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The Effects of Schema-Based Instruction on Solving Mathematics Word Problems

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Abstract

The purpose of this study was to investigate the frequency with which students use math word problem strategies during and after schema-based instruction. It examines the extent to which students increase their ability to correctly solve word problems. It compares students' attitudes toward mathematics problem solving before and after schema-based instruction. The study was conducted in a resource class with seven second-grade students on individualized education programs (IEPs). A single-subject research design was used. The schema-based instruction was implemented by the special education teacher in a small group setting. Students showed an increase in attempted and correct strategy use during instruction. Three students increased their attempts of strategy use from pretest to posttest, but only one student used the strategy correctly on all attempts. The mean problem-solving accuracy increased from 22 percent to 34 percent from pretest to posttest. Students showed minimal change in their attitude toward math word problems.

Keywords

schema-based instruction, mathematics word problems, special education, elementary education

The Common Core Standards emphasize the importance of mathematical word problem solving as detailed in the Standards of Mathematical Practice. General mathematics instruction has not been an effective strategy in teaching students with or at risk for learning disabilities (Jitendra et al., 2007), so it is necessary to investigate more effective strategies such as modeling and schema-based instruction. Before selecting and evaluating instructional strategies, it is important to first understand the needs of students who struggle with mathematics problem solving.

Traditionally, students with learning disabilities have been classified as having a disability in reading, mathematics, or both. More recent research suggests there could be differences between students who struggle with computation and those who struggle with math word problems. Because there are a variety of reasons for students' difficulties with learning math (Jordan & Hanich, 2000), it is worthwhile to explore different interventions. Schema-based instruction has a number of components and thus the potential to address a variety of different issues, and research has shown that it may be effective for students with disabilities (Kingsdorf & Krawec, 2016). The purpose of this study was to examine the needs of students who struggle with mathematics word problems, investigate math problem-solving strategies, and determine whether schema-based instruction is an effective intervention for students struggling with math.

Students with Difficulties with Mathematics Problem Solving

Fuchs et al. (2008a) conducted a study to investigate the cognitive processes related to problem solving and computation. They analyzed relationships between cognitive variables and computation and problem-solving deficits. Multivariate analyses indicated that the predictor specific to problem solving difficulty is language, while those specific to computation are attentive behavior and processing speed. This suggests that difficulty with computation and problem solving could be two separate types of learning disabilities.

Tolar, Fuchs, Fletcher, Fuchs, and Hamlett (2016) investigated differences between students who were identified as having a learning disability based on low achievement, classified as below the tenth percentile, and those who had a discrepancy between IQ and achievement. After analyzing data from 813 3rd grade students, researchers found that students identified as LD based on achievement differed from their peers in arithmetic skills while those with an IQ and achievement discrepancy differed in word problem solving. Working memory was also lower for the latter group.

Jordan and Hanich (2000) analyzed the performance of students with varying academic achievement levels on mathematics tasks. They analyzed 76 2nd grade students' scores on the *Comprehensive Tests of Basic Skills* to categorize them into achievement groups. Scores at or below the 13th percentile were defined as indicating difficulties, and scores at or above the 40th percentile were defined as being normally achieving (NA). Students were categorized into the following groups: 0 math difficulties-only (MD), 10 MD and reading difficulties (RD), 9 RD-only, and 20 NA. Students were assessed on math facts, place value, story problems, and written calculation. Data were collected about students' strategy use during math facts and story problem tasks, for example, counting on fingers, verbal counting, automatic retrieval, etc. On word problems, both the RD-only and the NA groups performed significantly better than the MD-only and MD/RD groups. This suggests that RD alone is not an indicator for difficulty with math word problems. However, the MD-only group performed significantly better on word problems than the MD/RD group ($p < 0.5$). Students with MD/RD used finger counting and verbal counting far less accurately than their peers. When solving word problems, students in all groups used physical referents, with students with MD/RD using strategies least effectively.

A Variety of Problem-Solving Strategies

To meet the needs of students with learning disabilities, as well as others who perform below grade-level expectations, teachers use a variety of instructional strategies. Kingsdorf and Krawec (2016) outline the main instructional components of current math problem-solving research and identify the following to be among the key components: direct instruction or explicit instruction, problem type identification, and visual representation models. Some effective strategies may also combine two or more of these components.

Direct Instruction. Direct instruction as part of a mathematics word problem-solving strategy has been supported in a variety of contexts. Dynamic Strategic Math is a direct-instruction strategy that includes three phases of instruction: pre-teaching of vocabulary and concepts, a seven-step strategy, and practice with a partner (Kong & Orosco, 2016). In a study by Kong and Orosco (2016), eight 3rd grade students received 20 sessions of direct instruction over ten weeks. All students demonstrated an increase in word problem solving accuracy throughout the intervention as compared to their baseline. Swanson, Moran, Lussier, and Fung (2014) examined the benefits of direct instruction of generative strategy, in which students paraphrase word problems before solving them. In this study, 82 3rd grade students were randomly assigned to one of four conditions: restatement of the question, restatement of relevant information, restatement of the complete problem, and a control group. The results of a mixed ANCOVA on pretest and posttest scores indicated a significant treatment effect. Direct instruction is also a key component of the bar model strategy (Morin, Watson, Hester & Raver, 2017), the cognitive strategy (Zhu, 2015), and story grammar (Xin, Wiles & Lin, 2008), each of which is discussed in greater detail in a later section. Research suggests that each of these strategies yields success for struggling learners.

Problem-type identification. Evidence also supports teaching students to identify types of problems based on their structure. Story grammar is a type of cognitive strategy borrowed from reading comprehension instruction that teaches students to analyze the elements of the story problem and use story mapping to solve word problems (Xin et al., 2008). Xin et al. investigated the use of story grammar instruction with five 4th and 5th grade students with or at risk for math disabilities and found that all students demonstrated growth on both word problem solving assessments and algebra expressions probes. These findings suggest that the use of story grammar instruction and conceptual models promotes problem solving ability and prealgebra concepts.

Visual representation. Visual representations may also benefit students as they solve mathematics word problems. Cognitive strategy instruction teaches cognitive processes such as visualization and metacognitive processes including self-questioning (Zhu, 2015). Students receive instruction in drawing schematic representations of the problem. Zhu conducted a study comparing the use of cognitive strategy instruction to a control group receiving general word problem instruction. The study found that students in all ability groups in the treatment classes showed greater growth than their counterparts in the control classes. Yet students with disabilities in the control classes made little progress.

Morin et al. (2017) studied the effectiveness of bar models as visual representations with a group of six 3rd grade students with learning disabilities. Students demonstrated a mean gain of over 50% from pretest to posttest. Chen and Hu (2013) likewise evaluated the effectiveness of web-based concept mapping software on word problem instruction. The treatment group used a program based on concept maps while the control group used a program that taught in a more traditional model, similar to that in the textbook. Results revealed that the experimental group showed significant progress across students at all achievement levels while the control group showed only minimal progress. Gonsalves and Krawec (2014) focused on the potential benefits of using a number line as a visual model when they conducted single-subject design research with a 6th grade student with LD. Before treatment, the student did not use adequate or correct representations. She met mastery criteria on the visualizing strategy after five sessions and was then able to produce and label appropriate models. Problem solving accuracy reached 100% after mastery of the visualizing strategy.

Schema-Based Instruction

Schema-based instruction combines the key components identified by Kingsdorf and Krawec (2016) of explicit instruction, problem type identification, multiple exemplars, and visual representation models. This strategy has received considerable attention from researchers. In schema-based instruction, students receive direction instruction during which they learn to categorize math word problems based on the structure of the problem. After students have identified the problem type, they then use visual representations or number sentences to represent schemas (Powell, 2011).

Schema-based instruction versus general instruction. Jitendra et al. (2007) sought to determine if schema-based instruction is more beneficial than general instruction for word problem solving. The schema-based instruction included the use of diagrams. The general instruction included four strategies typically used for problem solving instruction: manipulatives, drawing a model, writing the equation, and analyzing data from graphs. Ninety-four 3rd grade students participated from a low-achieving school with high rates of poverty. The sample included, but was not limited to, students with learning disabilities. Three groups received schema-based instruction while three groups received general instruction.

Posttest results indicated that problem solving accuracy significantly increased among students in the schema-based instruction group as compared to the general instruction control group with an effect size of 0.52 on immediate post test results and 0.69 on a six-week maintenance measure (Jitendra et al., 2007). Immediate posttest results displayed no significant difference between schema-based instruction and general strategy instruction for students with learning disabilities, but participants in the schema-based instruction group performed significantly higher on the maintenance test as compared to the general strategy group. A notable limitation to this study is that only four participants were identified as having a learning disability.

A previous group design study by Jitendra et al. (1998) had similar results. This study compared students' performance on word problems after receiving either explicit schema-based instruction or traditional basal instruction using a sample of 34 elementary students in 2nd through 5th grade who scored below 60% on a math word-problem screening. This sample included students who had been identified as learning disabled, educationally intellectually impaired, or seriously emotionally disturbed. Both the schema group and the traditional instruction group showed progress, but the schema group demonstrated greater gains in word problem solving, increasing 26% as compared to 16% in the traditional group. Students with LD and educationally intellectual impairment in the schema group demonstrated greater growth than students with similar disabilities in the traditional group and maintained skills on the delayed posttest. There was no significant difference across conditions among students with emotional disorders and at-risk students.

Griffin and Jitendra (2009) conducted a similar study in which 60 3rd grade students were randomly assigned to a schema-based instruction condition or a general instruction condition. The type of instruction was similar to that of the previous study described above. One difference, however, was the timing of instruction. In this study, students received instruction for 100 minutes per day, one day per week. While all participants showed growth from pretest to posttest, there was no significant difference between the schema-based instruction group and the control group. The researchers surmise this could be due to the long duration of each lesson not being appropriate for elementary school students.

Visual diagramming. Swanson, Lussier, and Orosco (2013) hypothesized that many students with learning disabilities suffer more from verbal deficits than visual processing. If so, the visual schema-based instruction approach may be more effective than a more traditional approach that focuses on highlighting important portions of the text, known as general-heuristic strategies. Students were divided into four conditions: visual-schematic strategies, general-heuristic strategies, a combination of the two strategies, and a "business-as-usual" control group. In the visual-schematic strategy, students were taught to use two diagrams, one of which represented how parts make up a whole and another which represented how quantities are compared. In the general-heuristic strategy, students learned to complete a set of steps that included underlining the question, circling numbers, placing a square around keywords, crossing out irrelevant sentences, deciding which operation to use, and finally solving the problem.

When comparing posttest results of students with math difficulties, participants in the visual-schematic-only group outperformed the control group with a moderate effect size of 0.57 (Swanson et al., 2013). These results support the idea that visual-spatial working memory is a relative strength for students with learning disabilities, and this strategy draws on those strengths. Students in the combined approach condition also showed growth in problem-solving accuracy, but the improvement was less substantial than in the visual-schematic alone condition. This further indicates that a student's working memory strengths play a role in the type of instruction that is most effective.

A similar study by Swanson, Orosco, and Lussier (2014) compared the effectiveness visual and verbal cognitive strategies. Third-grade students were randomly assigned into one of five conditions: control group, verbal strategies, verbal and visual strategies, visual strategies only, and a materials-only group that received booklets with word problems, but no specific strategy instruction. Of the 193 participants, 73 were categorized as being at-risk for MD based on norm-referenced word-problem assessment scores below the 25th percentile. In the verbal strategy, students identified the question, numbers, key words, and irrelevant information within a word problem, and then they decided whether to add, subtract, or both. In the visual-only strategy, students were taught to use a diagram for parts of a whole and comparing. Students with MD in the verbal plus visual group and materials-only group showed significantly higher posttest performance than the control group. Students with lower working memory showed more growth as a result of the intervention than those with higher working memory. Students with MD did significantly better in the verbal-only and verbal plus visual conditions as compared to other conditions ($p < .05$).

Computer-mediated versus teacher mediated instruction. As the use of technology in the classroom increases, researchers have investigated the effects of computer-mediated schema-based instruction compared to teacher-mediated instruction. Leh and Jitendra (2013) implemented schema-based instruction in both a computer-mediated condition and a teacher-mediated condition with 25 3rd grade students who struggled with math problem solving. Post-test results indicated there was no significant difference between the two groups. This study implies that both teacher-mediated instruction and computer-mediated instruction with the appropriate components are effective means of instruction for math word problem solving.

Schema-based instruction as an intervention. Schema based instruction has been used in a variety of contexts, including tutoring for students in Tier 2 of the response to intervention (RTI) process (Fuchs et al., 2008b). The RTI process is designed to provide tiers of support for struggling students (Georgia Department of Education, 2011). In Tier 1, students receive quality instruction and progress monitoring to measure adequate growth. Students who do not demonstrate expected growth in Tier 1 are moved to Tier 2, in which they receive small group or individualized intense instruction in their deficit area. In Tier 3, a student support team (SST) is formed to provide interventions, track progress, and make decisions about further evaluation. If students do not make progress in Tier 3, they are typically evaluated for a learning disability. Tier 4 instruction is specialized and may be delivered in the ESOL or special education setting.

Fuchs et al. (2008b) sought to compare the effectiveness of tutoring provided as a Tier 2 intervention for math word problems using schema-broadening instruction to the effectiveness of general instruction. The researchers randomly assigned a sample of 35 students at risk for math and reading disabilities into a tutoring group and a control group. Students in the tutoring group showed significantly more growth than those in the control group. While the schema-broadening method yielded student progress, more information is needed to compare it to other instructional methods.

Transfer of schema-based strategies. When teaching students specific strategies, it is essential that they are able to apply those strategies to novel problems. Fuchs et al. (2006) investigated the transfer of problem solving skills from the types of problems used in instruction to real-world problem solving. The study compared traditional instruction and schema-broadening instruction with and without direct instruction in real-life problem-solving strategies. While the students in the schema-based instruction and schema-based instruction with real-life problems groups showed more growth than those in the control group on immediate transfer and near transfer measures, the far transfer measures yielded mixed results. The mixed results indicate that further research is needed to determine effective transfer strategies.

Research Questions

Previous studies have explored the use of schema-based instruction as a method for teaching mathematics word problem solving for students at risk for math disabilities and students with identified disabilities served in the inclusion setting. Other studies have suggested that Tier 2 interventions using schema-based instruction have yielded student progress. Less evidence exists to support its use as a Tier 4 intervention with young students in the resource setting. Additionally, more studies have focused primarily on students with or at risk for only math disabilities rather than on those who also exhibit reading difficulties or other health impairments such as ADD/ADHD. The present study investigates the use of schema-based instruction in the resource setting with second grade students with a variety of special education eligibilities. It explores the extent to which students increase the frequency with which they use math word problem strategies during and after schema-based instruction implementation. It also examines the extent to which students increase their ability to correctly solve word problems during and after schema-based instruction. Finally, this study compares students' attitudes toward mathematics problem solving before and after receiving schema-based instruction.

Method

Contextual Factors

The study was conducted in an affluent county in north Georgia. Based on 2016 census information, the median household income was $88,816, and the median home value was $267,300 (U.S. Census Bureau, 2016). Of the more than 221,000 residents, 92% had a high school education, and more than 45% had earned a bachelor's degree or higher. The public-school system had 44,673 students, according to the most recent information from 2016 (Forsyth County Schools, 2016). Of those students, 65.22% were white, 15.21% were Asian, 12.94% were Hispanic, 3.39% were African American, and 2.79% were of two or more races.

The elementary school where the study was conducted had 1,334 students, of which 70.84% were white, 3.82% were Asian, 19.72% were Hispanic, 2.32% were African American, and 2.85% were of two or more races. Within the school, 17.65% of students qualified for free or reduced lunch, and 12.82% of students were English Language Learners. The school also served students with special needs, with 8.62% of the total student population in interrelated special education, and 1.42% in self-contained autism classes.

The participants of the study were seven second-grade students, ages 7 to 9 years old, including four boys and three girls. All participants have individualized education plans (IEPs) which indicate that students receive small group instruction in the resource setting for mathematics. Students were served daily for seventy minutes for mathematics and seventy minutes for English language arts in the small group setting with one special education teacher. The intervention took place within the small group math class for approximately thirty minutes daily. Students were in the general education setting with one general education teacher for the remainder of the school day. Four students were Hispanic, one was African American, and two were Caucasian. The students qualified for special education services based on the eligibilities of specific learning disability, other health impairment, emotional behavior disorder, or significant developmental delay.

Materials

Instructional materials for the schema-based word problem solving strategy included scripted teacher lessons, student practice pages, and visual diagrams from the book *Solving Math Word Problems: Teaching Students with Learning Disabilities Using Schema-Based Instruction* (Jitendra, 2007). The scripted lesson plans were divided into five-lesson units for each of the three types of addition and subtraction word problems: change problems, group problems, and compare problems. Each of these are discussed in more detail in the procedures section. Those units were followed by a three-lesson unit reviewing one-step problems and a three-lesson unit about two-step problems. The teacher followed the script to insure fidelity, but she studied the script rather than reading word for word.

Three out of five lessons in each of the first three units from the Jitendra resource (2007) contained a student practice page with three to six word problems (see Appendix A for sample). The problems on the student practice page correspond with the problem type of each unit. In the beginning of each unit, a schema model was provided for the students, and as students gained familiarity with the strategy, no model was provided on the page. For these problems, students were expected to draw the model themselves.

Visual diagrams were provided for the teacher to model writing the correct information on the schema-based diagrams (see Appendix B). Students also had a copy of the diagrams to use during guided practice. They were available as a reference for students while completing the student page independently.

Measures

A baseline for problem-solving accuracy was determined by an eight-problem assessment created by Jitendra (2007). The assessment contained two group type problems, two change type problems, two compare type problems, and two two-step problems (see Appendix C). The teacher read word problems aloud for students. The second problem on the pretest and posttest measure was changed from the original assessment. This problem was written by the researcher and modeled after similar problems from the student practice pages. This was done to equally represent each problem type on the pretest and posttest. On the original assessment, this was a change type problem.

Three additional baseline assessments were given at the beginning of each unit (see Appendix D for example). These tests contained one problem of each type. No schema-based diagrams were provided on the assessments. Students had the choice of using the standard algorithm or computation strategy of their choice. The pretest and additional baseline measures were scored based on the percentage of problems solved correctly out of the total number of problems.

Ongoing assessment for problem-solving accuracy was completed using the student practice pages that accompany the lessons (Jitendra, 2007). As previously described, these student pages consisted of three to six word problems. During the first unit, all problems were change-type problems, the problems in the second unit were group-type problems, and the problems in the third unit were compare-type problems. The fourth unit contained all problem types, and the fifth unit contained two-step word problems. Schema-based diagrams were provided on the page at the beginning of each unit. Students were asked to draw their own model during the last lesson of each unit. The student pages were scored based on the percentage of problems the student solved correctly.

Additional baseline measures were administered after the completion of each unit. These measures were created by the researcher. The problems were modeled after those on the student practice pages provided in the Jitendra (2007) materials. Each baseline measure consisted of one change type problem, one group type problem, one compare type problem, and one two-step problem. The order of the problem types varied.

The problem-solving accuracy posttest, created by Jitendra (2007) is the same assessment as the pretest (see Appendix C). Due to the length of time between the pretest and posttest measures, test effect was unlikely. Testing procedures were consistent with those described for the pretest.

Transfer of students' problem-solving skills were measured by the end-of-unit assessment on word problems taken from the basal math series *enVisionMath 2.0* (Charles et al., 2017). This assessment contained ten second-grade word problems requiring addition or subtraction that are aligned to the Georgia Standards of Excellence (see Appendix E). The problems within this assessment represented the types of problems students are expected to do in the general education second grade class and are not phrased in the same format as those used for treatment instruction. The problems can still be classified into the problem types taught in schema-based instruction. The assessment contained one change problem, four compare problems, four two-step problems, and one problem, which presents an equation and asks the student to create and solve a story problem. All items were read aloud by the teacher, and students' IEP accommodations were followed.

Students' use of mathematics problem-solving strategies was measured by an item analysis of the pretest, student practice pages, and the posttest (Jitendra, 2007). Transfer of the use of strategies was measured by evaluating students' work on an end-of-unit assessment on word problems taken from the second-grade basal math series *enVisionMath 2.0* (Charles et al., 2017). The teacher used a checklist to record students' use of word problem solving strategies (see Appendix F).

To measure students' attitudes about mathematics word problem-solving, an adapted version of the Attitudes Toward Mathematics Inventory (Tapia, 1996a) was given before and after the implementation of schema-based instruction. The adapted inventory consisted of fifteen items with a five-point Likert Scale. Possible responses ranged from strongly agree to strongly disagree. The inventory was adapted to ask about mathematics word problem solving specifically, rather than mathematics in general. The items selected from the original inventory were all related to students' sense of security. These items have a reliability of 0.95 (Tapia, 1996b). The original inventory in its entirety has an alpha reliability coefficient of 0.97. The items were read aloud by the teacher. Students had the opportunity ask for clarification about statements. Picture cues were added to each answer choice to better meet the needs of young students (see Appendix G).

Procedures

For pretest and posttest, students were given a paper copy of the assessment and a pencil. Word problems were read aloud by the teacher, and students' IEP testing accommodations were followed. The same testing procedure was followed for the practice problems and the transfer test from the basal (Charles et al., 2017).

Prior to the implementation of the schema-based instruction, a baseline condition was established. For three consecutive days, students received traditional word problem instruction using materials provided by the basal math curriculum (Charles et al., 2017). The lessons began with a short instructional video, approximately 2 to 3 minutes long that modeled solving a word problem. Next, the teacher modeled a problem from the workbook on the interactive whiteboard. Then students followed along with the teacher to solve other problems from the workbook. At the conclusion of each lesson, a baseline assessment was administered. This control condition was repeated after each unit of the schema-based instruction intervention.

The mathematics word problem schema-based instruction was implemented by the special education teacher in the small group setting. Students received direct instruction for approximately 30 minutes per day, four to five days per week. It took approximately eight weeks to complete all of the lessons. The sessions consisted of direct instruction, guided practice, teacher feedback, and independent practice. The instruction focused on addition and subtraction word problems, as these align with second grade standards.

According to the schema-based instruction model, addition and subtraction word problems can be categorized as one of the following problem types: change problems, group problems, and compare problems (Jitendra, 2007). A change problem begins with one amount, then an increase or decrease occurs, and a new amount results. A group problem contains two smaller amounts that are combined to make one larger amount. A compare problem asks for a difference between two amounts (see Appendix H for examples). Instruction was divided into units: a five-lesson unit on change problems, a five-lesson unit on group problems, a five-lesson unit on compare problems, a three-lesson unit to review all problem types, and a three-lesson unit on two-step problems.

The instructional strategies were similar to those of other studies on schema-based instruction (Griffin & Jitendra, 2009; Jitendra, et al., 1998). Instruction for each problem type included two phases, problem schema and problem solution (Jitendra, 2007). The problem schema phase was taught in the first lesson of each unit. Students were presented with story situations in which all amounts were known and used a schema diagram to organize the information. For example, students represented a change problem story situation by placing the beginning amount, change amount, and ending amount in the correct area of the schema diagram.

In the problem solution phase, students were presented with problems with one unknown amount (Jitendra, 2007). The acronym FOPS was introduced to anchor the four-step problem solving process: Find the problem type, Organize the information in the problem using the diagram, Plan to solve the problem, Solve the problem. When presented with a problem, students were prompted to identify the problem type (change, group, or compare) and organize the given information into the appropriate schema diagram (see Appendix B for examples of schema diagrams). At the beginning of instruction, schema diagrams were provided. As students gained proficiency, they were prompted to create their own diagrams rather than having one provided. After the schema diagram was completed, students planned to solve by using the information in the diagram to write the appropriate equation to solve for the unknown amount. Finally, they calculated to find the solution.

Each lesson began with direct instruction, followed by guided practice (Jitendra, 2007). Students then had opportunities to practice with a partner and complete independent practice problems with the teacher providing feedback. The teacher collected data on students' use of the schema-based strategies and problem-solving accuracy during the independent practice portion of the lesson, using a checklist and the student practice page.

Results

Seven second-grade students participated in the study. Three of the seven students missed a large portion of the instruction or baseline condition due to absences from school. The data for these students were incomplete, and therefor were not analyzed. These students' data can be found in Appendix I. Of the four remaining students, two were identified as having a significant developmental delay, and two were identified has having a specific learning disability.

Frequency of Strategy Use

The study was designed to determine the differences in the frequency with which students used word problem solving strategies during and after schema-based instruction. Students' frequency of strategy use was measured by item analyses of the pretest, student practice pages, and posttest (Jitendra, 2007), as well as the baseline measures and the transfer assessment (Charles et al., 2017). Each item was analyzed for students' attempted use of schema-based strategies and their correct use of schema-based strategies.

On the pretest, no students attempted to use the schema-based strategy. On the posttest, three students increased their attempts of schema-based strategy use, with students one and seven attempting the strategy on all problems and student six attempting the strategy on fifty percent of problems. Student 4 did not attempt to use the schema-based strategy on the posttest. See Figure 1 below. The transfer test contained addition and subtraction problems that fit the problem types introduced during schema-based instruction. For three students, the frequency of strategy use on the transfer test was even less than on the posttest, with two students attempting the strategy on one to two problems. Interestingly, students one and seven, who attempted the strategy on all problems on the posttest, did not attempt the strategy on any problems on the transfer test. Conversely, student four, who did not attempt the strategy on any problems on the posttest, attempted it on two problems on the transfer test.

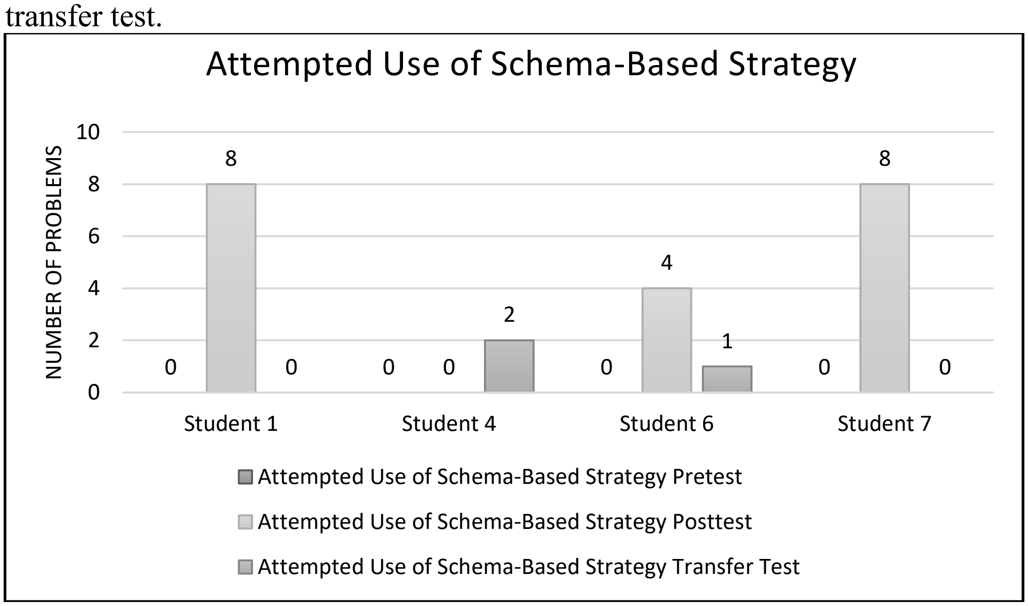


Figure 1: Students' attempted use of the schema-based strategy on pretest, posttest, and transfer test.

Students showed less growth on correct strategy use from pretest to posttest as compared to attempted strategy use. Student 1 used the schema-based strategy correctly one of eight attempts while student seven used the strategy correctly two of eight attempts. Student 6, however, used the strategy correctly four out of four attempts. See Figure 2 below. On the transfer test, only one student using the strategy correctly on one problem.

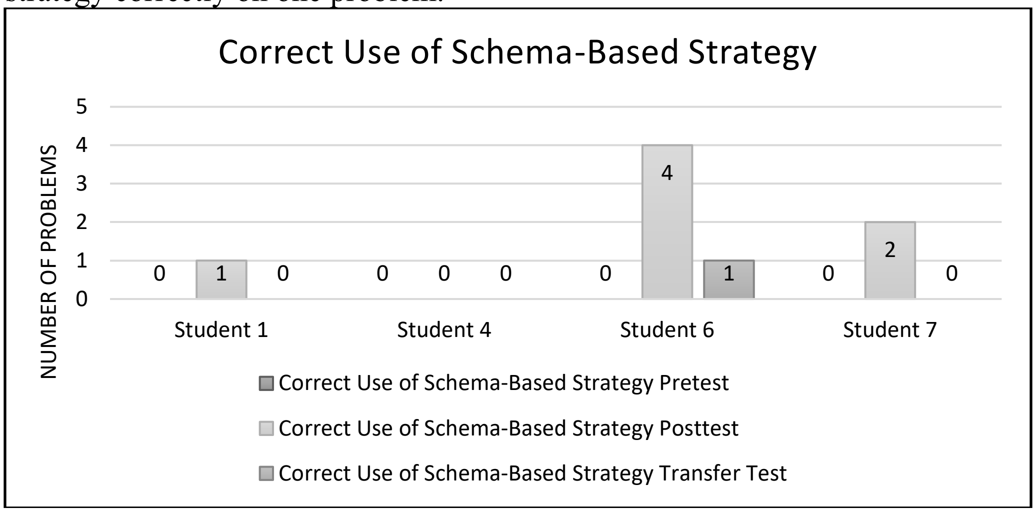


Figure 2: Students' correct use of schema-based strategy on pretest, posttest, and transfer test.

For the ongoing assessments, the number of problems on which students attempted and correctly used the schema-based strategy were tallied for each baseline period and each unit of intervention. See Figures 3 and 4. All students showed an increase in attempted and correct strategy use during instruction. Three students increased attempts of schema-based strategy use even on baseline measures after the initial unit of instruction, increasing attempts on each subsequent baseline measure. The number of problems on which students used the strategy correctly was less substantial and occurred only during instruction. The problems on which students wrote the correct equation to solve word problems were also tallied. Three students increased their use of correct equations. Student 1 and student six show a similar trend of correct equation use and correct schema-based strategy use.

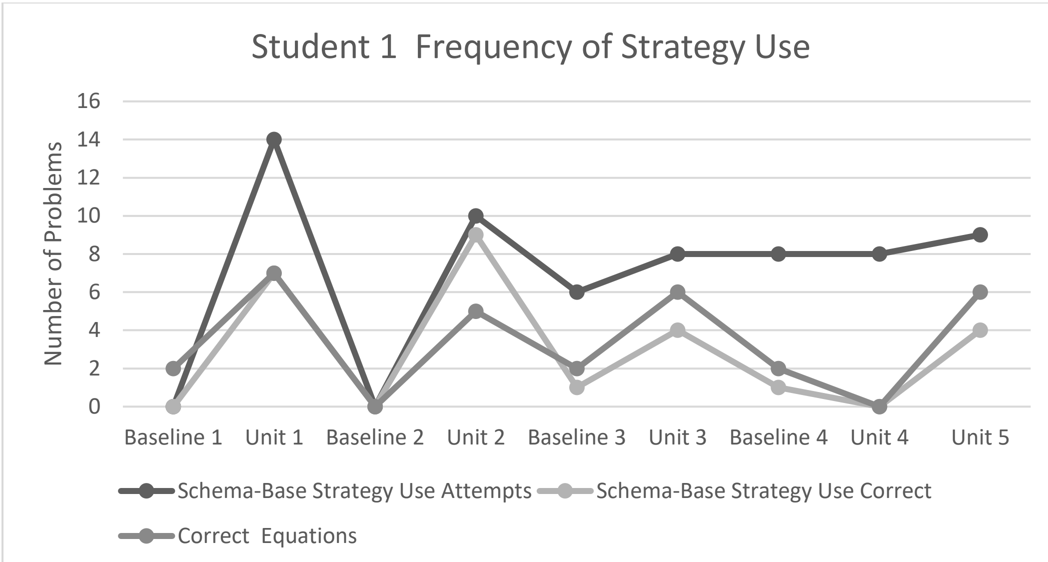
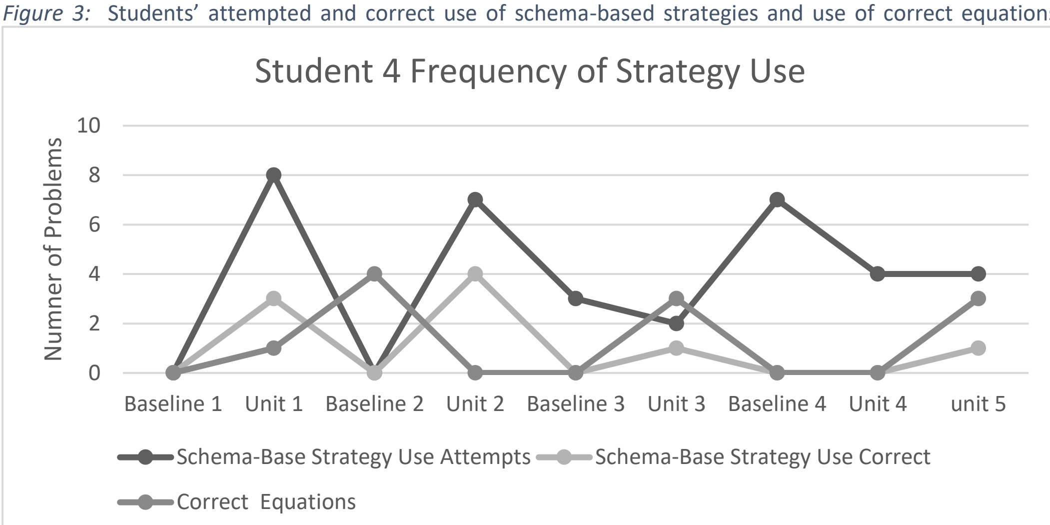


Figure 3: Students' attempted and correct use of schema-based strategies and use of correct equations



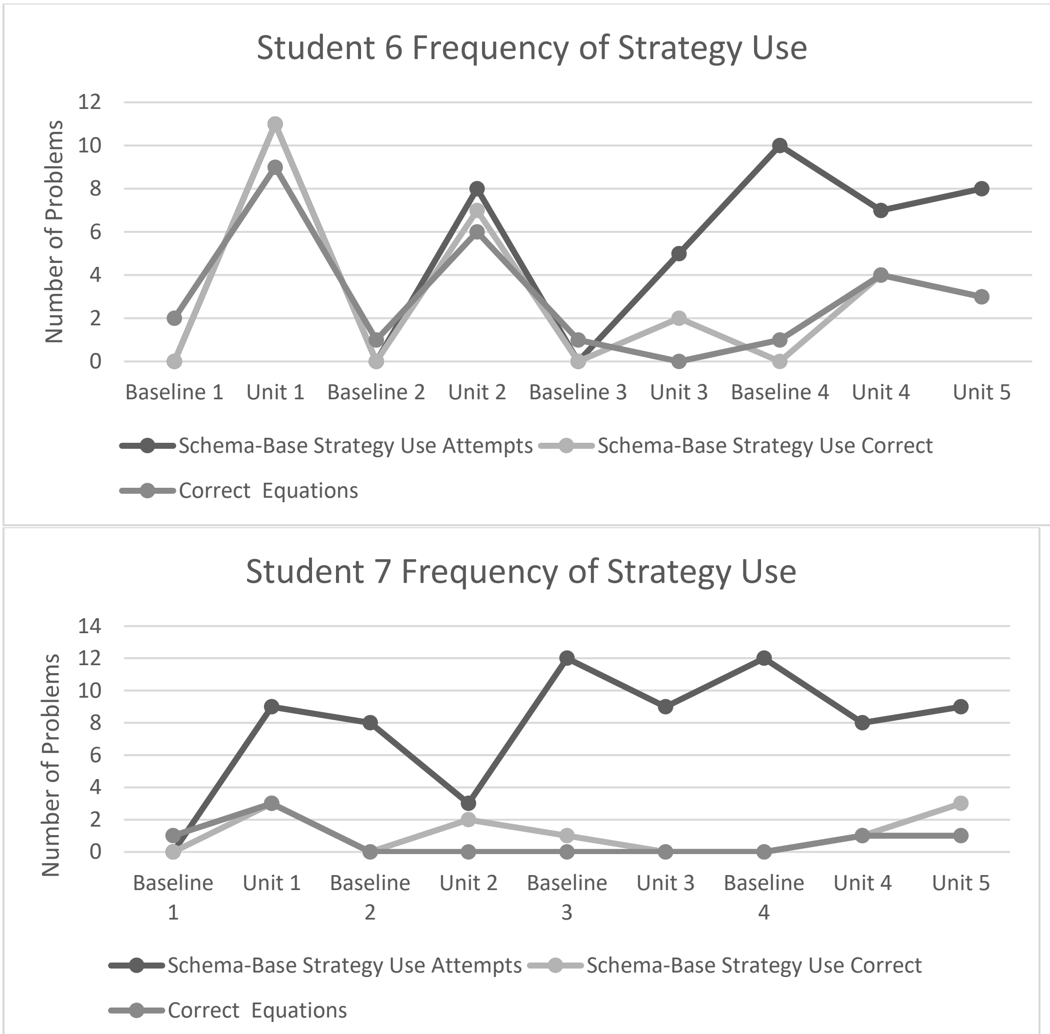


Figure 4: Students' attempted and correct use of schema-based strategies and use of correct equations.

Problem-Solving Accuracy

Another of the goals of the current study was to examine the extent to which students' ability to accurately solve mathematics word problems increased during and after schema-based instruction. Changes in students' word problem-solving accuracy after schema-based instruction were measured by a pretest and posttest (Jitendra, 2007). See Figure 5 for students' results. Based on these scores, two students increased their problem-solving accuracy. One student showed no change, and one student's score decreased. Of the four students whose data were analyzed, the average problem-solving accuracy increased from 22 percent on the pretest to 34 percent on the posttest.

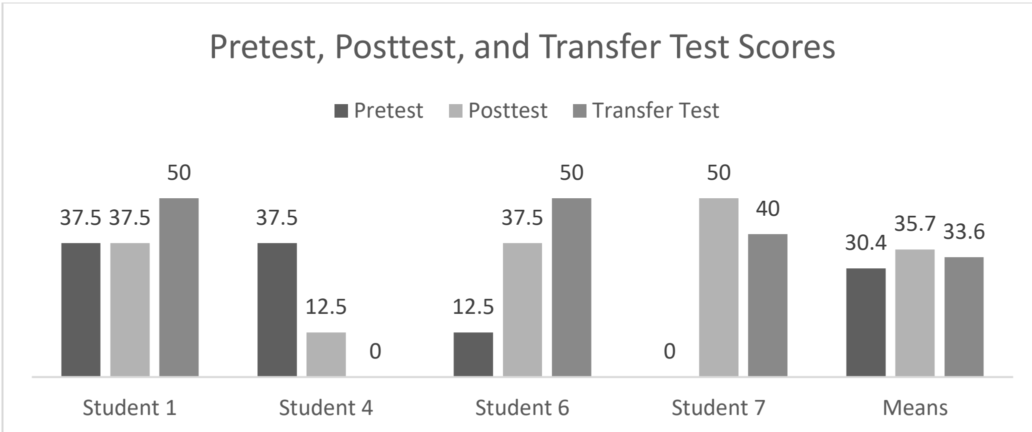


Figure 5: Percentage of problems correct on pretest, posttest, and transfer test.

A transfer test was used to measure students' application of problem-solving to grade-level contexts. The transfer test was taken from the second-grade math textbook and had a different appearance than the pretest and posttest and the materials used during instruction. The transfer test had landscape orientation, and problems were displayed in two columns on each page. On average, students' scores on the posttest and transfer test were very similar. Student 1 and student 6 performed better and the transfer test, while student 4 scored lower on the transfer test.

Students' problem-solving accuracy during schema-based instruction was measured by researcher-developed baseline measures and student practice pages for each instructional unit (Jitendra, 2007). All students demonstrated an increase in problem-solving accuracy during instruction when compared to the baseline condition. See Figures 6 and 7. Three students had higher accuracy rates during units one and two than in subsequent units. Students demonstrated less growth in accuracy during unit 3, which involved compare-type problems, with student six showing no growth as compared to the baseline. These were observed to be the most difficult for students. Similarly, students' accuracy decreased at the beginning of unit 5, which included multi-step word problems.

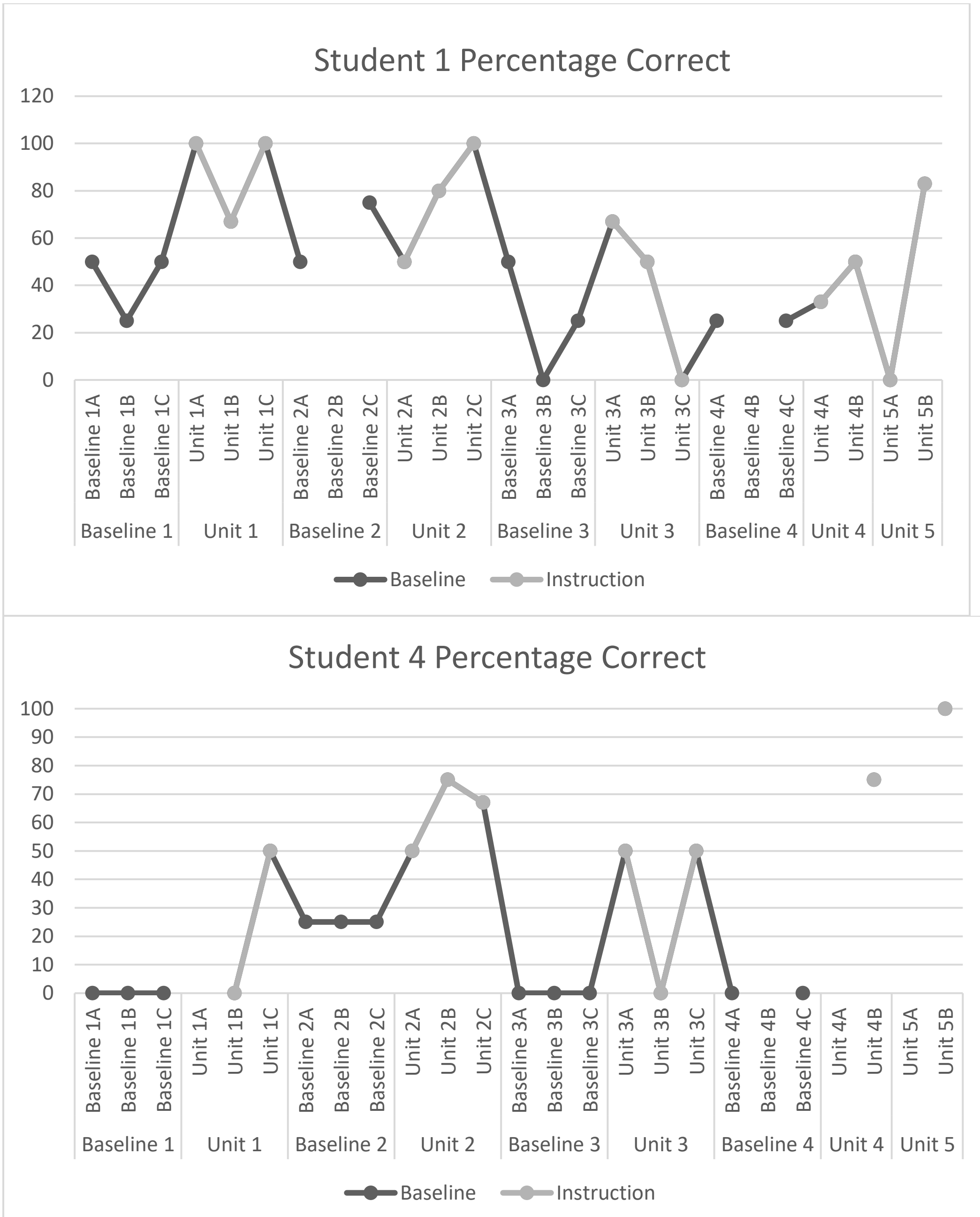


Figure 6: Percentage of problems solved correctly on ongoing assessments by student.

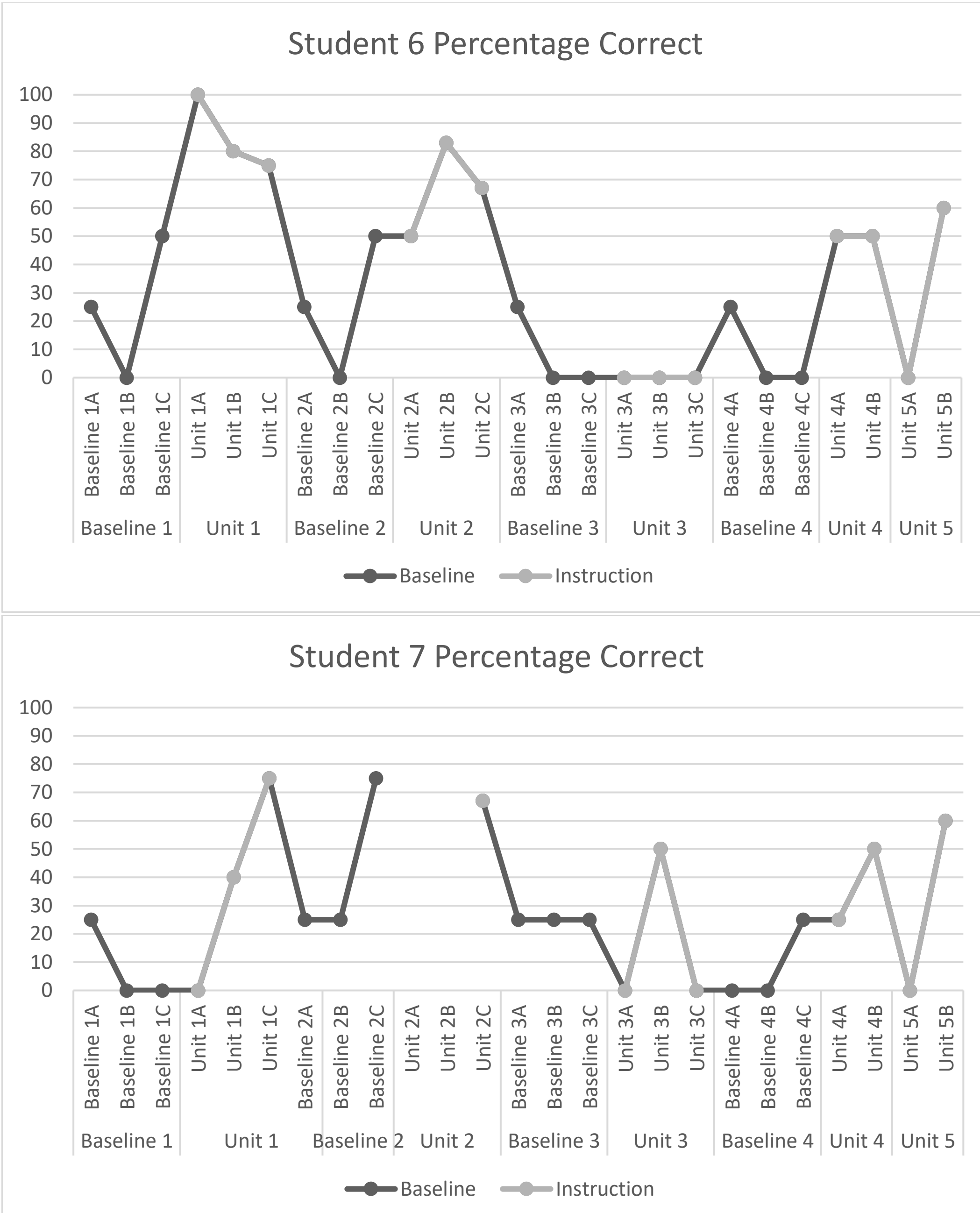


Figure 7: Percentage of problems solved correctly on ongoing assessments by student.

Trends indicate similarities between students' correct use of schema-based strategies and problem-solving accuracy during instruction. There also appears to be a relationship between attempted and correct strategy use and increased posttest scores, especially for students six and seven.

Attitudes Toward Mathematics Word Problems

An adapted version of the Attitudes Toward Mathematics Inventory (Tapia, 1996a) was administered before and after schema-based instruction. The inventory consisted of fifteen questions on a five-point Likert scale. Responses ranged from strongly agree to strongly disagree. Seven items were negatively coded, and seven items were positively coded. All items pertained to students' feelings of security with math word problems. Students' responses to each item were averaged to determine their attitude toward word problems. The group mean was also calculated to show overall changes in attitude. The mean for each student's pre-intervention and post-intervention inventories are shown in Figure 8.

As a class, students showed minimal change in their attitude toward math word problems, with a decrease of 0.302. The most notable changes were those of student 1, with a decrease of 1.14 point, and of student 4 with an increase of 0.73 point. There appears to be a slight negative relationship between pretest and posttest problem solving accuracy and students' responses to the attitude inventory for students 4, 6, and 7.

Discussion

Research Objectives

Frequency of strategy use. Analysis students' frequency of strategy use on ongoing assessments suggests that schema-based instruction was effective in improving these students' use of strategies. Pretest and posttest data suggest that schema-based instruction was somewhat effective in increasing strategy use. Students used correct schema-based strategies more often during Unit 1 and Unit 2 than in subsequent units. One possible explanation for this is that as more problem-types were introduced, students had increasing difficulty with determining the problem type. Students also tended to struggle with the compare type problems introduced in Unit 3, which in comparison is a more abstract concept than change or groups.

The impact of schema-based instruction on students' frequency of strategy use was modest as compared to increased strategy use in other studies. Morin et al. (2017) conducted a study using a bar model as a visual representation. On a posttest measure, students demonstrated correct strategy usage on 54.33% of problems. Comparatively, in the current study, students' mean correct strategy use was 21.88% of problems on the posttest. In both studies, students used the visual representation strategies more consistently during instruction than on posttest measures. In a case study by Gonsalves and Krawec (2014), the participant demonstrated mastery of visual representation using a number line to 100% within five instructional sessions.

In both of the previously discussed studies, students received instruction in groups of two (Morin et al., 2017) or individually (Gonsalves & Krawec, 2014). In the current study, instruction took place in a resource classroom with seven students. Instruction in smaller groups could have contributed to greater correct strategy use. Additionally, both the number line strategy and the bar model strategy offer students one visual representation model, while in schema-based instruction; students must choose one of three models for addition and subtraction problems. Having one visual representation model may lead to greater frequency of correct strategy use.

Problem-solving accuracy. Changes in students' pretest and posttest scores suggest that the schema-based instructional strategy was only minimally effective for most students. Two of the students whose data was not included in the analysis due to absences showed declining pretest to posttest scores.

Xin et al. (2008) found that students' problem-solving ability increased with instruction in problem-type identification. Zhu (2015) conducted a study in which students who received instruction in visual representation achieved greater results than a control group. Similarly, in a study by Morin et al. (2017), students' problem-solving accuracy increased 50% from pretest to posttest after receiving visual representation instruction using bar models. Comparatively, students in the present study showed a mean increase of 12 percentage points from pretest to posttest.

In a study with 34 struggling students in second through fifth grades, Jitendra et al. (1998) reported that students who received schema-based instruction increased their problem-solving ability 26% as compared to a 16% increase in the control group. Jitendra et al. (2007) conducted a larger study of 88 third grade students. This study reported no significant difference in growth of problem-solving ability between students who received schema-based instruction and general word problem instruction. In a later study, comparing schema-based instruction and general instruction (Griffin & Jitendra, 2009) involving 60 third-grade students there was no significant difference between schema-based and general instruction. Fuchs et al. (2008b) found schema broadening tutoring to be effective, but the study did not compare the strategy to other methods.

Additionally, transfer of problem-solving ability has been inconsistent. The mean score of the transfer test of the current study was 34% with a range of 0% to 50%. Similarly, Fuchs et al. (2006) found mixed results on a transfer test.

Attitudes toward mathematics word problems. Students' responses on the Attitudes Toward Mathematics Inventory (Tapia, 1996a) suggest that schema-based instruction had little to no effect on students' attitudes toward word problems. Two of the students who were excessively absent indicated a more positive attitude toward word problems after instruction as compared to before instruction. There appeared to be a slight decrease in attitude for students who demonstrated increased problem-solving accuracy. One possible explanation is that these students' metacognition may have increased during the schema-based instruction, and they became more aware that they were struggling with some of the concepts, which negatively affected their attitudes toward mathematics in the short term. The results of the Attitudes Toward Mathematics Inventory (Tapia, 1996a) should be interpreted with caution. Although the items were read aloud and picture cues were provided, some students did not heed the negative wording of some questions and selected agree or strongly agree for all items, especially on the second administration of the inventory, thereby skewing the results.

Limitations

One limitation of the current study is the sample size. The analyzable sample was further reduced because three students were absent from school for a significant number of days. The short duration of the study is another limitation. The study lasted only eight weeks, with each unit lasting only five days. Some students did not have time to achieve mastery of each unit before the introduction of a new problem-type. Having time to teach each problem-type to mastery could have led to an increase correct strategy use and problem-solving ability.

Another possible limitation to the study is students' math computation ability. Some participants require support for math computation, such as the use of a number line or hundreds chart. This deficit in computation could have affected students' problem-solving ability. Behavioral disruptions could also have hindered student achievement.

Implications

Further research is needed to determine if schema-based instruction is an effective strategy for second-grade students with disabilities. While there is some evidence from prior studies to suggest its effectiveness for older students, the current study found the strategy to be only minimally successful in increasing problem-solving accuracy. The strategy did appear to yield increased attempts at strategy use. Over time, increasing strategy use may translate into more correctly solved problems, and thus increased learning. Further investigation about the most effective timing or scheduling of instruction would be beneficial as well. Future studies should allow time for teaching each problem type to mastery before the introduction of the next problem type. Teaching the intervention to smaller groups of students at once could increase on-task behavior. Future studies should include more participants to increase reliability and generalizability of results. Additionally, participants should be proficient at two-digit addition and subtraction computation prior to the study.

Conclusion

Mathematics word problems have become an increasingly important aspect of state and local curricula. Students in special education often struggle with math problem solving and require different instructional strategies than their typical peers. Schema-based instruction provides direct instruction, problem-type identification, and visual representations of math word problems, all of which have been supported by prior research. While students in the current study demonstrated increased strategy use and problem-solving accuracy during the course of instruction, these skills did not carry over to posttest and transfer test results. Consistent, ongoing practice is a common component of special education instruction and may be needed in future research to enhance the success of schema-based instruction.

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Appendix A

Student Practice Page Sample

Addition and Subtraction

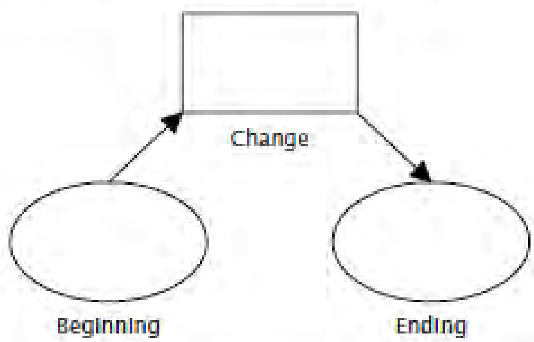
Unit 1: Change

Lesson 2: Problems 1, 2, and 3

Name: ______________________ Date: ____________

Teacher: ______________________ Grade: ____________

Change Problem 1:
Tammy likes to paint pictures of flowers. She has painted 12 pictures so far. If she paints 4 more pictures, how many will she have?

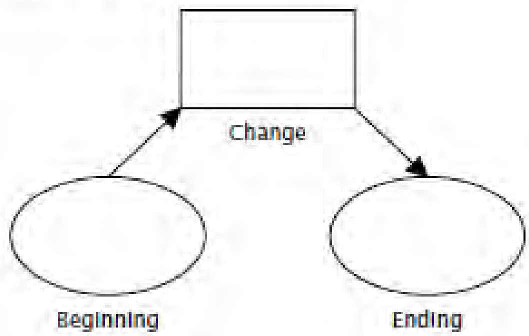


Work	Explanation

Answer: ______________________

 Student Pages: Change Lesson 2

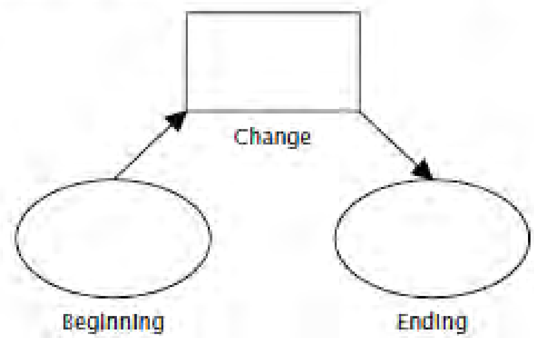
Change Problem 2:
Brian bought hot dogs for a picnic. He gave the cashier $20. He got $6 back.
How much did the hot dogs cost?



Work	Explanation

Answer: ______________________________

Student Pages: Change Lesson 2



Change Problem 3:
The zoo tour bus is pulling into the Fairview stop. 14 people get on the bus. Now there are 35 people on the bus. How many people were on the bus before the Fairview stop?

Work	Explanation

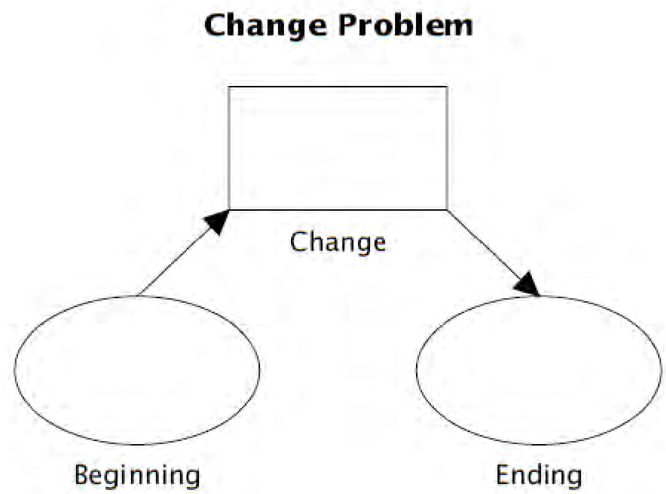
Answer: ____________________

 Student Pages: Change Lesson 2

(Jitendtra, 2007)

Appendix B

Schema-Based Diagrams



Figrure D1 Change Problem Schema-Based Diagram (Jitendra, 2007)

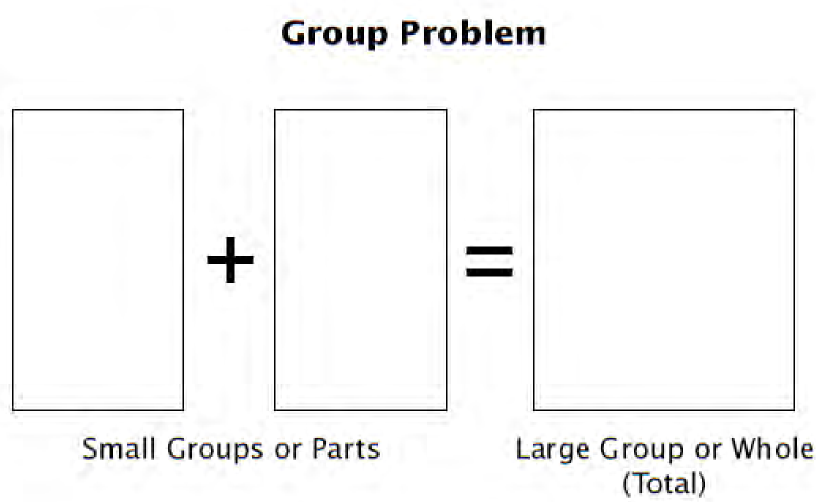


Figure D2 Group Problem Schema-Based Diagram (Jitendra, 2007)

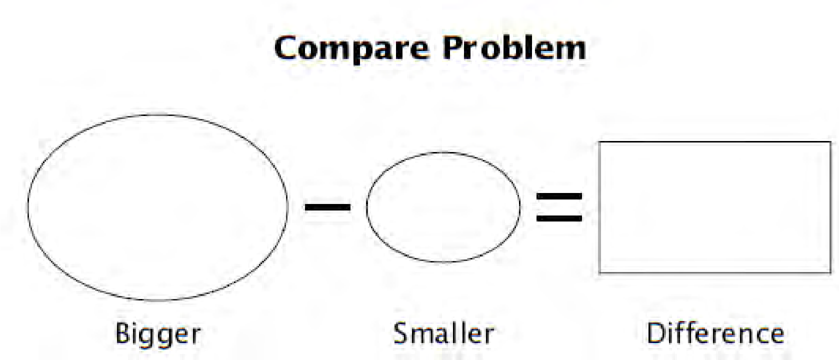


Figure D3 Compare Problem Schema-Based Diagram (Jitendra, 2007)

Appendix C

Pretest

Form A

Name: ______________________ Date: ____________

Solve the following word problems and show how you solved them.

1. A piano has 52 white keys and 36 black keys. How many keys are there?

Answer: ______________________

2. were there?

Answer: ______________________

3. Shonak has 15 more colored pencils than pens. He has 49 colored pencils. How many pens does he have?

Answer: ____________________

4. Tanya has 15 more pages to read than Lana. Lana has 12 pages to read. How many pages does Tanya have to read?

Answer: ____________________

5. Suppose your family packed 36 meals to eat on a camping trip. If 12 meals were left over at the end of the trip, how many meals were eaten?

Answer: ____________________

 Progress Assessment: Addition and Subtraction Form A

6. There are 14 monkeys playing in a tree. If 8 jump out, how many monkeys are left in the tree?

Answer: ______________________________

7. A scout troop leader is taking 14 scouts to the movies. 3 scouts cancelled, and 8 more decided to go. How many scouts are going to the movie now?

Answer: ______________________________

8. There are 10 crickets in the shed and 16 crickets outside. If 2 more crickets are found in the shed, how many more crickets are outside than inside the shed?

Answer: ______________________________

Appendix D

Example of Baseline

Addition and Subtraction

Baseline 1

Name: ______________________________ Date: ______________

Teacher: ______________________________ Grade: ______________

Directions: Read the story and solve the problem.

Problem 1:

Anna likes to draw pictures of trees. She has drawn 11 pictures so far. If she draws 3 more pictures, how many will she have?

Work	Explanation

Answer: ____________________

Problem 2:

There are 64 different flavors of juice. Jill's Juices has 44 flavors. How many flavors of juice are not at Jill's Juices?

Work	Explanation

Answer: ____

Problem 3:

Tyler picked 12 apples. He picked 4 fewer pears than apples. How many pears did Tyler pick?

Work	Explanation

Answer: ____

Problem 4:

Susan goes up 8 steps and then back down 3 steps to pick up a pencil she dropped. Then she goes up 7 steps. How many steps has she gone up at the end?

Primary (Main) Problem	Secondary Problem
Work	**Work**

Answer: ____________________________________

Appendix E

Transfer Assessment

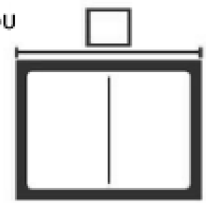
Name ______________________________

TOPIC 7

Assessment

1. Jodi has 28 apples. She buys some more.
Now Jodi has 43 apples.
How many apples did she buy?

Use the bar diagram to help you write an equation. Then use the open number line to solve.



_____ ◯ _____ = _____

_____ apples

2. Alayna draws 18 more stars than Pearl. Alayna draws 37 stars. How many stars does Pearl draw?

Can you use the equation to solve the problem? Choose Yes or No.

$37 - 18 = ?$	○ Yes	○ No
$18 + 37 = ?$	○ Yes	○ No
$18 + ? = 37$	○ Yes	○ No
$? + 18 = 37$	○ Yes	○ No

3. Emily has 17 fewer ribbons than Piper.
Piper has 48 ribbons.
How many ribbons does Emily have?

Solve any way you choose.
Show your work.

_____ ribbons

4. Write a number story for $72 - 36 = ?$.
Then solve the story problem.

$72 - 36 =$ _____

Topic 7 | Assessment

four hundred thirty-one 431

(Charles et al., 2017)

5. Joy needs 99 coats for children in need.
She gets 54 coats from her school.
She gets 22 coats from friends.
How many more coats does Joy need?

Write equations to solve.
Then write the answer.

_____ ◯ _____ = _____

_____ ◯ _____ = _____

Joy needs _____ more coats.

6. Shane has 27 more cards than Tom.
Shane has 62 cards.
How many cards does Tom have?

Explain how you will solve the problem.
Then solve.

Tom has _____ cards.

7. Grace found 36 shells.
She threw 8 shells back into the sea.
Then she found 9 more shells.
How many shells does Grace have now?

Which pair of equations shows a way to solve the problem?

Ⓐ $36 - 8 = 28$, $28 - 9 = 19$

Ⓑ $36 - 8 = 28$, $28 + 9 = 37$

Ⓒ $36 + 9 = 45$, $45 + 8 = 53$

Ⓓ $36 + 8 = 44$, $44 + 9 = 53$

432 four hundred thirty-two

Topic 7 | Assessment

(Charles et al., 2017)

Name ______________________________

TOPIC 7

Performance Assessment

School Fair
Meadow School is having a school fair. The table shows the number of tickets Ms. Davis's class has sold.

Number of Tickets Sold	
Monday	42
Tuesday	17
Wednesday	21

1. How many fewer tickets did Ms. Davis's class sell on Wednesday than on Monday?
Complete the bar diagram to model the problem. Then solve.

_____ fewer tickets

2. Ms. Davis says the class can have a party if they sell 95 tickets.

Part A
Write an equation to show how many tickets the class has sold.

Then solve the equation. Show your work.

_____ tickets sold

Part B
How many more tickets does the class have to sell to have a party? Explain.

_____ tickets

Topic 7 | Performance Assessment   four hundred thirty-three **433**

(Charles et al., 2017)

3. The table shows the number of tickets Mr. Rios's class has sold.

How many more tickets did his class sell on Monday and Tuesday than on Wednesday?

Number of Tickets Sold	
Monday	24
Tuesday	18
Wednesday	28

Write two equations to solve both parts of the problem.

____ ◯ ____ = ____

____ ◯ ____ = ____

____ more tickets

Here are some models you can use or make.

Models
arrays
bar diagrams
drawings
equations
open number lines
place-value blocks

434 four hundred thirty-four

© Pears

(Charles et al., 2017)

Appendix F

Strategy-Use Checklist for Pretest/Posttest

	The student correctly uses a schema-based diagram	The student attempts to use a schema-based diagram	The student correctly writes an equation	The student attempts to write an equation	The student uses a different problem-solving strategy	There is no evidence of strategy use.
1						
2						
3						
4						
5						

6						
	The student correctly uses a schema-based diagram	The student attempts to use a schema-based diagram	The student correctly writes an equation	The student attempts to write an equation	The student uses a different problem-solving strategy	There is no evidence of strategy use.
1						
2						
3						
4						
5						
6						
7						
8						

Strategy-Use Checklist for Student Practice Pages

Strategy-Use Checklist for Transfer Assessment

	The student correctly uses a schema-based diagram	The student attempts to use a schema-based diagram	The student correctly writes an equation	The student attempts to write an equation	The student uses a different problem-solving strategy	There is no evidence of strategy use.
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Appendix G

Attitudes Toward Mathematics Word Problems Inventory

This inventory has statements about your attitude toward math word problems. There are no correct or incorrect answers. Read and listen to each problem carefully. Please think about how you feel about each item. Choose the response that shows your feelings. Please answer every question.

1. Math word-problem solving is one of my most dreaded subjects.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
2. My mind goes blank and I am unable to think clearly when working with math word problems.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
3. Studying math word problems makes me feel nervous.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
4. Math word problems make me feel uncomfortable.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
5. I am always under a terrible strain when solving math	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

word problems.					
6. It makes me nervous to even think about having to do a math word problem.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
7. Math word problems do not scare me at all.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
8. I have a lot of self-confidence when it comes to math word problems.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
9. I am able to solve math word problems without too much difficulty.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
10. I expect to do fairly well with math word problems.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
11. I feel a sense of insecurity when attempting math word problems.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

12. I learn math word problems easily.	Strongly Disagree	Disagre e	Neutral	Agree	Strongly Agree
13. I am confident that I could learn advanced math word problems.	Strongly Disagree	Disagre e	Neutral	Agree	Strongly Agree
14. I am comfortable answering math word problems in class.	Strongly Disagree	Disagre e	Neutral	Agree	Strongly Agree
15. I believe I am good at solving math word problems.	Strongly Disagree	Disagre e	Neutral	Agree	Strongly Agree

(Tapia, 1996a)

Appendix H

Examples of Schema-Based Problem Types

Change Problem	"Tammy likes to paint pictures of flowers. She has painted 12 pictures so far. If she paints 4 more pictures, how many will she have?" (Jitendra, 2007, p. 15).
Group Problem	"There are 75 different flavors of ice cream. Julie's Treats has 35 flavors. How many flavors of ice cream are not at Julie's Treats?" (Jitendra, 2007, p. 57).

Compare Problem	"Nathan picked 11 green beans. He picked 7 fewer carrots than green beans. How many carrots did Nathan pick?" (Jitendra, 2007, p. 97).