaller than 6? Get ready? (Signal)
S: Smaller.
T: Good. So are we going to write plus or minus to make this side of equation and
this side of equation equal? Plus or Minus? Get ready? (Signal)
S: minus.
T: Good!! Write it. (Pause). Show me your RC. Get ready? Cards up!
S: Write 4 in the box. And show their RC to the teacher with a cue.
T: (praise / correction + repetition until firm.)
T: And 6 take away what number equals 2? Get ready? (Signal)
S: four.
T: (praise / correction + repetition until firm.)
T: The number in the box is always the answer. So what is the answer? Get ready? (Signal)
S: four.
T: Write the number in the box. (Pause). Show me your RC. Get ready? Cards up!
S: Write 4 in the box. And show their RC to the teacher with a cue.
T: (praise / correction + repetition until firm.)
T: You will write the answer over the answer line. Do it. (Pause). Show me your RC. Get ready? Cards up!
S: Write 4 over the answer line. And show their RC to the teacher with a cue.
T: (praise / correction + repetition until firm.)

Practice Problems Worksheet

T: (After the students finish their Instructed Problems Worksheet, collect their response cards. Pass out Practice Problems Worksheet.) Let's do this worksheet without using response card. Write an equation and an answer for each question.
S: (Work on the probe worksheet.)
T: (Collect the worksheet and give praise.)
APPENDIX H:

Example of Response Card
APPENDIX I:

Example of Instructed Problem Worksheet
Name:

1. Michelle has 6 marbles. She has 4 more marbles than Sam. How many marbles does Sam have?

Equation

2. Ken has 5 pens. He has 3 more pens than David. How many pens does David have?

Equation

3. Linda has some pencils. Tom has 2 pencils. They have 5 pencils in all. How many pencils does Linda have?

Equation

4. Emily had some stickers. Then she gave 2 stickers to Jen. Now Emily has 3 stickers. How many stickers did Emily have at the beginning?

Equation

5. Linda has some pencils. Tom has 2 pencils. They have 5 pencils in all. How many pencils does Linda have?

Equation

6. Bill has some cookies. Sara has 4 cookies. They have 7 cookies in all. How many cookies does Bill have?

Equation
APPENDIX J:

Example of Practice Problem Worksheet
1. Jenny has 5 pencils. Josh has 2 pencils. How many pencils does Josh have less than Jenny?

Equation

Answer

2. Mary has 4 cookies. Bob has 4 more cookies than Mary. How many cookies does Bob have?

Equation

Answer

3. Paula had 6 stickers. Then she gave 4 stickers to Mike. How many stickers does Paula have now?

Equation

Answer

4. Chuck has 5 candies. Laura has 2 candies. How many candies do they have in all?

Equation

Answer

5. Ron had 5 pencils. Then Sam gave him 3 pencils. How many pencils does Ron have now?

Equation

Answer

6. Rebecca and Tim have 6 toys in all. Rebecca has 4 toys. How many toys does Tim have?

Equation

Answer
APPENDIX K:

Example of Generalization Test
Name:

1. Mary has 2 candies. Ann has 6 candies. How many candies do they have in all?

   Equation  
   Answer

2. Amy had 8 crayons. Then Chuck gave her 2 crayons. How many crayons does Amy have now?

   Equation  
   Answer

3. Chuck has 5 apples. Bob has 4 apples. How many apples does Bob have less than Chuck?

   Equation  
   Answer

4. Tom and Lisa have some cookies. Tom has 4 cookies. Lisa has 3 cookies. How many cookies do they have in all?

   Equation  
   Answer

5. Rick has 8 apples. Rick has 2 more apples than Jenny. How many apples does Jenny have?

   Equation  
   Answer

6. Matt has some stickers. Amy has 3 stickers. They have 9 stickers in all. How many stickers does Matt have?

   Equation  
   Answer
Name:______________

1. Sam and Ken have 9 pens in all. Sam has 8 pens. How many pens does Ken have?

Equation__________________________Answer__________________________

2. David has 5 candies. Matt has 3 candies. How many candies does David have more than Matt?

Equation__________________________Answer__________________________

3. Julie has 3 candies. Bill has 3 more candies than Julie. How many candies does Bill have?

Equation__________________________Answer__________________________

4. Shelly had some pens. Then Shelly gave 4 pens to Rick. Now Shelly has 4 pens. How many pens did Shelly have at the beginning?

Equation__________________________Answer__________________________

5. Bill had 5 crayons. Then Bill gave some crayons to Shelly. Now Bill has 1 crayon. How many crayons did Bill give to Shelly?

Equation__________________________Answer__________________________

6. Becky has 2 pens. Becky has 8 pens less than Sara. How many pens does Sara have?

Equation__________________________Answer__________________________
1. Rose and Joe have 10 stickers in all. Rose has some stickers. Joe has 7 stickers. How many stickers does Rose have?

Equation

Answer

2. Jenny has 8 cookies. Rose has 1 cookie less than Jenny. How many cookies does Rose have?

Equation

Answer

3. Sara had 2 apples. Then Julie gave her some apples. Now Sara has 7 apples. How many apples did Julie give Sara?

Equation

Answer

4. Bob had 7 stickers. Then Bob gave 4 stickers to David. How many stickers does Bob have now?

Equation

Answer

5. Joe has 4 cookies. Becky has some cookies. They have 8 cookies in all. How many cookies does Becky have?

Equation

Answer

6. Ann had some crayons. Then Mary gave her 3 crayons. Now Ann has 7 crayons. How many crayons did Ann have at the beginning?

Equation

Answer
1. Shelly had some pens. Then Shelly gave 4 pens to Rick. Now Shelly has 4 pens. How many pens did Shelly have at the beginning?

Equation

Answer

2. Bill had 5 crayons. Then Bill gave some crayons to Shelly. Now Bill has 1 crayon. How many crayons did Bill give to Shelly?

Equation

Answer

3. Julie has 3 candies. Bill has 3 more candies than Julie. How many candies does Bill have?

Equation

Answer

4. Chuck has 5 apples. Bob has 4 apples. How many apples does Bob have less than Chuck?

Equation

Answer

5. Tom and Lisa have some cookies. Tom has 4 cookies. Lisa has 3 cookies. How many cookies do they have in all?

Equation

Answer

6. Amy had 8 crayons. Then Chuck gave her 2 crayons. How many crayons does Amy have now?

Equation

Answer
Name:

1. Mary has 2 candies. Ann has 6 candies. How many candies do they have in all?

   Equation
   Answer

2. David has 5 candies. Matt has 3 candies. How many candies does David have more than Matt?

   Equation
   Answer

3. Rick has 8 apples. Rick has 2 more apples than Jenny. How many apples does Jenny have?

   Equation
   Answer

4. Bob had 7 stickers. Then Bob gave 4 stickers to David. How many stickers does Bob have now?

   Equation
   Answer

5. Sara had 2 apples. Then Julie gave her some apples. Now Sara has 7 apples. How many apples did Julie give Sara?

   Equation
   Answer

6. Matt has some stickers. Amy has 3 stickers. They have 9 stickers in all. How many stickers does Matt have?

   Equation
   Answer

GA2-2
1. Becky has 2 pens. Becky has 8 pens less than Sara. How many pens does Sara have?

Equation

Answer

2. Sam and Ken have 9 pens in all. Sam has 8 pens. How many pens does Ken have?

Equation

Answer

3. Ann had some crayons. Then Mary gave her 3 crayons. Now Ann has 7 crayons. How many crayons did Ann have at the beginning?

Equation

Answer

4. Joe has 4 cookies. Becky has some cookies. They have 8 cookies in all. How many cookies does Becky have?

Equation

Answer

5. Jenny has 8 cookies. Rose has 1 cookie less than Jenny. How many cookies does Rose have?

Equation

Answer

6. Rose and Joe have 10 stickers in all. Rose has some stickers. Joe has 7 stickers. How many stickers does Rose have?

Equation

Answer
APPENDIX L:

Example of Answer Key
Name: Answer Key

1. Mary has 2 candies. Ann has 6 candies. How many candies do they have in all?

\[2 + 6 = \square\]  
8 Answer

2. David has 5 candies. Matt has 3 candies. How many candies does David have more than Matt?

\[5 - 3 = \square\]  
2 Answer

3. Rick has 8 apples. Rick has 2 more apples than Jenny. How many apples does Jenny have?

\[8 - 2 = \square\]  
6 Answer

4. Bob had 7 stickers. Then Bob gave 4 stickers to David. How many stickers does Bob have now?

\[7 - 4 = \square\]  
3 Answer

5. Sara had 2 apples. Then Julie gave her some apples. Now Sara has 7 apples. How many apples did Julie give Sara?

\[2 + \square = 7\]  
5 Answer

6. Matt has some stickers. Amy has 3 stickers. They have 9 stickers in all. How many stickers does Matt have?

\[\square + 3 = 9\]  
6 Answer
APPENDIX M:

Picture of Lottery Tickets and Prizes
APPENDIX N:

Picture of Marbles and Marble Jar
APPENDIX O:

Example of Data Recording Sheet
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APPENDIX P:

Graphs Representing Each Student's Number of Correct Answers and Equations across Three Different Sets of Teaching Examples
Figure P.1: Number of correct answers and equations on each problem set for Andy during baseline, instruction, generalization assessment, and follow-up. Left part shows number of correct answers. Right part shows number of correct equations. The first tier of each part represents number of correct on MCSP problems (total six problems). The second tier represents MCMP problems (total six problems). The third tier represents SCMP problems (total six problems). The fourth tier represents other problems that were not included either of three problem groups above (total five problems. "A" represents the probe the student was absent from. Shaded parts represent instruction sessions.
Figure P.2: Number of correct answers and equations on each problem set for Ed during baseline, instruction, generalization assessment, and follow-up. Left part shows number of correct answers. Right part shows number of correct equations. The first tier of each part represents number of correct on MCSP problems (total six problems). The second tier represents MCMP problems (total six problem). The third tier represents SCMP problems (total six problems). The fourth tier represents other problems that were not included either of three problem groups above (total five problems. "A" represents the probe the student was absent from. Shaded parts represent instruction sessions.
Figure P.3: Number of correct answers and equations on each problem set for Alice during baseline, instruction, generalization assessment, and follow-up. Left part shows number of correct answers. Right part shows number of correct equations. The first tier of each part represents number of correct on MCSP problems (total six problems). The second tier represents MCMP problems (total six problems). The third tier represents SCMP problems (total six problems). The fourth tier represents other problems that were not included either of three problem groups above (total five problems. “A” represents the probe the student was absent from. Shaded parts represent instruction sessions.
Figure P.4: Number of correct answers and equations on each problem set for Amber during baseline, instruction, generalization assessment, and follow-up. Left part shows number of correct answers. Right part shows number of correct equations. The first tier of each part represents number of correct on MCSP problems (total six problems). The second tier represents MCMP problems (total six problem). The third tier represents SCMP problems (total six problems). The fourth tier represents other problems that were not included either of three problem groups above (total five problems. "A" represents the probe the student was absent from. Shaded parts represent instruction sessions.
Figure P.5: Number of correct answers and equations on each problem set for Matthew during baseline, instruction, generalization assessment, and follow-up. Left part shows number of correct answers. Right part shows number of correct equations. The first tier of each part represents number of correct on SCMP problems (total six problems). The second tier represents MCMP problems (total six problem). The third tier represents MCSP problems (total six problems). The fourth tier represents other problems that were not included either of three problem groups above (total five problems). “A” represents the probe the student was absent from. Shaded parts represent instruction sessions.
Figure P.6: Number of correct answers and equations on each problem set for Theresa during baseline, instruction, generalization assessment, and follow-up. Left part shows number of correct answers. Right part shows number of correct equations. The first tier of each part represents number of correct on SCMP problems (total six problems). The second tier represents MCMP problems (total six problem). The third tier represents MCSP problems (total six problems). The fourth tier represents other problems that were not included either of three problem groups above (total five problems). "A" represents the probe the student was absent from. Shaded parts represent instruction sessions.
Figure P.7: Number of correct answers and equations on each problem set for Willy during baseline, instruction, generalization assessment, and follow-up. Left part shows number of correct answers. Right part shows number of correct equations. The first tier of each part represents number of correct on SCMP problems (total six problems). The second tier represents MCMP problems (total six problem). The third tier represents MCSP problems (total six problems). The fourth tier represents other problems that were not included either of three problem groups above (total five problems). "A" represents the probe the student was absent from. Shaded parts represent instruction sessions.
Figure P.8: Number of correct answers and equations on each problem set for Jason during baseline, instruction, generalization assessment, and follow-up. Left part shows number of correct answers. Right part shows number of correct equations. The first tier of each part represents number of correct on SCMP problems (total six problems). The second tier represents MCMP problems (total six problems). The third tier represents MCSP problems (total six problems). The fourth tier represents other problems that were not included either of three problem groups above (total five problems). "A" represents the probe the student was absent from. Shaded parts represent instruction sessions.
Figure P.9: Number of correct answers and equations on each problem set for Sam during baseline, instruction, generalization assessment, and follow-up. Left part shows number of correct answers. Right part shows number of correct equations. The first tier of each part represents number of correct on SCMP problems (total six problems). The second tier represents MCMP problems (total six problem). The third tier represents MCSP problems (total six problems). The fourth tier represents other problems that were not included either of three problem groups above (total five problems). “A” represents the probe the student was absent from. Shaded parts represent instruction sessions.
Figure P.10: Number of correct answers and equations on each problem set for Chuck during baseline, instruction, and generalization assessment. Left part shows number of correct answers. Right part shows number of correct equations. The first tier of each part represents number of correct on MCMP problems (total six problems). The second tier represents MCSP problems (total six problem). The third tier represents SCMP problems (total six problems). The fourth tier represents other problems that were not included either of three problem groups above (total five problems). "A" represents the probe the student was absent from. Shaded parts represent instruction sessions.
Figure P.11: Number of correct answers and equations on each problem set for Debbie during baseline, instruction, and generalization assessment. Left part shows number of correct answers. Right part shows number of correct equations. The first tier of each part represents number of correct on MCMP problems (total six problems). The second tier represents MCSP problems (total six problem). The third tier represents SCMP problems (total six problems). The fourth tier represents other problems that were not included either of three problem groups above (total five problems). “A” represents the probe the student was absent from. Shaded parts represent instruction sessions.
Figure P.12: Number of correct answers and equations on each problem set for Al during baseline, instruction, and generalization assessment. Left part shows number of correct answers. Right part shows number of correct equations. The first tier of each part represents number of correct on MCMP problems (total six problems). The second tier represents MCSP problems (total six problems). The third tier represents SCMP problems (total six problems). The fourth tier represents other problems that were not included either of three problem groups above (total five problems). "A" represents the probe the student was absent from. Shaded parts represent instruction sessions.
Figure P.13: Number of correct answers and equations on each problem set for Amy during baseline, instruction, and generalization assessment. Left part shows number of correct answers. Right part shows number of correct equations. The first tier of each part represents number of correct on MCMP problems (total six problems). The second tier represents MCSP problems (total six problem). The third tier represents SCMP problems (total six problems). The fourth tier represents other problems that were not included either of three problem groups above (total five problems). “A” represents the probe the student was absent from. Shaded parts represent instruction sessions.
Figure P.14: Number of correct answers and equations on each problem set for Tim during baseline, instruction, and generalization assessment. Left part shows number of correct answers. Right part shows number of correct equations. The first tier of each part represents number of correct on MCMP problems (total six problems). The second tier represents MCSP problems (total six problems). The third tier represents SCMP problems (total six problems). The fourth tier represents other problems that were not included either of three problem groups above (total five problems). "A" represents the probe the student was absent from. Shaded parts represent instruction sessions.
Figure P.15: Number of correct answers and equations on each problem set for Ali during baseline, instruction, and generalization assessment. Left part shows number of correct answers. Right part shows number of correct equations. The first tier of each part represents number of correct on MCMP problems (total six problems). The second tier represents MCSP problems (total six problem). The third tier represents SCMP problems (total six problems). The fourth tier represents other problems that were not included either of three problem groups above (total five problems). “A” represents the probe the student was absent from. Shaded parts represent instruction sessions.
APPENDIX Q:

Tables Representing Each Group’s Average Percentage of Correct Answers and Equations by Problem Subtypes
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a Gray shaded part indicates MCSP problems
b White part indicates untaught problems
c Diagonal line part indicates MCMP problems

Table Q.1: MCSP group's average percentage of correct answers and equations by problem subtypes. CB, CH, and CP indicate Combination, Change, and Comparison respectively.
Table Q.2: SCMP group’s average percentage of correct answers and equations by problem subtypes. CB, CH, and CP indicate Combination, Change, and Comparison respectively.

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Notes:
- a White part indicates untaught problems
- b Diagonal line part indicates MCMP problems
- c Gray shaded part indicates SCMP problems
### Table Q.3: MCMP group’s average percentage of correct answers and equations by problem subtypes. CB, CH, and CP indicate Combination, Change, and Comparison respectively.

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- a White part indicates untaught problems
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