2014

The Effect of the PIES Mnemonic Strategy on the Word Problem Solving Skills of Middle School Students

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Research Paper

Submitted to the Special Education Faculty of Marshall University College of Education and Professional Development

In Partial Fulfilment of the Requirements for the Degree

Masters of Arts

By

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May 8, 2014

Keywords: mnemonic strategy, word problems, math, students with disabilities, learning disability, emotional/behavioral disorder

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Abstract

This purpose of this study was to determine the effect of the PIES mnemonic strategy on the word problem solving skills of middle school students in inclusive math classes. Participants in the study were 109 students in a rural middle school in a mid-Atlantic state. Seventy-five participants were normally achieving students, and 34 were students with disabilities (Other Health Impairment, Specific Learning Disability, and Emotional/Behavioral Disorders). A pretest consisting of 10 grade-level word problems covering concepts that had already been taught was administered. Students then learned the PIES mnemonic strategy (Picture, Information, Equation, Solution) and participated in five weeks of practice sessions. A posttest was administered, and mean pretest and posttest scores were compared using a paired-sample t-Test. There was a significant difference between pretest and posttest scores for both sixth grade (t (68) = 4.944, $p<.001$) and seventh grade students (t (41) = 3.861, $p<.001$). Results for the SWD subgroup were mixed, with significant improvement for sixth grade SWD (t (21) = 4.468, $p<.001$) but not for seventh grade SWD (t (13) = 1.783, $p=0.999$).

Chapter 1: Introduction

Solving word problems in mathematics is a difficult skill for many students, but especially so for students who have disabilities in the area of mathematics. Even when students have the necessary skills to solve a problem presented in isolation, they experience difficulty when the same problem is presented as a word problem (Heater, Howard, & Linz, 2012). Mnemonic strategies have been found to be effective in helping students recall information (Mastropieri & Scruggs, 1998; Scruggs, Mastropieri, Berkeley, & Marshak, 2010; Wolgemuth, Cobb, & Alwell, 2008), and several studies suggest that students benefit from mnemonic strategy instruction in the area of math (Test & Ellis, 2005; Xin & Zhang, 2009). The purpose of this research is to determine whether a mnemonic strategy called PIES will be effective in helping middle school students with and without disabilities in mathematics improve their ability to solve word problems.

Statement of the Problem

Solving word problems is difficult for many students. Many students are reluctant to attempt word problems, even though they may possess adequate computational skills to solve the same problem when it is presented as an equation (Heater et al., 2012). As students progress through school grades, problem solving skills become even more important (Zheng, Flynn, & Swanson, 2013). Ultimately, success in the area of mathematics can give individuals more options for college and can increase their potential for future careers and income (National Mathematics Advisory Panel, 2008).

The US Department of Education has recommended teaching students strategies that involve self-monitoring and reflecting, as well as creating diagrams and drawings to solve word problems (Woodward et al., 2012). Students who are taught to use visualization strategies and to create representations of the information contained in word problems have been found to have a better understanding of word problems and a better ability to solve word problems than students who are taught through traditional methods (Abdullah, Zakaria, & Halim, 2012).

Generating a diagram to represent the problem is an effective strategy for solving word problems, but students with learning disabilities may not know how to generate them and use them to find solutions. Van Garderen, Scheuermann, and Jackson (2013) found that students with learning disabilities were less able to create effective diagrams and used them less strategically than their non-disabled peers to solve word problems. However, when students are taught how to generate diagrams and use them to solve problems, they show improvement in their ability to solve one- and two-step problems (Van Garderen, 2007).

Part of the frustration that students face in solving word problems may stem from the fact that multiple steps are required to reach one correct answer, and if a mistake is made at any point in the process, then the whole problem is incorrect. However, helping students to switch from a belief that success in mathematics is a function of their ability to a focus on their own effort can lead students to become more engaged and persistent in their mathematics learning (National Mathematics Advisory Panel, 2008). Strategies that recognize effort by providing reinforcement during each step of the problem solving process have been found to improve problem solving ability and on-task behaviors with students with emotional and behavioral disorders (Alter, 2012).

Mnemonic strategies, which are procedures that help students take in information and retrieve it later when it is needed (Mastropieri & Scruggs, 1998), have been found to be effective instructional tools for students with learning disabilities in various instructional settings and across curricular areas (Wolgemuth et al., 2008). Mnemonic strategies typically associate new information to familiar information in ways that aid recall of the new information (Mastropieri & Scruggs, 2013a). Mnemonic strategies have been commonly used for vocabulary acquisition and to teach content information in social studies and science (Mastropieri & Scruggs, 2013a). Mnemonic strategies have also been effective for mathematics instruction. For example, the pegword strategy associates rhyming words with numbers (i.e., shoe-two, door-four) and has been used to promote memorization of difficult multiplication facts (Scruggs et al., 2010). The LAP fraction strategy is a mnemonic letter strategy that has been found to have a positive effect on students' word problem solving skills (Test & Ellis, 2005). The LAP strategy uses the acronym LAP to help students recall the steps for adding and subtracting fractions (e.g., Look at the sign and denominator; Ask if the smaller denominator will divide evenly into the larger denominator; and Pick a fraction type) (Test & Ellis, 2005).

The PIES strategy (Heater et al., 2012) employs a mnemonic strategy to teach students a series of steps when solving word problems. Students learn to draw a picture (P) to represent the problem, identify key words and important information (I) from the problem and write them next to the picture, identify the correct equation (E) to represent the problem, and solve (S) the equation to answer the question. Students are awarded points for their work at each step of the procedure, which may encourage them to persist in solving the problem and to continue using the strategy even when their final answers are incorrect (Heater et al., 2012). It has been used successfully with students in an inclusive high school Physics class and with high school students in self-contained science classes; students who learned the strategy in these classes also demonstrated transfer of the knowledge by using it in their math classes (Heater et al., 2012).

Purpose of the Study

The purpose of this study was to investigate the effectiveness of the PIES mnemonic strategy on the problem solving abilities of middle school students in inclusive mathematics classes. Participants were sixth and seventh grade students enrolled in basic mathematics classes in one school in a rural school district in a mid-Atlantic state. Some of the students have been identified as having learning disabilities and other mild disabilities (e.g., ADHD, other health impairment, and emotional/behavioral disorders). Teachers of the participating classes were trained how to teach the PIES strategy and implemented the strategy using problems from the existing curriculum used in their classrooms.

Prior to introducing the study, a pretest consisting of ten word problems similar to the types of problems students would encounter on benchmark tests and regular unit tests were administered. Next, students were introduced to the PIES strategy. During the intervention, they learned to create a pictorial representation of the problem, identify information needed to solve the problem, identify or create an equation to solve the problem, and execute the calculations to solve the problem. Teachers engaged students in practice sessions using the strategy several times a week for three to four weeks, requiring students to use the steps of the PIES strategy as they solved practice problems. At the end of the study, a posttest was administered, and posttest scores were compared with pretest scores to determine whether the PIES strategy had a positive effect on students' ability to solve word problems.

Rationale for the Study

American students are not achieving as well as their peers worldwide in the area of mathematics (National Mathematics Advisory Panel, 2008). It is estimated that five to eight percent of school-age students have learning disabilities in the area of mathematics (Fuchs &

Fuchs, 2002; Geary, 2004). Solving word problems is difficult for many students, but especially so for students who have disabilities. However, providing explicit instruction which includes clear models for solving a variety of problems can have positive effects on students' problem solving abilities (National Mathematics Advisory Panel, 2008). Further, leading students to discover that their effort, not their ability, leads to success in mathematics will promote engagement and persistence in students' mathematics learning (National Mathematics Advisory Panel, 2008).

Research Question

The purpose of the current study was to investigate the effectiveness of the PIES mnemonic strategy when teaching word problems to middle school students of average ability and those with disabilities in the area of mathematics in inclusive mathematics classes. Through the research, the following question was investigated: *Will students in inclusive middle school math classes who are taught the steps of the PIES mnemonic strategy demonstrate improvement in word problem solving, as evidenced by improved scores from pretest to posttest measures?*

Chapter 2: Review of Related Literature

A student's difficulties in solving word problems can be affected by factors other than simple arithmetic ability, such as deficits in attention, nonverbal problem solving, language skills, reading skills, and concept formation (Fuchs et al., 2008). Additionally, working memory deficits can adversely affect a student's ability to solve word problems (Geary, 2004). Students with working memory deficits may have difficulty holding information from the problem in memory, making connections between pieces of information, and maintaining the information throughout the problem solving process until the solution can be reached (Swanson, Jerman, & Zheng, 2008). Many students are reluctant to attempt word problems, even though they may possess adequate computational skills to compute the answer to the same problem presented as an equation (Heater et al., 2012). As students progress through school grades, problem solving skills become even more important (Zheng et al., 2013).

Word Problem Solving and Students with Disabilities

It is estimated that approximately five to eight percent of school-age children are identified as having learning disabilities in the area of mathematics (Fuchs & Fuchs, 2002; Geary, 2004), and many of those students also have reading disabilities that can affect their ability to solve word problems (Fuchs & Fuchs, 2002). In general, students with learning disabilities may have problems reading and comprehending word problems, maintaining attention to the problem, identifying important information contained in the problem, creating a visual representation of the problem, deciding on a plan of action to solve the problem, and executing the computations to find the correct solution (Montague, 2006).

In addition, students with learning disabilities may have difficulty with self-regulation strategies. They may be disorganized in their thinking and planning, be unsure of where to begin to solve the problem, and lack adequate strategies. Those who have a sufficient number of strategies may not be able to choose a strategy that is appropriate for the problem they are trying to solve (Montague, 2006). Students with learning disabilities are often unable to abandon an ineffective strategy and replace it with a better one (Montague, 2006), which may result in students engaging in trial-and-error strategies and performing irrelevant computations (Montague, 1997). These students are typically unable to adapt previously learned strategies and generalize them to new situations (Montague, 2006). Unlike their non-disabled peers, students with learning disabilities are not strategic learners, have low motivation, tend to give up easily when working with problems they perceive as difficult, and are unable to monitor their own performance to find and correct errors (Montague, 2006).

Poor reading ability can affect a student's ability or willingness to solve word problems. Many students with learning disabilities have experienced years of reading failure as they have tried to make sense of reading materials, so as they reach higher grades, they may be unwilling to spend the time trying to comprehend word problems (Bottge, 2001). Although many students with mathematics disabilities may also have reading disabilities that affect their decoding and comprehension of word problems (Fuchs & Fuchs, 2002), it may not be enough to simply read word problems to students who lack reading fluency (Parmar, 1992).

Students who have sufficient arithmetic knowledge may have difficulty solving word problems for several reasons (Parmar, 1992). These students may not comprehend a word problem as a whole, so they may require additional help identifying important features of the problem and developing a plan to solve it (Parmar, 1992). They may lack the ability to adequately represent the information in the problem in order solve the problem, and they may not correctly apply appropriate strategies to select the correct operation (Parmar, 1992).

Many students may face frustration when solving word problems because multiple steps are required to reach one correct answer, and if a mistake is made at any point in the process, then the whole problem is incorrect. As a result, many students will simply give up or guess at an answer (Alter, 2012). It is important for teachers to shift the focus of students from a belief that ability rather than effort leads to success in the area of mathematics (National Mathematics Advisory Panel, 2008). When students believe that their own effort rather than natural ability is responsible for their mathematics achievement, they become more engaged and persistent in mathematics learning (National Mathematics Advisory Panel, 2008).

Alter (2012) investigated the effects of combining a multi-step problem solving strategy with a token economy on the problem solving skills of fourth- and fifth-grade students with emotional and behavioral disorders. Students were taught to use a series of steps to solve problems (read the problem aloud, paraphrase, visualize/draw a diagram, state the problem, hypothesize, estimate, calculate, and self-check). Each student was given an index card at the beginning of each practice session. As students worked through the steps of the problem solving strategy, they would receive a hole punched on their index cards for completion of the steps. At the end of each fifteen-minute practice session, students were allowed to "cash in" their index cards for rewards, such as computer games, football and magnetic dartboard games, and snacks. This strategy of rewarding students for persistence and completing each step of the problem solving steps proved effective for improving students' ability to produce the correct answers and for increasing their on-task behavior while working on the problems (Alter, 2012).

Visual Representations

One recommendation of the US Department of Education for teaching students to become better problem solvers is using teaching students strategies that involve creating diagrams and drawings to solve word problems (Woodward et al., 2012). There are several compelling reasons to incorporate visual representations into word problem solving instruction (van Garderen, 2006). Diagrams help students with working memory deficits manage the information contained in a problem; they are a flexible tool that can be used with various problem types and with students of any grade level; and creating diagrams can increase motivation and persistence in students with disabilities (van Garderen, 2006).

Students with mathematics disabilities can benefit from instruction that goes beyond traditional problem solving instruction and leads to deeper understanding of the problem structure (Jitendra & Star, 2011). Typical textbook instruction for problem solving involves introducing a mathematical concept and then presenting word problems which require the same procedure to solve them throughout the lesson (e.g., all problems involve adding fractions with like denominators) (Jitendra et al., 2007). However, for students to become effective problem solvers, they need opportunities to discriminate among different problem types and choose appropriate strategies to solve them (Jitendra et al., 2007; Parmar, 1992).

Abdullah et al. (2012) compared the performance of students who were taught visualization strategies and how to create representations of the problems with students who were taught using methods traditionally found in math textbooks. Students who learned to create representations of the information in the problems were found to demonstrate better understanding of the problems and solved them more successfully than their peers who received traditional instruction (Abdullah et al., 2012). Creating a visual representation for a problem helps students link the relationships between the numbers in the problems with the operations needed to solve them (Woodward et al., 2012). Further, students who learn to create visual representations prior to choosing an operation and writing the equation to solve the problem tend to be more successful at solving the problems (Woodward et al., 2012).

Generating a picture or diagram to represent the strategy is an effective strategy for solving word problems, but students with learning disabilities may not know how to generate and use them to find solutions. Van Garderen et al. (2013) found that students with learning disabilities were less able to create effective diagrams and used them less strategically than their non-disabled peers to solve word problems. However, when students are taught how to generate diagrams and use them to solve problems, they show improvement in their ability to solve one- and two-step problems (Van Garderen, 2007).

Van Garderen et al. (2013) investigated whether students understand what diagrams are and how they can be used as tools to assist in solving word problems. Three interesting findings resulted from their study. First, they found that students with learning disabilities did not differ significantly from their non-disabled peers in the average number of diagrams used to solve word problems. They would generate a diagram when prompted, but their diagrams tended to be more pictorial and less schematic than the diagrams generated by their non-disabled peers. Second, students with learning disabilities generated lower quality diagrams than their non-disabled peers and used them less strategically when solving word problems. Finally, students with learning disabilities did not clearly understand what a diagram was or how they could be used to assist with problem solving. Therefore, it is not enough to simply tell students to “draw a picture” when solving a problem; rather, it may be necessary to provide explicit instruction that helps students develop their ability to create visual representations for problem solving (Van Garderen et al., 2013). Further, when creating visual representations of pictures, the goal should be to help students develop conceptual knowledge that will lead them to link their representations to the information in the problems and become more effective problem solvers (Xin & Jitendra, 1999).

In an earlier study, Van Garderen (2007) provided three students with math disabilities instruction in creating visual representations combined with strategy instruction for solving one- and two-step problems. Again, students in the study lacked knowledge of what a diagram was and how they could be used to solve a problem. Van Garderen (2007) found that students did not perform at mastery level after being taught only how to create a picture or diagram. Students also needed strategy instruction for solving problems to improve performance. It is not enough to instruct students to draw a picture when solving problems; they also need strategy instruction in solving problems to be successful (Van Garderen, 2007).

Students with learning disabilities in the area of mathematics can benefit from instruction that teaches them to visualize, represent, and think analytically about the problem (Abdullah et al., 2012). Teaching students how to create and use diagrams to solve problems should begin with a clear definition of what a diagram is, which is a visual representation (e.g., drawing, picture, chart, or table) that clearly show the parts of a word problem and how those parts are related to each other (van Garderen, 2006). A good diagram will help students to understand what information the problem is asking for, keep track of the information needed to answer the problem during the problem solving process, and evaluate the answer to ensure that it makes sense (van Garderen, 2006). Students should realize that a diagram is a tool that will help them reason through the problem solving process and arrive at a reasonable answer (van Garderen, 2006). When teaching students to create and use diagrams, the most effective instructional method is explicit instruction, which involves presenting concepts clearly and directly through modeling and practice (National Mathematics Advisory Panel, 2008; van Garderen, 2006).

An effective mathematics curriculum is one that simultaneously builds computational fluency, conceptual knowledge, and problem solving skills (National Mathematics Advisory Panel, 2008). Mathematics instruction focuses on three areas of knowledge: declarative knowledge (e.g., the math "facts," such as 4x5=20), procedural knowledge (e.g., knowing how to regroup when subtracting), and conceptual knowledge, which incorporates declarative and procedural knowledge and represents a deeper understanding of math concepts (Bottge, 2001). Creating a visual representation of the information contained in a word problem actively involves students in learning and improves conceptual and procedural knowledge (Abdullah et al., 2012).

Word Problem Solving Instruction

Two popular frameworks for teaching students to develop problem solving skills are schema-based instruction and cognitive strategy instruction.

Schema-Based Instruction.

Schema-based strategies promote conceptual knowledge by helping students understand the underlying structure of problems (Powell, 2011). Schema-based strategies often involve teaching students to identify the type of problem that is presented and then applying a "schema," or framework, to solve the problem (Powell, 2011). Further, schema-based instruction (SBI) teaches students to look beyond the surface of word problems and analyze relationships within the problem (Jitendra & Star, 2011). A schematic diagram will go beyond a simple pictorial representation that may include irrelevant details; schematic diagrams demonstrate how objects or quantities in the problem are related to each other (Jitendra & Star, 2011).

Jitendra et al. (1998) compared schema-based strategy instruction to traditional instruction included in math textbooks in a study that included thirty-four elementary level students who had mild disabilities or were at-risk for mathematics failure. In their study, students were assigned to one of two groups. One group received traditional math instruction, while the other group received instruction in two phases.

In the first phase of the Jitendra et al. (1998) study, students were taught how to identify problem types (change, group, and compare type problems). Change type problems were defined as problems involving a beginning amount, a change involving addition or subtraction, and an ending amount. Group type problems were defined as problems in which smaller groups were combined (added) to form a larger group, or problems which started with a larger group that was reduced by having a quantity subtracted. Compare problems involved two quantities that were compared and solved using addition or subtraction (e.g., “how many more ducks than chickens”).

In the second phase of the Jitendra et al. (1998) study, students were taught how to design a strategy to solve the problem, select the correct operation, and solve the problem. Students in the schema-based treatment group showed more improvement in their ability to solve word problems involving change, groups, and comparing than students in the traditional instruction group in post-test, delayed post-test, and generalization phases (Jitendra et al., 1998). Two limitations noted in the study were that students were taught in a small group setting rather than in the regular classroom, and instruction was provided by researchers rather than teachers. Jitendra et al. (1998) recommended that instruction be delivered by teachers to provide continuity and follow through.

Jitendra and Star (2011) have promoted the use of schema-based strategy instruction rather than traditional instruction found in many textbooks. Traditional instruction often relies on key words (“in all” for add, “left” for subtraction) that can lead to errors, and it does not require students to discriminate among different problem types when problems within a lesson are all solved using the same basic procedure (Jitendra & Star, 2011). Jitendra and Star (2011) used schema-based instruction to help students understand and solve ratio and proportion problems. Their strategy involved teaching students the underlying structure of each problem type and then identifying or generating a schematic diagram that could be used to solve the problem (Jitendra & Star, 2011).

Xin, Jitendra, and Deatline-Buchman (2005) also compared the effects of schema-based instruction with general strategy instruction that is used in many math textbooks. Participants in their study included twenty-two students who had learning disabilities, emotional disabilities, or were at-risk for math failure. Students in the schema-based instruction group were first taught to identify the problem type or structure and to create a schematic diagram without being required to solve the problems. Problem types included multiplicative compare and proportion problems. Multiplicative compare problems included a referent quantity and a second quantity that was a part or a multiple of the first quantity (e.g., “Dave ate six jelly beans. George ate half as many jelly beans as Dave.”). Proportion problems were defined as ratio problems, pairs of numbers with four quantities, and involved “if…..then” statements (e.g., “if one page holds 12 photographs, then 4 pages holds 48 photographs”).

The second phase of the Xin et al. (2005) study included strategy instruction and solving the problems. During strategy instruction, students were taught to apply four steps: Read the problem for understanding, identify the problem type and represent the problem using a specific schematic diagram for the problem type identified, create an equation and solve the problem, and look back at the problem to check for accuracy.

During the pretest phase, all students lacked conceptual knowledge required to solve the problems, and many used all of the numbers in the problem to attempt to solve the problem. After instruction, students in the general strategy instruction group drew pictures to represent the problems, but they were not as efficient when larger numbers were found in the problems and tended to give up before reaching a solution. Students who received schema-based instruction demonstrated higher order thinking and were able to identify the problem type and solve the problems more successfully. A limitation noted in this study was that instruction occurred in a small group setting rather than in the regular class (Xin et al., 2005).

Xin and Zhang (2009) used the conceptual model-based problem strategy (COMPS) to teach word problem solving to three fourth- and fifth-grade students who had or were at risk for mathematics disabilities. COMPS differs from schema-based strategy instruction but still emphasizes conceptual understanding of structure of word problems. Their intervention focused on two problem types: Equal Groups (unit rate x number of units = product) and Multiplicative Compare (compared quantity = relation/multiplier x referent unit). Instruction included dialog to help students identify grammar and key elements to solve the problems and to discover patterns between similar problems. Students in the study demonstrated improvement after strategy instruction on criterion tests designed by researchers and on a standardized test (Xin & Zhang, 2009).

A common feature of the schema-based strategies is their use of schematic diagrams that represent the structure of the problems. Students were taught to identify the type of problem and then apply the appropriate schematic framework to solve the problem (Jitendra et al., 1998; Jitendra & Star, 2011; Xin et al., 2005; Xin & Zhang, 2009).

Cognitive Strategy Instruction.

Cognitive strategy instruction is based on behavioral and cognitive theory; its goal is to teach students the cognitive skills and processes that good problem solvers and strategic learners possess (Montague, 2008). Instruction features cognitive strategies such as visualization, metacognitive strategies such as self-questioning (Montague, 2008). Cognitive strategy instruction is effective for students with learning disabilities who are typically poor strategic learners and lack problem solving skills. As a result of their strategy deficits, they do not perform as well as their normally achieving peers on higher order thinking tasks. When students with learning disabilities choose a strategy that does not work for a particular task, they have difficulty abandoning that strategy and replacing it with another, more effective one, and they often lack the ability to generalize effective strategies to other problem situations. These students require explicit instruction that teaches them to choose and execute effective strategies for specific tasks (Montague, 2008).

When teaching students using cognitive strategy instruction, it is important for the teacher to explicitly model the strategy by thinking aloud through the steps (Montague & Dietz, 2009). Equally important is teaching meanings of words contained in word problems for students with language disabilities or delays (Mastropieri & Scruggs, 2013b).

Self-regulation strategies are another important component of cognitive strategy instruction (Montague, 2006). Students with learning disabilities often exhibit disorganization in their thinking and planning for problem solving, difficulty maintaining attention throughout the problem solving process, difficulty determining which information contained in the problem is important, and choosing an appropriate strategy for solving a problem (Montague, 2006). Self-regulation includes the ability to self-verbalize (i.e., telling oneself what to do), self-questioning, and self-evaluation (i.e., monitoring one's own performance). Students with learning disabilities often lack self-regulation , but through cognitive instruction, they learn to think and act like strategic learners (Montague, 2007). Teaching students to use self-regulation strategies helps them to become more independent learners (Montague, 2007). Self-monitoring checklists which list the steps to solve problems can assist students when solving complex math problems (Montague, 2007). As students become more proficient at self-regulation, they begin to feel more confident in their math abilities, which leads to increased motivation and perseverance (Montague, 2007)

SOLVE IT! is a research-based cognitive intervention that has been found to be effective for improving word problem skills in students with disabilities as well as in average achieving students (Krawec, Huang, Montague, Kressler, & de Alba, 2013; Mastropieri & Scruggs, 2013b; Montague, Enders, & Dietz, 2011). This approach involves scripted lessons and explicit instruction, and its emphasis is to teach students cognitive and metacognitive processes that help them become more strategic thinkers and problem solvers (Montague et al., 2011). A key component of *Solve It!* is teaching students to paraphrase the information contained in problems and to create visual schematic representations (Montague et al., 2011). Students learn to apply a series of steps (read the problem, paraphrase, visualize/create a representation, hypothesize, estimate, compute to find a solution, and check). After each step, students learn to apply self-questioning and thinking strategies (Say, Ask, Check (Montague et al., 2011).

Mnemonic Strategies

Mnemonic strategy instruction has been found to be effective with students with learning disabilities in various instructional settings and across curricular areas (Wolgemuth et al., 2008). Mnemonic strategies are procedures that help students take in information and retrieve it later when it is needed (Mastropieri & Scruggs, 1998). Through these strategies, students learn to connect new information with knowledge they already possess through visual and acoustic clues (Mastropieri & Scruggs, 1998; Mastropieri, Sweda, & Scruggs, 2000). Mnemonic strategies fall into three common categories: pegword, keyword, and letter strategies. Pegword strategies are used for remembering numbered or ordered information. Students learn to associate a number with a rhyming word (e.g., one-bun, two-shoe). Keyword strategies use familiar words that sound similar to the new words to be learned and sometimes use pictures to link the words. Letter strategies are used to remember steps or lists (Scruggs et al., 2010).

Although letter strategies are the most well-known mnemonic strategies, they are also the least studied (Wolgemuth et al., 2008). Examples of commonly used letter mnemonic strategies include the acronym HOMES, used to aid recall of the five great lakes (Huron, Ontario, Michigan, Erie, and Superior), and the acrostic “Please excuse my dear aunt Sarah” to aid recall of the orders of operation (parentheses, exponents, multiplication and division, addition and subtraction) (Scruggs et al., 2010). Each letter of the mnemonic stands for a step in the strategy. Acronyms are usually words formed from the first letter of each word in a list, while acrostics are phrases in which the first letter of each word stands for a key word in the list to be remembered (Mastropieri & Scruggs, 2013a; Scruggs et al., 2010). Unlike other instructional methods that simply teach students *what* to remember, mnemonic strategies also teach students *how* to remember (Mastropieri & Scruggs, 1998)

Mnemonic strategies are effective for students with disabilities as well as typically achieving students, though students with disabilities typically require more practice to master the steps (Mastropieri et al., 2000). Effective mnemonic strategy instruction includes explicit instructions for executing each step (Mastropieri & Scruggs, 2013a).

Mastropieri, Scruggs, and Levin (1985) used a combined keyword-pegword strategy to teach mineral hardness levels to two groups of students. The first group consisted of ninth-grade students with learning disabilities. The second group consisted of non-disabled students in the seventh grade. Participants were randomly assigned to one of three treatment groups: free study, questioning, and mnemonic instruction. Students in the mnemonic treatment group were first taught the pegwords for numbers ("one is bun, two is shoe," etc.). Next students were taught a keyword for each mineral to be learned. Finally students were taught the minerals and their hardness level using the keyword for the mineral and the pegword for its corresponding number. Students who received mnemonic instruction recalled more minerals and their hardness levels both on an immediate recall test and a delayed test twenty-four hours later (Mastropieri et al., 1985).

More recently, Fontana, Scruggs, and Mastropieri (2007) studied the effects of mnemonic strategy instruction with a group of 59 secondary students in four inclusive world history classes. In each class, the teacher used direct instruction methods that would typically be used in their classes to teach content material for one unit. A second unit was taught using keyword mnemonic strategies that used words that sounded like or rhymed with key content words, or that used a part of the word under study (*balance* of trade), both combined with an illustration. For example, to teach the term *anarchist*, students were shown a picture of ants pushing over the capital building. Students in two classes received mnemonic instruction for the first unit and direct instruction for unit two, while students in the other two classes received direct instruction for unit one and mnemonic instruction for unit two. Both classes obtained higher scores on tests of information they learned through mnemonic strategy instruction. In addition, students exhibited improved time on task during the mnemonic strategy intervention (Fontana et al., 2007).

Mnemonic Strategies in Mathematics

One example of a mnemonic strategy that has been found to be effective in the area of mathematics is the pegword strategy, which associates numbers and rhyming words (e.g., two-shoe, 30-dirty) (Scruggs et al., 2010). Zisimopoulos (2010) used the pegword strategy to teach 28 multiplication facts to two students with moderate intellectual disabilities. The intervention in this study paired pegword multiplication facts with pictures. For example, the fact “4x8=32” was accompanied by a picture of a dog carrying a shoe and wearing a clothespin on his nose; students learned to associate the picture (a dog fetching a “dirty shoe,” which sounds like 32) with the multiplication fact. Both students were able to complete tests on the 28 multiplication facts with at least 90% accuracy (Zisimopoulos, 2010).

The LAP Fraction strategy is a mnemonic strategy that has been used to teach students to add and subtract fractions (Test & Ellis, 2005). Six middle school students in a special education classroom were taught the steps for adding and subtracting fractions using the LAP mnemonic: L- Look at the sign and denominator; A-Ask “Will the smaller denominator divide evenly into the larger denominator?”; P-Pick a fraction type. Each step included additional steps to use to work through the process of adding and subtracting fractions with like and unlike denominators. Five of the six students were able to learn the steps contained in the mnemonic strategy and to apply the strategy steps to successfully solve problems involving addition and subtraction of fractions. In addition, students demonstrated maintenance of the skill six weeks after the intervention ended (Test & Ellis, 2005).

Mnemonic strategy instruction has been used in conjunction with schema-based instruction to help students recall the steps to use to solve problems. Xin and Zhang (2009) used the DOTS strategy with their conceptual model-based problem solving approach when teaching problem solving skills to fourth- and fifth-grade students. DOTS is an acronym used to remind students of the steps required to solve word problems: Detect the problem type, Organize the information into the appropriate diagram, Transform the information in the diagram into an equation, and Solve the problem. The DOTS steps were presented as a checklist to which students could refer as they worked through the problems (Xin & Zhang, 2009).

PIES Strategy

The PIES strategy (Heater et al., 2012) uses a letter mnemonic strategy to teach students a series of steps when solving word problems. The acronym PIES is used to remind students to draw a Picture to represent the problem, identify important Information and key words from the problem and write them next to the picture, identify the correct Equation to represent the problem, and Solve the equation to answer the question. Students are awarded points for their work at each step of the procedure, which may encourage them to persist in solving the problem and to continue using the strategy even when their final answers are incorrect (Heater et al., 2012). It has been successfully used with students in an inclusive high school physics class and with high school students in self-contained science classes; students who learned the strategy in these classes also demonstrated transfer of the knowledge by using it in their math classes (Heater et al., 2012).

PIES employs a cognitive approach by applying a mnemonic strategy to aid students in recalling the steps required to solve word problems, in addition to requiring students to create a visual representation to organize the information contained in the problem. It also uses a strategy similar to schematic instruction by providing a list of equations from which students must choose, rather than providing a schematic diagram for students to plug in the information found in the problem. In addition, students are encouraged to be persistent in their attempts at solving the problem by being awarded points for each completed step toward finding a final solution. Thus, the PIES strategy combines evidence-based practices from cognitive (Krawec et al., 2013; Mastropieri & Scruggs, 2013b; Montague, 2008; Montague & Dietz, 2009; Montague et al., 2011) and schematic (Jitendra et al., 1998; Jitendra & Star, 2011; Xin & Jitendra, 1999; Xin et al., 2005; Xin & Zhang, 2009) instruction, creating a representation (Abdullah et al., 2012; van Garderen, 2006, 2007; Van Garderen et al., 2013; Woodward et al., 2012; Xin & Jitendra, 1999), and incremental reinforcement (Alter, 2012) as a strategy for improving problem solving.

Statement of the Hypothesis

Solving word problems is a difficult skill for students who have disabilities in math, but with effective strategy instruction, their performance can be improved. The PIES strategy is a systematic approach to teaching word problem solving that combines a mnemonic strategy for recalling the steps to complete the problem and generation of pictures that represent relevant information in the problem with a system that reinforces completion of the steps toward finding the solution. It has been successfully used with secondary students in science classes. The purpose of the current study is to investigate the effectiveness of the PIES strategy when teaching word problem solving to middle school students of average ability and those with disabilities in math in inclusive math classes. The hypothesis of this study is that students in inclusive middle school mathematics classes who learn to use the PIES mnemonic strategy will demonstrate improvement from pretest to posttest measures of word problem solving performance.

Chapter 3: Methods

The PIES word problem strategy has been used in high school science classes to assist students in solving word problems, with evidence suggesting its effectiveness when used by the same students in their algebra classes (Heater et al., 2012). However, the strategy had never been tested with middle school students in inclusive or self-contained mathematics classes. The purpose of the current study was to determine the effectiveness of the PIES strategy in improving the problem solving skills of middle school students in inclusive and self-contained mathematics classes.

Research Question

The current study attempted to answer the following question: Will students in inclusive and self-contained middle school mathematics classes who are taught the PIES word problem solving strategy demonstrate improvement from pretest to posttest measures of word problem-solving performance?

Research Design

Setting and Participants.

Participants for this research project were middle school students in inclusive and self-contained mathematics classes in a rural school district in a mid-Atlantic state. The middle school has approximately 725 students in grades six, seven, and eight. Students at the school are primarily middle to upper-middle class with the following populations: 12% Special Education, 20% Economically Disadvantaged, 2% ELL, and 12% Gifted students.

The school operates on a modified block schedule, with all mathematics and language arts courses being taught in 95-minute blocks, five days a week, for the entire school year.

History and Science classes are taught in 95-minute blocks, five days a week, for one semester each.

Three teachers and their classes participated in the study, for a total of 127 students. Of those students, 41 were identified as students with disabilities (SWD). A total of 109 students' scores were included in the data for this study, as three students moved from the district and 15 students were absent on the day the pretest was administered. See Table 1 for participants.

Table 1

Participants

Grade	Female	Male	Total	SWD
6	29	39	68	21
7	17	24	41	13

One teacher taught a self-contained special education math class with students in grades six and seven. Her class consisted of 12 students with disabilities (LD, OHI, and ED), 10 in sixth grade and two in seventh grade. Nine of her students, seven in sixth grade and two in seventh grade, participated in the study.

The second teacher taught three sixth grade math classes, two of which were co-taught with special education teachers and included students with disabilities. The researcher was the co-teacher in one of her classes. Her third class included one student with learning disabilities. There were a total of 39 participants in the sixth grade inclusive math classes, 14 of whom were identified as students with disabilities.

The third teacher taught two seventh grade math classes, both of which included students with disabilities. One class was co-taught with the researcher, who is a special education teacher, while the other class received assistance from a special education instructional assistant.

A total of 46 seventh grade students were in both classes. Thirteen of the 15 of the students who were identified as students with disabilities participated in the study.

Teachers were selected based on the fact that their classes included students with disabilities. Teachers who participated in the study received training from the researcher for using and providing instruction with the PIES strategy.

Procedures.

Pretest/Posttest. A researcher-created pretest which consisted of ten grade-level word problems, based on grade-level state standards, was administered prior to instruction for the PIES strategy. Separate pretest measures were created for the sixth grade classes and the seventh grade classes and were based on state standards that had previously been taught during the year in their math classes. None of the pretest word problems had been used in previous lessons. At the end of instruction, the pretest questions were rearranged and administered as a posttest. The pretest and posttest for each grade level are included in Appendices A through D.

The pretest for each grade level was administered in one class period. Students who did not finish within one class period were given additional time in class the next day. Students enrolled in study hall used that class period to finish if necessary.

PIES Instruction Procedures. After the pretest was administered, students received instruction for using the PIES strategy. On the first day of instruction, students viewed a Power Point presentation which explained the rationale for the strategy and how it would be used. Students learned that each letter stood for a step in the strategy: P – Picture; I – Information; E – Equation; S – Solution. Additional steps were included to remind students to write the *unit* for the answer, and to *circle* the final answer.

Students were taught to use the strategy as follows:

P – Draw a picture. Students were taught that their pictures did not have to be "artwork," but that they should represent what was happening in the problem. For example, a stick figure for a person was acceptable, or a box with the number written inside and labeled with what it stood for was acceptable. Students were taught that the idea was to simply get started with the problem. The purpose of the picture was to get a visual representation of what was happening in the problem.

I – Information. Students learned to pull out the important information from the problem and to write it next to the picture. Information could be the numbers in the problem or important key words that would help them solve the problem. If irrelevant information was included in the problem, students could mark it out as unnecessary for solving the problem.

E – Equation. At this step, students were taught to identify the operation needed to solve the problem and to write the mathematical equation they would use to calculate the answer. If they knew a formula (such as "area = length x width"), they were encouraged to write the formula next to the picture.

S – Solution. At this stage, all the work had been completed and students were told to simply calculate and write the solution to the problem. Students were allowed to use a calculator to find the solutions. They were also told to reread the problem to determine whether the answer "made sense" and adequately answered the question. Two important parts of writing the solution were to include the units associated with the answer (e.g. feet, square feet, etc.), and then circling the final answer.

A unique feature of the PIES strategy is the awarding of points for each step of the strategy. Students learned that they would earn up to ten points per problem when they used the PIES strategy, awarded as follows: 2 points for the Picture, 2 points for writing Information next to the picture, 2 points for writing the correct equation, 2 points for calculating the correct solution, 1 point for writing the unit, 1 point for circling the final answer.

Each class participated in at least eight separate 20-minute practice sessions using the PIES strategy with problems provided by the researcher. All problems were based on grade-level state mathematics standards that had been previously taught. Students received a practice sheet with eight problems, printed four problems on each side of the sheet, with ample room to show work and draw their pictures. At the beginning of the practice session, the teacher presented an example problem on the interactive white board. The example problem would be completed as a class, with the teacher modeling appropriate use of the steps of the strategy. Next, students completed the first daily practice problem on their individual sheets, with teachers circulating around the room to provide guidance and assigning points for completing each step. After students completed the first practice problem, the teacher reviewed the problem on the board, allowing students to show their pictures and to explain how they completed the steps and formulated the equation and solutions to the problem. Finally, students completed the second practice problem independently and turned them in to the teacher to receive their points. The second problem would then be reviewed on the interactive white board.

Practice problems for sixth grade students covered the concepts of area and perimeter of rectangles, operations with fractions and decimals, and circumference and area of circles. Seventh grade problems targeted the concepts of operations with integers, two-step equations, and proportions.

After the initial eight practice sessions, teachers incorporated the PIES strategy within their daily lessons to practice current grade-level standards that were being taught. Additional practice sheets were provided, which students completed as independent practice. These activities were intended to provide students the opportunity to apply the PIES strategy to new material.

A feature of the PIES strategy that encourages students who are reluctant to attempt word problems is the awarding of points for completing each step of the strategy. During practice sessions, students received up to ten points for each problem:

- Draw a picture = 2 points for a picture that adequately represented the problem. Students received 1 point for attempting a picture or for a picture that did not completely represent the problem, or 0 points for no picture.
- Write the information needed to solve the problem = 2 points for writing information needed to solve the problem next to the picture. Students received 1 point if they wrote some but not all of the key information, or 0 points for including no information.
- Write the correct equation to solve the problem = 2 points for writing the correct equation. Students received 1 point for writing an equation that was incorrect or partially correct, or 0 points for writing no equation.
- Calculate the correct solution = 2 points for correct solution, 0 points for incorrect solution.
- Write the unit associated with the solution = 1 point for writing the correct unit, 0 points if no unit was included.
- Circle the final answer = 1 point for circling the final answer, 0 points if the answer was not circled.

Students were allowed to use a calculator for all problems during the pretest, practice sessions, and on the posttest.

The posttest was administered over a period of three to four days. Sixth grade students were given 55 minutes on the first day to complete the posttest. Those who did not finish worked on them during independent practice time over the next two days. Seventh grade students were preparing for a unit test and a formative assessment, both of which were administered during the week the posttest was planned. They were given twenty to thirty minutes per day for five days to complete their posttests.

Data Collection

The dependent variable in this study was students' scores on a ten-question posttest which was administered five weeks after the strategy was introduced. The pretest was scored by the researcher by counting the number of problems correctly answered by each student. The posttest was scored by the researcher in the same way. Pretest and posttest means for each grade level were then compared using a paired sample t-Test to determine whether there was a significant difference in students' ability to solve word problems.

Chapter 4: Data Analysis

Pretests were administered in each class during one class period (see Appendix A for the sixth grade pretest and Appendix B for the seventh grade pretest). The pretest consisted of ten grade-level word problems which were based on concepts the students had already been taught during the school year.

Pretest data were entered into an Excel spreadsheet in which student names were listed in the first column. Each pretest item number was listed across the top of the spreadsheet, and for each student, the number "1" was placed in the item cell for a correct answer, and a "0" was placed for an incorrect answer. The final column returned the number of items each student answered correctly. These numbers were transferred to a separate spreadsheet which calculated the average number of correct answers for each grade level. A similar procedure was used to record posttest data.

Data for All Students.

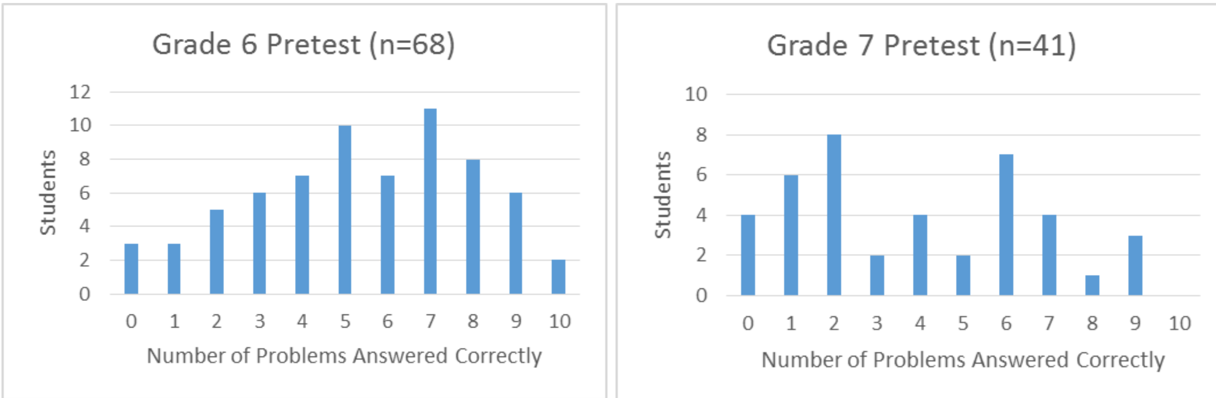
As shown in Table 2, the mean pretest score for sixth grade students (n=61) was 5.38. Scores ranged from 0 correct answers (three students) to 10 correct answers (two students), with a median score of 5.5. The mean score for seventh grade students (n=41) was 3.88. Scores for this group ranged from 0 correct answers (4 students) to 9 correct answers (three students), with a median core of 4. See Figure 4.1 for the distribution of pretest scores.

Table 2

Mean Pretest Scores for All Students

Grade	Participants (n)	Pretest Mean	Standard Deviation	Standard Error	Median	Mode	Range
6	68	5.38	2.61	0.32	5.5	7	10
7	41	3.88	2.78	0.43	4	2	9

Figure 4.1. Distribution of Pretest Scores for All Students.



Posttests were administered after five weeks of instruction and practice sessions using the PIES strategy (see Appendix C and D for posttests for each grade, and Appendix E and F for practice problems). Students who were absent from school when the pretest was administered were given the posttest, but their scores were not included in the research data.

The posttests were not administered in one class period, due to several factors. First, the amount of time it took students to complete the problems on the posttest was longer than the time it took for the pretest, possibly because they were applying the steps of the PIES strategy. Second, the school district had missed several days of school due to inclement weather, so teachers were behind schedule on presenting new material that would be assessed on the spring formative assessment and could not devote an entire class period for posttest administration. Finally, the seventh grade classes had a regular unit test scheduled for the week prior to the PIES posttest that had to be moved to the Monday on which the posttest was planned.

In the sixth grade classes, the teacher made time at the beginning of class for students to finish their pretests, and they were able to finish them in three separate class sessions. Because seventh grade students had a unit test and a formative test during the week the posttest was planned, they were only allotted twenty-to-thirty minutes a day to complete the posttest. For several seventh grade students, it took five days to complete the posttest.

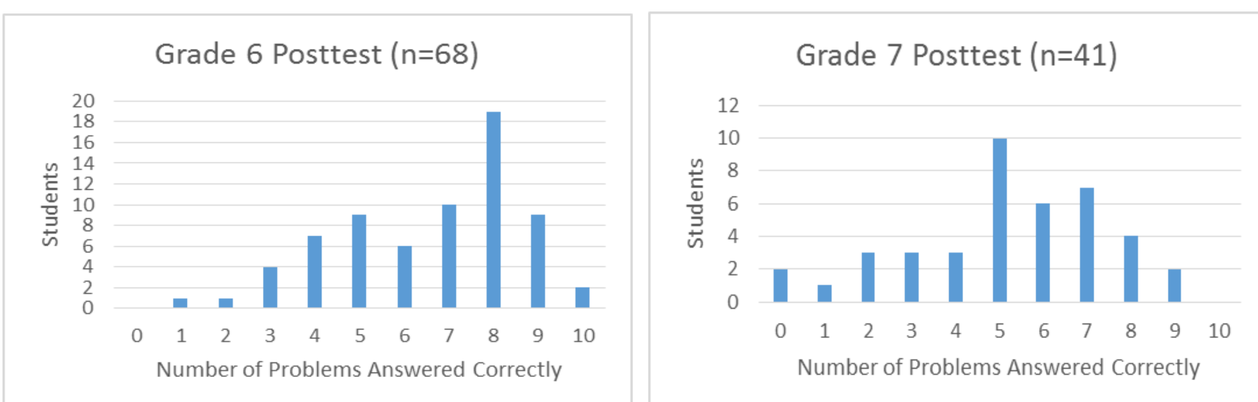
As shown in Table 3, the mean posttest score for sixth grade students (n=68) was 6.57. Posttest scores for sixth grade students ranged from 1 correct answer (one student) to 10 correct answers (two students), with a median score of 7. The mean posttest score for seventh grade students (n=41) was 5.20. Scores ranged from 0 correct answers (two students) to 9 correct answers (two students). See Figure 4.2 for the distribution of posttest scores.

Table 3

Mean Posttest Scores for All Students

Grade	Participants (n)	Posttest Mean	Standard Deviation	Standard Error	Median	Mode	Range
6	68	6.57	2.08	0.25	7	8	9
7	41	5.20	2.28	0.36	5	5	9

Figure 4.2. Distribution of Posttest Scores for All Students.



Both groups showed improvement from pretest to posttest. A paired sample t-test was performed to determine whether there was a statistically significant difference between pretest and posttest means.

As shown in Table 4, among sixth grade participants in the study, there was a significant difference between pretest and posttest scores (t (68) = 4.944, p<.001). Similarly, there was a significant difference between pretest and posttest mean scores for seventh graders (t (41) = 3.861, p<.001). Therefore, the data support the hypothesis, which was that students in inclusive middle school mathematics classes who learn to use the PIES mnemonic word problem strategy will demonstrate improvement from pretest to posttest measures of word problem solving performance.

Table 4

Comparison of Means and Paired Sample t-Test Results – All Students

Grade	Participants (n)	Pretest Mean	Posttest Mean	t Stat	t Critical two-tail	P(T<=t) two-tail
6	68	5.38	6.57	4.944	1.996	0.0000
7	41	3.88	5.20	3.861	2.021	0.0002

Data for Students with Disabilities (SWD)

Separate data analysis, identical to analysis for all participants, was conducted for participating students with disabilities to determine whether the same results would be observed for this subgroup.

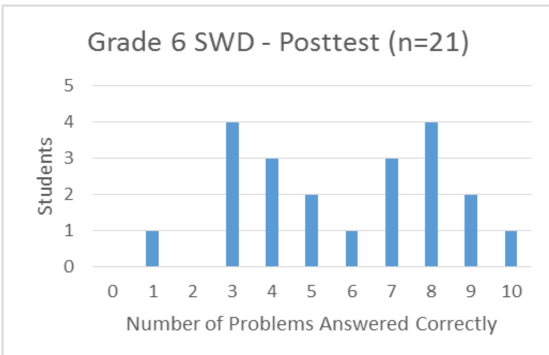
As shown in Table 5, the pretest mean score for sixth grade SWD (n=21) was 3.95. Scores for this group ranged from 0 correct answers (two students) to 8 correct answers (one student), with a median score of 4. The mean score for seventh grade SWD (n=13) was 2.54. Scores ranged from 0 correct answers (three students) to 7 correct answers (two students), with a median score of 2. The distribution of pretest scores for SWD is shown in Figure 4.3.

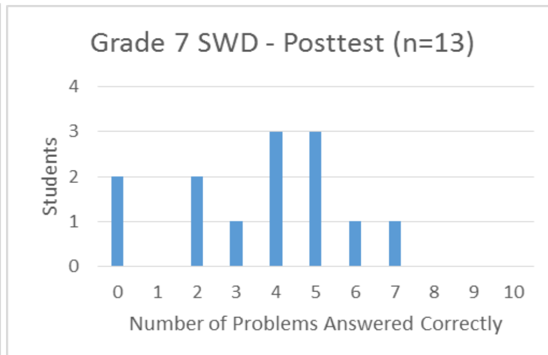
Table 5

Mean Pretest Scores - SWD

Grade	Participants (n)	Pretest Mean	Standard Deviation	Standard Error	Median	Mode	Range
6	21	3.95	2.45	0.54	4	3	8
7	13	2.54	2.53	0.70	2	2	7

Figure 4.3. Distribution of Pretest Scores – SWD.





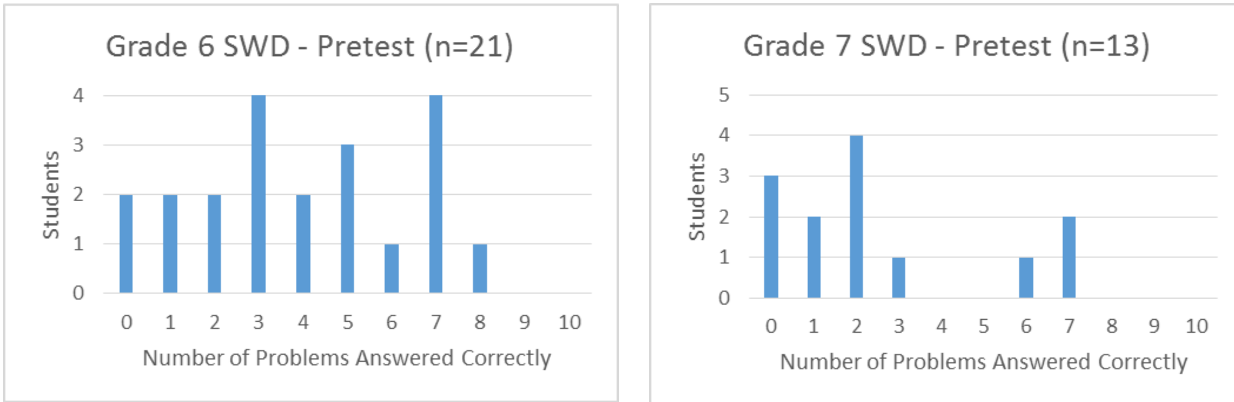
As shown in Table 6, the posttest mean score for sixth grade SWD (n=21) was 5.81, with a median score of 6. Scores ranged from 1 correct answer (one student) to 10 correct answers (one student). The mean posttest score for seventh grade SWD was 3.62, with a median score of 4. Scores ranged from 0 correct answers (two students) to 7 correct answers (one student). The distribution of posttest scores is shown in Figure 4.4.

Table 6

Mean Posttest Scores - SWD

Grade	Participants (n)	Posttest Mean	Standard Deviation	Standard Error	Median	Mode	Range
6	21	5.81	2.52	0.55	6	8	9
7	13	3.62	2.14	0.59	4	5	7

Figure 4.4. Distribution of Posttest Scores – SWD.



Again, both groups showed improvement from pretest to posttest. A paired sample t-test was performed to determine whether there was a statistically significant difference between pretest and posttest measures for this subgroup. As shown in Table 7, there was a significant different between pretest and posttest mean scores for sixth grade participants (t (21) = 4.468, p<.001). However, there was no significant difference between pretest and posttest mean scores for seventh grade students (t (13) = 1.783, p=0.999). Because of the mixed results, it is difficult to draw a conclusion about the effectiveness of the PIES strategy with students who have disabilities. These results are discussed in Chapter 5.

Table 7

Comparison of Means and Paired Sample t-Test Results – SWD

Grade	Participants (n)	Pretest Mean	Posttest Mean	t Stat	t Critical two-tail	P(T<=t) two-tail
6	21	3.95	5.81	4.4677	2.08596	0.0002
7	13	2.54	3.62	1.7828	2.17881	0.0999

Chapter 5: Discussion

The purpose of this study was to determine whether students who were taught to use the PIES mnemonic strategy would demonstrate improvement in their ability to solve mathematics word problems. This chapter presents: (a) interpretation of results, (b) limitations of the study, and (c) questions for future research.

Interpretation of Results

The hypothesis for this study was that students who are taught to use the PIES mnemonic strategy would demonstrate improvement in their ability to solve mathematics word problems, as evidenced by improvement from pretest to posttest scores. Both grade levels demonstrated significant improvement from pretest to posttest. However, when comparing the pretest and posttest means for students with disabilities, the results were mixed.

Sixth grade students with disabilities showed a significant improvement, while the seventh grade students did not. However, the number of participants with disabilities in this study was only 13, which may not have been enough to make a sound conclusion. Also, several factors, particularly during posttest administration, may have contributed to the smaller increase from pretest to posttest scores of seventh grade students with disabilities, as discussed later in this chapter.

Strategy Use. While many students had previously been told to “draw a picture” to help them solve word problems, few had been introduced to a specific strategy for using pictures and diagrams to solve word problems. For example, at the beginning of the school year during the sixth grade unit on calculating perimeter and area of rectangles and triangles, the teacher instructed students to draw a picture, label it with the given dimensions, and to indicate whether they were calculating perimeter by shading around the figure or area by shading inside the figure.

When the PIES strategy was introduced, many students, particularly in sixth grade classes, verbally expressed that drawing a picture and having a set of steps for solving word problems was helpful. On the day the strategy was introduced, a sixth grade girl made the comment that PIES made it easier for her to “see” what was being asked in the problem and to set up a strategy for solving it.

When the pretest was administered, students were told to use any strategy they knew to solve the problems. No instructions were given to draw a picture. As shown in Table 8, 48.5% of students in sixth grade attempted to draw a picture to solve the problem. Students who drew pictures used an average of one or two, and only one picture was associated with a correct answer. Only eight seventh grade students (19.5%) used pictures to assist in problem solving on the pretest. Again, the students who used pictures drew one or two, with only one of them being associated with a correct answer.

During the five weeks of practice sessions, students became more consistent in their use of pictures to solve problems. When the posttest was administered, students were instructed to use the PIES strategy to solve the problems. As shown in Table 8, 100% of sixth grade students and 92.7% of seventh grade students included pictures to solve problems. Sixth grade students used an average of nine pictures, with 5.9 of those pictures associated with correct answers. Seventh grade students used fewer pictures. Their posttests revealed an average of six to seven pictures with three to four being associated with correct answers.

Table 8

Strategy Use on Pretest and Posttest

Grade 6 (n=68)	Pretest	Posttest
Number of students who used pictures	33	68
Percent	48.5%	100%
Average number of pictures	1.8	9.1
Pictures associated with correct answers	1	5.9
Grade 7 (n=41)	Pretest	Posttest
Number of students who used pictures	8	38
Percent	19.5%	92.7%
Average number of pictures	1.5	6.6
Pictures associated with correct answers	1	3.9

Examination of pretests and posttests for students with disabilities showed similar results in regard to strategy use. As shown in Table 9, 10 sixth grade students (47.6%) used pictures on the pretest to solve their problems, drawing an average of two to three pictures, with one being associated with correct answers. Sixth grade students increased strategy use on the posttest, with 100% of students drawing a picture. These students drew an average of seven or eight pictures on the posttest, with four being associated with correct answers.

Only two seventh grade students with disabilities (15.4%) used pictures on the pretest. On the posttest, 11 of the 13 seventh grade students (84.6%) used pictures. Those students who used pictures drew between five and six pictures, with two being associated with correct answers.

Table 9

Strategy Use on Pretest and Posttest – Students with Disabilities (SWD)

Grade 6 (n=21)	Pretest	Posttest
Number of students who used pictures	10	21
Percent	47.6%	100%
Average number of pictures	2.3	7.8
Pictures associated with correct answers	1	4.4
Grade 7 (n=13)	Pretest	Posttest
Number of students who used pictures	2	11
Percent	15.4%	84.6%
Average number of pictures	1	5.5
Pictures associated with correct answers	1	2

All teachers in the study regularly told students in regular lessons throughout the year to "show their work" when solving any type of problem in math classes. During the study, students showed improvement in the quality of work included when solving word problems. The second step of the PIES strategy is to pull out important information from the problem, including numbers and key words (Heater et al., 2012). Examination of student work during the study and on the posttest revealed that students were putting more effort into identifying important information and rewriting it in the workspace, as well as writing the equation needed to solve the problem.

Unsolicited comments from teachers about the PIES strategy were positive. Participating teachers in the study found the PIES strategy to be easy to implement and perceived it to be an effective strategy for teaching problem solving. The sixth grade general education teacher made the decision to incorporate the PIES strategy into her regular curriculum for the remainder of the school year and in future years. The seventh grade teacher shared the strategy with a colleague, who implemented the practice activities in her own classroom and developed an additional set of problems to use in her daily focus activities. Although her class was not included in the study, she reported that her students enjoyed the strategy and were showing improvement in their ability to distinguish between the three main problem types that had been taught (two-step equations, operations with integers, and proportions).

Students also found the PIES strategy to be easy to remember and use. Throughout the study, students made comments that they enjoyed using the strategy and that they could tell it was helping them to become better at solving word problems. One seventh grade student made a comment during the posttest that he was now able to solve a problem that he hadn't been able to solve before.

Limitations

Although the results of this study suggest that the PIES mnemonic strategy is effective at improving the problem solving skills of students in middle school mathematics classes, there are several limitations to the study which are detailed below.

Pretest Administration. Due to time constraints, the pretest for this study was administered on only one day. As a result, students who were absent on the day the pretest was administered were not included in the pretest and posttest data, though they participated in the practice sessions and took the posttest. Ideally, the pretest should be administered over several days, allowing all students to participate and to be included in the data.

Practice Sessions. All students participated in five weeks of practice sessions using the PIES strategy. Practice problems included a checklist with the steps of the PIES strategy listed for their reference. Sixth grade students were exposed to at least four practice sessions with problems that did not list the steps when the general education teacher was teaching circumference and area of a circle. These students were instructed to use the PIES strategy even though the steps were not provided, thus possibly encouraging them to memorize the steps more effectively than the seventh grade students, who were not exposed to problems that did not include the steps. Teachers using the PIES strategy as a part of regular instruction should consider providing the steps while students are learning the strategy and then fading them to encourage students to memorize the steps.

It was noted on the posttest, on which strategy steps were not provided, that many students independently listed the steps and used them as a checklist to ensure they were completing each step. In general, students who wrote the steps on their posttest papers were more likely to create a drawing and identify the important information needed to solve the problems. In addition, one seventh grade student with disabilities was observed independently listing the PIES strategy steps to complete word problems in a remediation session with the school's instructional coach. In order for the strategy to become a natural part of solving word problems, students should learn to independently generate the list of steps prior to completing the problems.

It should be noted that this study was conducted during the winter when there were several unexpected school delays and closings. Prior to beginning the study, schools had been closed seven times, opened two hours late five times, and closed two hours early one time due to inclement weather. During the study, the school experienced three closings, two delayed openings, and one early dismissal due to inclement weather. Because of the number of school closings and delays, teachers were at times behind their instructional pacing schedules. These interruptions to the schedule often led to shortened classes, and as a result, shortened practice sessions.

Posttest Administration. Posttests in the sixth grade classes were administered in two sessions of approximately 50 minutes each. Students began the pretest and were allowed ample time to finish on the first day. Students who did not finish were provided time on the second day. Any student who was absent on the day the pretest was administered was provided the same amount of time on the following day.

In the seventh grade classes, the posttest administration dates fell during the time of the county-wide formative assessment. In addition, the seventh grade students were scheduled to take a unit test in their classes. The PIES posttest was administered in several shortened sessions of approximately 30 minutes or less over the course of one week. Some students worked on the posttest after they had finished the formative assessment and/or the unit test. This may not have been an ideal situation and may have affected their ability to fully concentrate and put their best effort into the posttest.

Questions for Future Research

This study was conducted with six intact classes in one middle school and consisted of a total of 109 students. The researcher chose not to pursue an experimental design with a control group because it was believed that the strategy would be effective, and the researcher did not want to exclude students who might have benefitted from it. For future research, an experimental design with a control group might reveal differences that this study could not address.

This study included students with identified disabilities (Specific Learning Disability, Emotional/Behavioral Disorders, and Other Health Impairment). The results for this segment of the total population of participants were mixed, with sixth grade students demonstrating significant improvement that was not found with seventh grade students. The sixth grade sample consisted of 21 students, while the seventh grade sample included only 13. The small sample size makes it difficult to generalize the results to a larger population. Future research should include a larger sample of students with disabilities to determine the effectiveness of the PIES strategy with this population.

The word problems in this study were all open-ended, meaning students were given a problem and had to work it out to calculate a solution. However, on the classroom tests, formative assessments, and statewide assessments that students routinely took, a formula sheet was provided for reference. In addition, most problems on these tests were written in multiple choice format, allowing students to choose the correct answer from a list of choices. When PIES was originally used in a classroom setting, students were provided with a list of equations from which to choose at the Equation step of the strategy (Heater et al., 2012). Future research should include formulas, equations, and/or answer choices from which students may choose. This addition would present problems in a way that would more closely match the format students will encounter on statewide assessments.

PIES was initially used in high school Physics classes (Heater et al., 2012), but this study focused on students in grades six and seven in inclusive mathematics classes. Students in sixth grade were consistently more receptive to using the PIES strategy. They quickly adopted it as a strategy they could use to solve difficult word problems, whereas the seventh grade students seemed to view it as a separate activity (i.e., PIES practice, rather than solving word problems).

Sixth grade students were more likely to use it even when they were not prompted to do so. Future research should focus on students in grade five, when word problems become more prevalent in the curriculum. In addition, future research should focus on the effect of using the PIES strategy when each new math concept is taught. Perhaps if students learn the strategy early in school and use it throughout math instruction, they will develop stronger problem solving skills.

Conclusion

The results of this study support the hypothesis that the PIES mnemonic strategy is an effective strategy for improving the word problem solving skills of middle school students in inclusive and self-contained mathematics classes. Students in this study, particularly the sixth grade students, quickly learned the steps and began using them to solve any type of word problem they encountered. Teachers expressed interest in incorporating the strategy as a part of their overall math curriculum because they viewed it as easy to implement and easy for the students to learn.

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APPENDICES

Appendix A. Grade 6 Pretest

Directions: Please solve each of the following word problems. You may use the space provided for work.

1. Roberto has a rectangular garden that is 13 feet long and 9 feet wide. If he extends each dimension by 2.5 feet, how much fencing will he need to enclose the entire garden?	**2.** In her shopping cart, Jody has 2 pounds of oranges at \$0.99 per pound, 3 cans of soup at \$1.19 per can, and 1 gallon of ice cream at \$3.79 per gallon. Which is the total cost of the items in her shopping cart?
3. Ryan ordered 3 pizzas for dinner. Each pizza was cut into 8 equal slices. If Ryan and his friends ate $\frac{3}{4}$ of all the slices of pizza, how much pizza was left over?	**4.** Hayden has \$20 to spend at the county fair. Admission to the fair is \$5.00 per person, and tickets for games are \$1.25 per ticket. If Hayden bought 8 tickets to play games, how much money did he have let over?

5. Jake has a board that is 15 feet long that he wants to cut into pieces that are $\frac{3}{5}$ of a foot long. How many smaller boards will Jake have?	**6.** At your birthday party, you had 7 8-slice pizzas. 41 slices were eaten. What fraction of pizza is left?
7. Mrs. Chan purchased 2 oranges at lunch every day for 9 days. The oranges cost \$0.49 each. How much did Mrs. Chan pay for all the oranges?	**8.** Karl earns \$8.50 per hour at his part-time job. Last week he worked 18 hours. This week he worked 14 hours. How much money did Karl earn during the two weeks?

9. A garden in the shape of a rectangle has length of 18 feet and a width of 12 feet. Covering the garden with fertilizer will cost \$1.15 per square foot. How much will it cost to fertilize the garden?	**10.** A farmer has $\mathbf{20\frac{2}{5}}$ acres of land that he is selling to 4 people. If the each person receives the same amount of land, how many acres will each person receive?

Appendix B. Grade 7 Pretest

Directions: Please solve each of the following word problems. You may use the space provided for work.

1. Jacob is selling T-shirts at a music festival. Yesterday, he sold 51 shirts and earned \$191.25. How many shirts must Jacob sell today and tomorrow to earn a total of \$536.35 for all 3 days?	2. Two cats and a dog together weigh 65 pounds. The dog weighs 47 pounds. Both cats weigh the same amount. How much does each cat weigh?
3. Jason and two friends ordered a large cheese pizza for \$8.00, 3 large drinks for \$0.98 each, and a salad for \$1.75. If they split these costs equally, how much should each person pay?	4. John and a friend hiked a mountain that is 5,872 feet high. They hiked 947 feet but had to go back down 373 feet. Then they hiked another 2, 645 feet. How far from the top of the mountain are they now?

5. You owe \$225 on your credit card. You make a \$55 payment and then purchase \$87 worth of clothes at the mall. What is the balance on your credit card now?	6. On Monday, 520 students went on a trip to the zoo. All 9 buses were filled and 7 students had to travel in cars. How many students were in each bus?
7. Together Beth and Joan earned \$30 mowing and trimming a yard. Since Beth provided all the equipment, Joan's share of the profits was \$6 less than Beth's share. How much did each girl earn?	8. Sally had \$245 to spend on 8 books. After buying them she had \$13. How much did each book cost?

9. A bakery needs to have 720 donuts for tomorrow's bake sale. They have already boxed half of this amount. The donuts are boxed 12 to a box. How many more boxes are needed to box the remaining amount of donuts?	10. It was a very freaky weather day. The temperature started out at 9°C in the morning and went to -13°C at noon. It stayed at that temperature for six hours and then rose 7°C. How far below the freezing point (0°C) was the temperature at 6 PM?

Appendix C. Grade 6 Posttest

Directions: Use PIES to solve each problem.

1. A garden in the shape of a rectangle has length of 18 feet and a width of 12 feet. Covering the garden with fertilizer will cost $1.15 per square foot. How much will it cost to fertilize the garden?	2. A farmer has $\mathbf{20\frac{2}{5}}$ acres of land that he is selling to 4 people. If the each person receives the same amount of land, how many acres will each person receive?
3. Lisa has to buy 16 gallons of gas that cost $2.38 per gallon. If she pays with a $50 dollar bill, how much change should she get back?	4. Mrs. Chan purchased 2 oranges at lunch every day for 9 days. The oranges cost $0.49 each. How much did Mrs. Chan pay for all the oranges?

5. Jake has a board that is 15 feet long that he wants to cut into pieces that are $\frac{3}{5}$ of a foot long. How many smaller boards will Jake have?	6. In her shopping cart, Jody has 2 pounds of oranges at \$0.99 per pound, 3 cans of soup at \$1.19 per can, and 1 gallon of ice cream at \$3.79 per gallon. How much did Jody spend at the grocery store?
7. Emily needs $4\frac{1}{4}$ yards of fabric to make a dress. About how many dresses can she make from 17 yards of fabric?	8. Roberto has a vegetable garden that is 13 feet long and 9 feet wide. If he extends each dimension by 2.5 feet, how much fencing will he need to enclose the entire garden?

9. Ryan ordered 3 pizzas for dinner. Each pizza was cut into 8 equal slices. If Ryan and his friends ate $\frac{3}{4}$ of all the slices of pizza, how much pizza was left over?	10. Hayden has $20 to spend at the county fair. Admission to the fair is $5.00 per person, and tickets for games are $1.25 per ticket. If Hayden bought 8 tickets to play games, how much money did he have let over?

Appendix D. Grade 7 Posttest

Directions: Use PIES to solve each problem.

1. Two cats and a dog together weigh 65 pounds. The dog weighs 47 pounds. Both cats weigh the same amount. How much does each cat weigh?	2. On Monday, 520 students went on a trip to the zoo. All 9 buses were filled and 7 students had to travel in cars. How many students were in each bus?
3. John and a friend hiked a mountain that is 5,872 feet high. They hiked 947 feet but had to go back down 373 feet. Then they hiked another 2, 645 feet. How far from the top of the mountain are they now?	4. You owe $225 on your credit card. You make a $55 payment and then purchase $87 worth of clothes at the mall. What is the balance on your credit card now?

5. Together Beth and Joan earned \$30 mowing and trimming a yard. Since Beth provided all the equipment, Joan's share of the profits was \$6 less than Beth's share. How much did each girl earn?	6. Sally had \$245 to spend on 8 books. After buying them she had \$13. How much did each book cost?
7. A bakery needs to have 720 donuts for tomorrow's bake sale. They have already boxed half of this amount. The donuts are boxed 12 to a box. How many more boxes are needed to box the remaining amount of donuts?	8. Cathy's Girl Scout troop was collecting cans to recycle. They collected 12 sacks of cans in 90 minutes. If they continue collecting at this same rate, how many sacks can they collect in 3 hours?

9. Jason and two friends ordered a large cheese pizza for $8.00, 3 large drinks for $0.98 each, and a salad for $1.75. They left a 15% tip. If they split these costs equally, how much should each person pay?	10. It was a very freaky weather day. The temperature started out at 9°C in the morning and went to -13°C at noon. It stayed at that temperature for six hours and then rose 7°C. How far below the freezing point (0°C) was the temperature at 6 PM?

Appendix E. Grade 6 Practice Problems

PIES - DAY 1

Shawn wants to purchase 3 CDs for \$14.99 each, a shirt for \$9.59, and a cap for \$11.99. How much money will Shawn spend? Score: P _____ I _____ E _____ S _____ U ____ C ____	You went shopping with \$20. You bought a notebook for \$3.70, 3 pencils for 30¢ each, and a drink, fries, and burger for \$2.20. How much money did you have left? Score: P _____ I _____ E _____ S _____ U ____ C ____

PIES - DAY 2

John needed to triple the ingredients in a recipe. If the original recipe required $3\frac{2}{3}$ cups of flour, what would be the new amount of flour? Write your answer as a fraction. Score: P _____ I _____ E _____ S _____ U ____ C ____	Mr. Frazier has 6 yards of fence wire. He wants to divide the wire into strips that are $\frac{3}{4}$ yard long. How many strips of wire will he be able to make? Score: P _____ I _____ E _____ S _____ U ____ C ____

PIES - DAY 3

Logan needs to order a cover for his swimming pool, which is 18 feet long and 12 ½ feet wide. How many square feet of pool cover does Logan need? Score: P _____ I _____ E _____ S _____ U ____ C ____	An auto mechanic tells John that labor is \$47.00 per hour. If it takes the mechanic 2 ½ hours to fix John's car, how much will the labor cost? Score: P _____ I _____ E _____ S _____ U ____ C ____

PIES - DAY 4

The dimensions of Andrea's bedroom are 8 feet by 10 feet. She is buying a rectangular rug that is $3\frac{3}{4}$ feet wide and $4\frac{1}{2}$ feet long. What is the total area that the rug will cover? Score: P _____ I _____ E _____ S _____ U ____ C ____	You have 15 yards of ribbon for your gift boxes. Each box gets the same amount of ribbon. How much ribbon will each of your 20 gift boxes get? Score: P _____ I _____ E _____ S _____ U ____ C ____

PIES - DAY 5

Lisa will use $1\frac{3}{4}$ cups of flour to make pancakes and $2\frac{1}{2}$ cups flour to make brownies. If she starts with 6 cups of flour, how much flour will be left after she makes the pancakes and brownies? Score: P ______ I ______ E ______ S ______ U ____ C ____	A popcorn machine can make $15\frac{1}{2}$ cups of popcorn in one minute. How many cups of popcorn can it make it 6 minutes? Score: P ______ I ______ E ______ S ______ U ____ C ____

PIES - DAY 6

Lisa has a wall that is 19.3 yards long. The wall is divided into 4 equal sections. What is the total length of three of these sections? Score: P ______ I ______ E ______ S ______ U ____ C ____	You have a 14-foot board and need to cut the board so that it is $11\frac{1}{4}$ feet long. How much do you have to cut off? Write your answer as a fraction. Score: P ______ I ______ E ______ S ______ U ____ C ____

PIES - DAY 7

Michael’s garden is 15.35 feet by 11.75 feet. If he buys 60 feet of fencing to go around his garden, how much will he have left over?

Score:

P ______

I ______

E ______

S ______

U ____

C ____

Mr. Chen has a backyard in the shape of a rectangle that has a perimeter of 128 feet. If the width of the backyard is 25 feet, what is the length?

Score:

P ______

I ______

E ______

S ______

U ____

C ____

PIES - DAY 8

Mrs. Smith wants to put silver tape around the rectangular bulletin board in her classroom. The bulletin board, which nearly covers 1 wall, is 3.45 meters high and 6.7 meters long. How much silver tape will Mrs. Smith need?

Score:

P ______

I ______

E ______

S ______

U ____

C ____

Donald's game room is 14 ft. by 16 ft. He wants to put a square game table in the room. The sides of the table are 5 feet long. How much area will be left in the room after he places the game table in it?

Score:

P ______

I ______

E ______

S ______

U ____

C ____

Appendix F. Grade 7 Practice Sessions

PIES - DAY 1

A monkey sits on a limb that is 25 feet above the ground. He swings up 10 feet, climbs up 6 feet more, and then jumps down 13 feet. How far off the ground is the monkey now? Score: P _____ I _____ E _____ S _____ U ____ C ____	The record low temperature of –23° F for Texas occurred on February 8, 1933. The record high temperature of 120° F occurred on August 12, 1936. What is the difference between these two temperatures? Score: P _____ I _____ E _____ S _____ U ____ C ____

PIES - DAY 2

Kate called her grandfather long- distance on Tuesday. The first 3 minutes cost $2, and each minute after that cost $0.50. How much did it cost if they talked for 15 minutes? Score: P _____ I _____ E _____ S _____ U ____ C ____	Ian went bowling at the Links Bowling Center. Shoe rental was $1.75 and games were $2.50 each. If he spent $9.25 on shoe rental and games, how many games did he bowl? Score: P _____ I _____ E _____ S _____ U ____ C ____

PIES - DAY 3

Ray needs to buy new socks. The socks he wants are advertised at 6 pairs for $16.50. Ray only wants to buy 2 pairs. How much will he have to pay, before tax? Score: P ______ I ______ E ______ S ______ U ____ C ____	A recipe calls for 2 cups of sugar and 3 tablespoons of butter. How many tablespoons of butter would be needed if the amount of sugar were increased to 10 cups? Score: P ______ I ______ E ______ S ______ U ____ C ____

PIES - DAY 4

This morning the temperature started out at 12°C and went to -5°C at noon. It stayed at that temperature for four hours and then rose 9°C. What was the temperature at 4:00 PM? Score: P ______ I ______ E ______ S ______ U ____ C ____	If you are 18 feet below sea level and walk to 15 feet above sea level, how far have you walked? Score: P ______ I ______ E ______ S ______ U ____ C ____

PIES - DAY 5

Alana is 61 inches tall and at 10:00 a.m. her shadow is 29 inches. If the shadow of the tree next to her is 76 inches, about how tall is the tree? Score: P _____ I _____ E _____ S _____ U ____ C ____	The world's highest elevation point is on Mt. Everest at an elevation of 29,028 feet. The world's lowest elevation point is the Dead Sea at –1,312 feet. What is the difference in these two elevations? Score: P _____ I _____ E _____ S _____ U ____ C ____

PIES - DAY 6

Jody used a photocopier to enlarge a rectangular image that was 4 inches wide and 6 inches long. If the enlarged image was 27 inches long, how wide was the enlarged image? Score: P _____ I _____ E _____ S _____ U ____ C ____	Adam earns $6.00 an hour working as a waiter. During his last shift at work, he earned his hourly wage plus $63 in tips. If he earned a total of $105, how many hours did he work? Score: P _____ I _____ E _____ S _____ U ____ C ____

PIES - DAY 7

Sara bought a soft drink for 3 dollars and 5 candy bars. She spent a total of 23 dollars. How much did each candy bar cost ? Score: P ______ I ______ E ______ S ______ U ____ C ____	The blueprint for Jessica's new room has a scale that states every $\frac{1}{4}$ inch is actually equal to 15 inches. If this blueprint shows the length of her new room to be $3\frac{1}{5}$ inches, what will be the actual length of her new room? Score: P ______ I ______ E ______ S ______ U ____ C ____

PIES - DAY 8

Oceanside Bike Rental Shop charges 13 dollars plus 9 dollars per hour for renting a bike. Nancy paid 49 dollars to rent a bike. How many hours did she pay to have the bike checked out ? Score: P ______ I ______ E ______ S ______ U ____ C ____	Jack caught a fish that weighs 924 grams. He knows that 3 ounces is approximately the same as 84 grams. How many ounces does Jack's fish weigh? Score: P ______ I ______ E ______ S ______ U ____ C ____