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The Effects of Schema-Based Instruction on Word-Problems in a Third-Grade Mathematics Classroom

Mallory G. Skinner
University of North Georgia, USA, *mgskin3792@ung.edu*

Joshua A. Cuevas
University of North Georgia, USA, *josh.cuevas@ung.edu*

In this study we tested the effects of schema-based instruction (SBI) strategies on 3rd grade students' mathematics skills. We compared SBI to general strategy instruction (GSI) when teaching multi-step word problems to students in mixed-abilities general education classrooms. SBI strategies were used to instruct students in an attempt to increase understanding of mathematical word problems, assist with planning a strategy, solving, and checking problems. We assessed the overall effectiveness of SBI on students' procedural accuracy and computational accuracy with mixed computation word problems. Students' attitudes toward problem solving were compared before and after the use of SBI. ANCOVA was used to analyse pre/post-test data on overall problem-solving, procedural and computational fluency, and attitudes toward mathematics. The results indicated that the treatment group consistently outperformed the comparison group on all three achievement assessments by a statistically significant margin, on measures of overall problem-solving ability, procedural fluency, and computational fluency, but not on attitudes towards mathematics. The intervention was shown to be beneficial for enhancing student learning of math across a number of academic constructs.

Keywords: mathematics, schema-based instruction, elementary education, word problem-solving, computational fluency, procedural fluency

INTRODUCTION

Mathematics is an academic subject that many students find to be difficult or demanding. However, math is highly relevant for professional success in the twenty-first century as more jobs require math skills than ever before (National Mathematics Advisory Panel [NMAP], 2008). Students today have different needs to prepare them for the workforce than students in our nation's past and must take an active role in their education to be prepared for their future outside of the school building (Barron & Darling-Hammond, 2008). Students need to graduate prepared to join a professional world that calls for skills in communication, collaboration, as well as skills in problem-solving, analyzing, and applying knowledge. Yet, many students navigate the

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mathematics curriculum without ever attaining the ability to apply their understanding of problem-solving to novel problems (Brown, et al., 1992). Mathematical problem solving is a central focus of the *Principles and Standards for School Mathematics* (National Council of Teachers of Mathematics [NCTM], 2000). Mathematical problem solving is defined by the cognitive processes associated with solving a mathematical problem that the student does not already know how to answer (Mayer & Hegarty, 1996). Current models emphasize authentic problem-solving in real-life settings, and word problems still account for the most common form of problem-solving in mathematics curricula (Jonassen, 2003).

Solving story or word problems can be more complex and challenging for some students than solving no-context problems, i.e., equations without context (Jitendra, Griffin, et al., 2007; Jitendra, Sczensniak, et al., 2007; Jonassen, 2003). When students' solve story problems, the use of several cognitive processes is needed, including (a) understanding what the problem is stating, (b) translating the problem to make a mental model of the solving process, (c) developing a solution plan, and (d) executing the correct procedures to solve the problem (Mayer & Hegarty, 1996).

With the emphasis on developing a conceptual understanding of mathematics (NCTM, 2000), traditional textbook problem-solving instruction has not effectively enhanced mathematical skills in solving story problems (Van de Walle, 2004). Many mathematical textbooks are organized with similar types of problems on the same page, known as "blocked practice", which does not allow for students to differentiate the strategies that could be used to solve the problem. In contrast, mixing problem types, known as "interleaving", has been shown to benefit learning, particularly in math (Rohrer & Pashler, 2010). Another issue with traditional instruction is the use of keywords. For instance, "in all" indicates addition, whereas "left" indicates subtraction). Using keywords as an instructional strategy does not teach students to develop a conceptual understanding of these traditional strategies. Without an effective approach, students often fail to develop reasoning to make sense of the problems, which is crucial for novel problems (Powell & Fuchs, 2018; Van de Walle, 2004).

Research studies conducted over the last two decades have provided empirical support for the problem-solving instruction of schema-based strategy instruction (SBI). Results from a number of studies investigating the use of SBI have shown benefits to students at-risk for math failure, special education students, and students in small group settings (Hughes & Cuevas, 2020, Jitendra et al., 1998; Jitendra & Star, 2011; Xin et al., 2005). Similar to the research of Jitendra and colleagues, Fuchs and colleagues focused most of their research on the effects of schema instruction on students with learning disabilities. However, little research has explicitly focused on mixed-ability classes. It is clear, though, that explicit instruction in problem-solving is needed, such as the instructional methods of SBI.

Although many studies have been conducted on the use of SBI on students with learning disabilities (Jitendra et al., 1998; Jitendra & Star, 2011) and middle-school aged children (Xin et al., 2005) fewer studies have been conducted on the use of SBI in a general education classroom with mixed-ability students. The purpose of the present study was to evaluate and compare schema-based instruction (SBI) and general strategy instruction (GSI) in teaching mixed-method, two-step word problem-solving in third-grade mixed-ability classrooms.

Theoretical/Conceptual Framework

Schema-Based Instruction

The framework for schema-construction theory has been used to design instructional strategies for the schema-based instructional model. A schema is defined as a mental representation that enables the student to solve a problem (Mayer & Hegarty, 1996), and according to Kirschner and Hendrick (2020), for decades this concept has taken a central role in formal teaching and learning. The schema is the framework or mental model of the problem needing to be solved. Students use schemas to organize and solve word problems (Powell, 2011). The broader the schema, the more likely it is that students will recognize connections between strategies that have been taught (source) and untaught problems that use the same strategy (novel) (Chen, 1999; Fuchs, et al., 2006). This is known as "transfer" and it is considered to be among the most important goals of instruction (Soderstrom & Bjork, 2015). Students who are successful at problem-solving create complete mental representations of problem schema, which in turn allows for the recall of information needed to solve those problems (Didierjean & Cauzinille-Marmeche, 1998; Fuson & Willis, 1989; Marshall, 1995; Mayer, 1982).

Prior works from Fuchs (e.g. Fuchs et al., 2003; Fuchs, et al. 2004; Fuchs et al., 2006) have revealed the benefits of SBI in enhancing students' understanding of problem-solving. One facet of SBI is to teach students to use schematic diagrams when finding a solution to a word-problem (Powell, 2011). Often three types of word problems are used when teaching problem-solving strategies (Cooper & Sweller, 1987). Change problems usually begin with an initial quantity, and an action causes that quantity to increase or decrease (Jitendra, Sczesniak, et al., 2007). Group problems (or combine) are another schematic type of word problem. In a group problem, two distinct groups are combined to form a new group or set. This can also be referred to as the part-part-whole relationship. The third type of SBI problem is the comparison problem. When students compare, it involves the comparison of two disconnected sets with an emphasis on the relationship between the two sets. These three types of word problem strategies are used to solve one or two-step word problems. If a student knows a schema (i.e. diagram, equation, or plan) for each type and understands how to sort the problems into problem types and apply the method for each schema, then the student should be able to solve most word-problems (Cooper & Sweller, 1987) and thus achieve transfer (Soderstrom & Bjork, 2015).

According to Cooper and Sweller (1987), three variables play a role in the ability of students to transfer schemas for problem-solving. Students must (a) understand and become proficient in the rules of problem-solution strategies, (b) develop categories to sort problems that have similar solution processes, and (c) be able to recognize novel problems that are related to previously solved problems. First teachers must help students learn the steps for solving problems within a given schema (Cooper & Sweller, 1987; Owen & Sweller, 1985), then explicit instruction and practice on the different types of schemas and problem types need to occur (Fuchs, Fuchs, Finelli, et al., 2004; Fuchs et al., 2006; Fuchs et al., 2003). Unfortunately, in most classroom settings, instruction ends with the understanding and mastery of problem-solution strategies. In this study, this instruction will be referred to as general strategy instruction (GSI), which is based upon Polya's (1990) four-step problem-solving model strategy.

General Strategies Instruction

This GSI model is commonly employed when teaching problem-solving skills to students in general education settings. This four-step problem-solving process includes (a) building an understanding of the problem, (b) having students devise a plan, (c) learning to carry out the plan, and (d) reviewing and reflecting upon the process (Polya, 1990). The limitation with GSI is that the steps to the strategy are too general to support the learning of students who struggle in mathematics (Hegarty & Kozhevinikov, 1999; Jitendra & Star, 2011). Furthermore, the literature is unclear if the use of the GSI strategy is effective for individuals not already familiar with using the strategy (Woodward, 2006).

Many students have difficulty with problem comprehension and solution strategies and would benefit from explicit instruction and practice in the development of categories to sort problems that have similar solution processes (Cooper & Sweller, 1987; Jitendra, Sczesniak, et al., 2007). For instance, being able to recognize novel problems that are related to previously solved problems, sorting the problems, and transferring schemas from previously solved problems to novel problems can all be used during explicit instruction and practice. SBI emphasizes semantic representation as one solution to advancing students' problem-solving skills.

Review of Literature

Successful problem-solvers can interpret and integrate information from the problem into a coherent mental representation that enables the student to solve the problem (Mayer & Hegarty, 1996). However, problem-solving and solutions are difficult for many students, so it is vital to teach students to construct a model and plan a strategy that will be used to solve the problem (Hegarty et al., 1995). As a result, research studies over the last two decades have focused on schema-based instructional strategies.

SBI helps students learn to use schematic diagrams when solving word-problems (Jitendra & Hoff, 1996; Jitendra, Sczesniak, et al., 2007). After reading the problem, the student will select a schema diagram that fits the scenario in order to solve the problem. Another approach to schema instruction is schema-broadening instruction. In schema-broadening instruction, students are taught to transfer knowledge of problem types, thereby recognizing problems that have novel features, ultimately sorting the problem into the correct schema type (Fuchs et al., 2003). The two approaches differ in one way. In schema-broadening instruction, students are specifically taught to transfer strategies to novel problems, whereas SBI utilizes diagrams and explicit instruction to help students organize the schema types (Powell, 2011). The next section will discuss the literature behind SBI and the results of the studies.

Previous Studies on Schema-Based Instructional Strategies

In order to investigate how SBI may benefit students with learning disabilities (LD), Jitendra and Hoff (1996) implemented a study with three 3rd grade students with LD. During the intervention, the students were taught to recognize word-problem types (change, group, and compare), classify the type of problem, complete a schema diagram, and solve the problem by using the diagram. All three students demonstrated growth during the intervention and maintained the understanding of schemas two to three weeks after the final session.

In order to investigate the effects of SBI with a larger sample size, Jitendra et al. (1998) conducted a study on 34 second-to-fifth-grade students who were identified as low-achieving in mathematics. Students were randomly assigned to receive SBI in 17-20 small group tutoring sessions versus traditional tutoring sessions. Students were taught to identify the three types of problems during tutoring sessions. Students were given a posttest and a delayed posttest, one week after the intervention ended. All students were able to maintain their word problem-solving skills, as well as apply the strategies for novel problems. Results from the posttest and delayed posttest both showed a significant effect of using schema-based tutoring instruction. The findings indicate that recognizing a similarity between the source problems and the novel problems is an essential cognitive step in solving word problems. Jitendra and colleagues suggest that exposure to sample problems that represent all four types of problems promotes schema development more than exposure to general strategies of word problems.

After examining the effects of small group SBI interventions, Jitendra moved to whole-group SBI instruction. Jitendra, Sczesniak, et al. (2007) provided explicit whole-group instruction on change, combine, and compare type problems to 38 third graders, including nine LD students. Students were taught to use schema diagrams to fill in word-problem information and generate a mathematical equation to help solve the problem. The instruction lasted 15 weeks with three 30-minute sessions per week. Results from this study compared the full sample (N = 38) and the group sample (n = 9 for the LD students). The effect size for the posttest over the pretest was large for the entire sample (ES = 2.98) and the LD students (ES = 2.16). Jitendra, Sczesniak, et al. suggested that having students solve story problems enhanced the development of their computational skills.

To continue the research on SBI whole group instruction, Xin et al. (2005) conducted a study on 22 middle school students with LD and math failures. This study included two randomized groups. The SBI group was taught via explicit instruction on problem structure, schema diagrams, and the use of diagrams to solve the problem. The other group experienced four-step GSI instruction. Both groups received twelve one-hour lessons, three times a week, for a total of four weeks. The results indicated the SBI group significantly outperformed the group taught using GSI on all measures of acquisition, maintenance, and generalization. Unlike many prior studies on SBI, this study employed the use of SBI to systematically teach the structure of each of the four problem types and explicitly reveal connections between the schematic diagrams and the problem solutions.

Using a larger sample size, Jitendra, Griffin, et al. (2007) compared SBI strategies to GSI strategies by randomly assigning 88 third-graders to two conditions. The GSI group learned four steps to solving problems (read, understand, plan, solve, and finally check) along with four strategies to assist in problem-solving (use manipulatives, draw a diagram, write a number sentence, or use the information found in the graph). Like Jitendra, Sczesniak, et al. (2007), the SBI group learned to recognize the three problem types (change, compare, or group) and to use that information in a schema diagram, then create an equation to help solve the problem. This instruction was based on 41 lessons each totaling 25 minutes. The last four weeks of instruction included two-step word problems using a two-schema diagram. Using a word-problem measure, results showed that the SBI group outperformed the GSI group with an effect size of 0.52. Then six weeks after the last instruction, students were given a second measure to determine the transfer of schema knowledge, and the SBI group once again outperformed the GSI group, this time to an even greater extent with an effect size of 0.69, suggesting that SBI also led to greater retention.

Unlike the previous study by Jitendra, Griffin, et al. (2007), Griffin and Jitendra's research (2009) did not reveal similar positive results when comparing SBI and GSI. Sixty students were randomly placed in the SBI and GSI groups. Explicit instruction that matched the study by Jitendra, Griffin, et al. (2007) was used for both SBI and GSI groups. This study was comprised of 20 lessons delivered once each week for 100 minutes. However, the results in regard to the word-problem measure indicated there were no statistically significant differences between the posttest scores of the two groups or at a 12-week maintenance interval. Fluency measures between the two groups also showed similar results. Griffin and Jitendra (2009) attributed their inconsistency in this finding to the long sessions once a week versus the shorter sessions occurring several days a week, a result that can be attributed to what is known about human learning in regard to spacing effects (Kirschner & Hendrick, 2020; Rohrer & Pashler, 2010).

Throughout research on the effectiveness of SBI, most studies explored the effects of SBI on arithmetic and proportion problem-solving. Jitendra and Star (2012) explored the effectiveness of SBI on percent word problem solving with seventy 7th grade students. The study focused on the extent that SBI improved high- and low-achieving students' learning, as well as the students' ability to transfer understanding to novel problems, as compared to their control group. The instruction consisted of nine lessons with direct teacher modeling using think-aloud, scaffolded instruction using the FOPS (find the problem, organize information on a diagram, plan to solve the problem, solve the problem) strategy. The measures included a fourteen-question mathematical problem-solving test. The results indicated a significant treatment by achievement level interaction, in which the high-achieving students' problem-solving abilities outperformed the low-achieving students. However, the results did not show a significant difference in the transfer effect for the high-achieving students. Jitendra and Star (2012) suggest more time and more extensive instruction are needed for low-achieving students to learn to solve a wide range of problem types.

Across these studies, it appears that the common design features play a positive role in the outcomes (i.e. explicit instruction, consistent problem types, diagrams, and multiple days a week of intervention). The studies conducted by Jitendra and colleagues offer a solid foundation for future SBI research for students with LD. Unfortunately, there has been very limited research that has examined the effects of SBI on mixed-ability students.

The focus of previous literature provides a basis for a framework of SBI, especially in settings with students with learning disabilities. It is clear that instruction should be explicit and scripted; the use of schema diagrams is also needed with organized and planned word problems; and lessons should occur at least two or more days a week during the intervention.

Overall, while Jitendra and colleagues have offered a solid foundation for schema-based studies by providing strategies for teachers to use to enhance the performance of students with learning disabilities, the effects of SBI on students taught in mixed ability classrooms (i.e., low-achieving, average, and high) have not been adequately explored. Research is unclear on the results of using SBI in general education settings with mixed ability students. More research is also needed for the use of real-world word problems and their effects on students' attitudes toward mathematics.

Purpose of Study and Research Questions

In this study we sought to extend the literature on SBI and its effects on helping students learn to solve word problems in a 3rd grade setting. We evaluated the use of SBI compared to GSI in teaching multi-step word-problems to 3rd grade students in mixed abilities general education classroom. Students were instructed using SBI strategies to build understanding of mathematical word-problems, plan a strategy, solve problems, and check the solutions. The SBI strategies described in the literature were used to investigate using real-world problems and the effects on the third-grade students. Specifically, the following research questions guided the study:

The first research question explored whether the use of SBI in mathematical word-problems would have an effect on students' overall performance in mathematics. Next, we sought to answer if the use of SBI resulted in an increase in students' problem-solving fluency when solving word-problems independently compared to students from the control group. In order to ascertain whether students' computational fluency improved as a result of SBI, we tested differences between pre- to post-test scores. Finally, the last question examined if using SBI in mathematical real-world word-problems enhanced students' attitudes towards mathematical word problems.

METHOD

Contextual Factors

This study was conducted at a public elementary school in north Georgia. The school was one of five Title 1 schools in the district of thirty-nine K-12 schools. It was located in a rural area of the county, with approximately 1,260 students in kindergarten through fifth-grade. The racial demographics of the student body were 76% Caucasian, 18% Hispanic, 2% African American, 3% Multi-racial, and 1% Asian. The economic disadvantage rate was 18%, with 35% of students receiving free and reduced lunch services. The students' academic growth for 2018 was higher than those in 85% of the schools in the state and similar to that of the district. The school was recognized for "Beating the Odds" because it had a College and Career Ready Performance Index (CCRPI) score that was higher than would be predicted based on the school demographics, according to the make-up of the student body, grade levels served, and enrollment ("Beating the Odds Analysis," n.d.).

The participants of the study consisted of 49 students from two third-grade mathematics classes. All students ranged between the ages of eight and ten. The racial demographics of the participants were similar to that of the school, proportionally. There were a combination of English Language learners, on-level, and gifted learners who participated in the study. Two classes were used to create two conditions for the study, one experimental group consisting of a total of 25 students and one comparison group consisting of a total of 24 students.

Materials and Measures

The study was conducted in two mixed-abilities third-grade classrooms with two third grade teachers. The study group was instructed using schema-based instructional strategies (SBI), while the comparison group used general instructional strategies (GSI) and followed the county-provided curriculum.

Teaching Materials

Scripted lessons were used by both instructors during the explicit instruction which ensured consistency of information. Key vocabulary and problem-solving posters for change, group, and compare problems were displayed in the SBI classroom. Posters for the GSI instruction were also visible for students. These posters included the instruction process of understanding the problem, choosing a strategy or plan, solving the problem, and checking. The instructors used the provided board in the classroom for students to visualize the process. Several one- and two-step word-problems derived from examples from Jitendra (2004), as well as the third-grade mathematical textbooks, were used for instruction and independent practice by both the SGI and GSI groups. The word problem types included addition, subtraction, multiplication, and division problems. In the schema condition, during instructional practice, initial word problem sets were sequenced to include only the specific problem types (i.e. change, group, and compare). Additional word problems were used later that included all three types. For the GSI group, word problems using all three problem types were used during instructional practice. Blank diagrams for the change, group, and compare problems were provided for student practice, as well as displayed on the board. Manipulatives (i.e. counters) and problem-solving worksheets with practice problems were provided for all students.

Testing Measures

Overall Problem-Solving Ability. To assess students' problem-solving ability on third-grade mixed computation (addition, subtraction, multiplication, and division) multi-step word problems, students completed a 16-problem pre-and post-assessment. This assessment was also used to record the overall progress on solving multi-step word problems for the third-grade standard-based report card. The pre-and post-assessment measured the effects of SBI on the students' overall ability in solving problems in mathematics compared to the GSI group. This assessment measured the overall effectiveness of using SBI on the students' procedural accuracy and computational accuracy, with mixed computation word problems.

The word problem-solving story questions were derived from the bank of questions created by teachers in the county that were created and used for the standard-based assessments. The questions for the pre-and post-assessments were similar in design (only story and numbers changed) and difficulty level. The question sets included 16 open-ended story problems (11 one-step problems and 5 two-step word problems). The question sets included a combination of change, group, and compare problems, as well as some "equal groups" problems (multiplication and division). Students were expected to show their completed work and write the answer with a label. The total possible score was 32 points (one possible point per question for the correct number model, and one possible point for the correct score and label). The instructors administered the assessments in their classrooms during math instruction.

Procedural Fluency. To measure the students' problem-solving procedural fluency, 8 questions were used with both the SBI and the GSI groups. The assessments measured the students' ability to answer word problems using the correct procedures (i.e. change, group, compare) using only addition and subtraction. According to NCTM (2000), procedural fluency can be defined as the ability to apply mathematical procedures accurately and efficiently. The NCTM suggests that once students have been taught problem-solving procedures, students need to practice using these procedures to solve unfamiliar problems.

Therefore, a procedural fluency assessment was used throughout the intervention phase to measure the students' progress in using the SBI procedures to solve problems. The question sets included 8 one-step addition or subtraction story problems (unlike the previous measure that included one-step and two-step problems and mixed computations). The problem sets included only one-step problems with no distractors, fewer questions, and a limited time to answer (unlike the overall problem-solving ability assessment). Students had ten minutes to complete the probe. The total possible score was 16 points (one possible point per question for the correct number model, and one possible point for the correct score and label). The instructor administered this assessment three times during the intervention to measure the students' progress in problem-solving procedural fluency using the timed assessment throughout the instructional period.

Computational Fluency. To monitor the students' proficiency in third-grade mathematical computation, basic math probes (e.g. 124 + 234 =) were used to measure the students' progress on solving basic addition and subtraction problems after the intervention phase. According to the NCTM (2000), students exhibit computational fluency when they demonstrate flexibility in solving mathematical equations using whole numbers. This assessment measured the students' ability to manipulate mathematical equations using whole numbers, and unlike the previous measures that used word-problems, this assessment only involved the equations.

The computational fluency assessment was given pre-and post-intervention to the SBI group and the GSI group. Students were given ten minutes to complete the computational fluency assessment. The computational fluency assessment measured the students' proficiency in basic mathematical addition and subtraction problems. Students were given 5 minutes to complete 12 problems, with a possible total score of 24 (one possible point for correct strategy and one possible point for the correct answer).

Attitudes towards Mathematics. A shortened version of the Attitudes Towards Mathematics Inventory (ATMI) (Tapia & Marsh, 2004) was administered to the SBI group and the GSI group before and at the end of the intervention. Students were asked to rate their attitudes towards mathematics before and after the implementation of the strategies. Items were rated on a 5-point Likert scale with students indicating their range of agreement with the statement. Tapia and Marsh's original ATMI consisted of 40 questions and measured students' mathematical enjoyment, motivation, self-confidence, and validation (Lim & Chapman, 2013). The Cronbach alpha reliability of this instrument was .97 for the entire 40 question inventory. For this study, a research question was developed to measure the students' attitudes toward mathematics after the implementation of SBI. To measure this, the enjoyment and self-confidence constructs were used, for a total of 25 questions. The Cronbach alpha reliability for the enjoyment construct was .87, and the Cronbach alpha for the self-confidence construct was .95 (Tapia & Marsh, 2004).

Procedures

In both classrooms, the instructor taught mathematical word problem-solving four times a week for approximately 30 minutes each day, for a total of 120 minutes a week. This instruction occurred during regularly scheduled mathematic instruction for 4 weeks. Instruction for both groups was scripted to ensure consistency of information and included an instructional model using think-aloud, followed by guided practice, partner work, and independent practice.

SBI Condition

The students who were in the SBI condition were instructed on solving one-step problems in two phases: problem schema and problem-solution (Jitendra, 2004). During the problem schema instruction, students read story situations which did not contain unknowns. Students were taught to interpret the story situation, focusing on the type of problem schema (change, group, compare), and represented the information on a schema diagram.

During the problem-solution phase, students solved problems with unknowns. A four-step strategy checklist was used to help anchor the students' learning of the schema strategies in change, group, and compare problems: find the problem, organize the information in the problem using the diagram, plan to solve the problem, and solve the problem (FOPS).

During instruction, the change, group, and compare problem-type posters were displayed in the room. Schema diagrams were faded by the end of the instructional unit for each problem type. After that time, the schema diagrams were replaced by student hand-created diagrams. Below is a description of SBI for solving change, group, and compare problems.

Change Problems. A change problem begins with an initial quantity which is followed by a direct or implied action that in turn results in either an increase or decrease in the quantity. The students started out learning about change problem types with a story situation such as "Jane had 4 video games. Then her mother gave her 3 more video games for her birthday. Jane now has 7 video games." A change problem is comprised of three sets of information: a beginning, the change, and an ending. Students used the first step of FOPS (i.e. find the problem type) by learning to identify the story situation as change because an action occurred to increase the number of video games. In step two, when students organize the problem information using a diagram, they were prompted to use the change schema diagram in order to organize and represent the problem (see Figure 1). Students read the story, where they found the quantities related to the beginning, the change, and an ending and wrote the numbers into the diagram. Students then learned to summarize the story information and finally check for accuracy. They did this by translating the information from the diagram into a number sentence (4 + 3 = 7). They learned that the correct representation should result in the correct number of sentences. However, if it did not, they were prompted to review the completed diagram and recheck the information in the story.

Next came the problem-solution instruction phase. At this point, students were taught to interpret word problems and solve for an unknown quantity. The students followed the same FOPS strategies as above. The only difference was the students were prompted to represent the unknown with a question mark (?) in the schema diagram. In step three, students were taught that when a change action results in an increase in quantity, the ending quantity is represented by either a larger number or a whole. Students were then taught that they would need to add the parts if the larger number was not known but subtract to find the solution for the part if the larger number was known (? – 55 = 38). Students were then, again, prompted to write a number sentence, then find the solution for the change, label the answer, and finally check for the logic and accuracy of their representation and calculations.

Group Problems. In the group situation, students were tasked with combining two distinct groups or subsets to form a new group or set. Students first were introduced to group situations with a story situation such as "68 students at Hillcrest Elementary took part in the school play. There were 22 third-graders, 19 fourth-graders, and 27 fifth graders in the school play." Group situations require an understanding of part-part-whole relations. Using step 1 of the FOPS strategy, students learned that the story described a situation in which three smaller groups (third, fourth, and fifth graders) were combined to make one larger group (all students in the play). For step 2, students were prompted to use the group diagram (see Figure 1) to represent the information in the problem. This step involved the students reading and identifying the three smaller groups and writing them in the diagram. Next, students summarized the information and transferred the information from the diagram into a number sentence (22 + 19 + 27 = 68). As they did for the change stories, students were prompted to review the diagram and number sentences for logic and accuracy.

During the phase for problem-solving instruction, students were initially prompted to identify the problem, as they did in the first and second steps, using the group schematic diagram. Steps three and four were the same as those described for the change problems. Students were taught to solve the operation for the unknown, with an understanding that the large group was the large number or the whole and the small groups were the parts that comprise the whole.

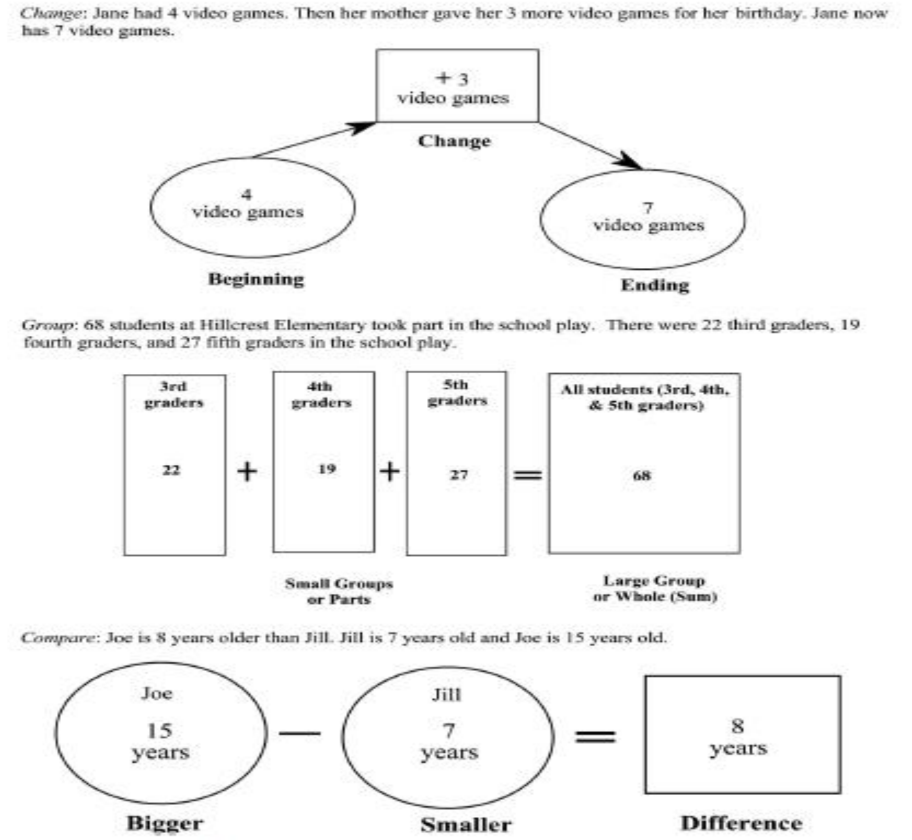

Figure 1. Schematic diagrams for change, group, and compare problem situations. Change diagram from *Schemas in Problem Solving* (p. 133), by S. P. Marshall, 1995, New York: Cambridge University Press. Copyright 1995. Adapted with permission.

Figure 1
Sample of schematic diagrams for change, group, and compare problem situations

Compare Groups. In the compare situation, students were taught to compare two disjointed sets. Students were introduced to this problem type with story situations such as “Joe is 15 years old. He is 8 years older than Jill. Jill is 7 years old.” During the first step of the instruction, students were asked to identify the story situation as a “compare” problem because it necessitated a comparison of the two ages. During the second step, students organized and represented the information using a compare diagram. Students identified the two sets being compared as the larger and smaller sets and labeled them in the diagram (see Figure 1). Next, students summarized the information by transferring it into a number sentence (15 – 7 = 8). As in the change and group situations, students were prompted to check their work for reasonableness and accuracy, related to the information from the story.

During the problem-solution instruction phase, students were prompted to identify and represent the problem (i.e. steps 1 and 2) using the compare schematic diagram. They were also taught that when solving for an unknown in compare-type problems, the larger set was associated with the big number or whole, whereas the smaller set and difference were the parts that comprise the whole.

Students were provided with schematic diagrams to use as templates and time for worksheet practice. The initial worksheet sets included story problems that were identified as change situations. After change and group problems were introduced, the worksheet sets included both problem types. After the students were introduced to the three problem types, they were exposed to worksheets that represented all three problem types. This prompted discussion of the relative sameness and differences of the problem types.

Two-Step Word Problems. Instruction for two-step word problems consisted of using a backward chaining procedure linking the two types of schema in the problems. According to Marshall (1995), a backward chain procedure of this nature uses a top-down method which requires the learner to identify the overall problem schema that needs to be solved. In this study, students were first taught to identify the primary problem schema that needed to be solved, such as "Linda walks her neighbors' dogs. On Wednesday, Linda walked 4 dogs. On Thursday, Linda walked 2 more dogs than on Wednesday. How many dogs did Linda walk altogether on both days?" In this story problem, the primary problem type is a group problem that focused on the question about how many dogs were walked on Wednesday and Thursday (Wednesday + Thursday = ?). The secondary problem type is a compare problem that had to be solved to answer the primary question (4 + 2 = ?).

The schematic diagrams were faded out during the two-step word problem instruction. Students began to independently solve word problems without the diagram template. Students were able to draw and work out the problems by showing their work. The posters and instructor were still available for student assistance when needed while working independently on two-step word problems.

GSI Condition

General Strategy Instruction was used with the comparison group of students. For this condition, students learned to solve one- and two-step word problems based on a four-step process derived from Polya's model (1990): (a) they first read and tried to understand the problem, (b) then developed a plan to solve the problem, (c) then attempted to solve the problem, and (d) finally reviewed and checked. Additionally, instruction involved four-word problem-solving strategies often employed in mathematical textbooks at the 3rd grade level, such as using objects or data from a graph or table, drawing a diagram, choosing an operation, or writing a number sentence. During instruction, the four-step problem-solving methods were displayed on posters in the classroom. During each lesson, students were presented with or reviewed the four problem-solving steps through the use of example problems and modeling.

Understand. The first step of the four procedures used in GSI was building understanding. The students read the story problem, and then the teacher asked the students what they knew about the story and what must be solved for the problem.

Plan. During the step devoted to developing a plan, each of the four strategies were introduced to the students. During the "*using objects"* stage, students were allowed access to manipulatives such as counters. They were prompted to use the manipulatives as a tool to help solve the word problem. In the "*acting it out or drawing a diagram"* phase, students were encouraged to create a skit or draw an image in order to best represent the information extracted from the problem. When students engaged in the "*choosing an operation or writing a number sentence"* process, they were guided to select an operation, such as addition or subtraction, and were assisted in constructing a number sentence to help them solve the problem. Finally, when "*using data from a graph or table"* was introduced, students learned how to use data as they planned to solve the problem.

Solve. For the step labelled "solve", the students were prompted to apply the operation or strategy from the "plan" step in order to solve the problem. The teacher facilitated the students in completing the number sentence and solving the equation. The teacher also prompted the students to label the answer.

Look Back or Check. For the last step of the word problem-solving phase, the students were asked to consider their answers, think about whether the answers were logical and made sense, and then they were ultimately asked to justify their answers.

Two-Step Problems. Students also learned to solve two-step problems using the same four steps and strategies they had been taught for solving one-step problems.

Like the SBI group, the GSI group received extensive guided practice, paired-learning opportunities, and enough time to solve word problems independently. The students also had opportunities to ask problem-solving questions to the instructor and view the four-step posters.

FINDINGS

Overall Problem Solving Ability

To determine if SBI had an effect on the students' overall ability in mathematical word problem-solving, including the procedure, computational accuracy, and using one- and two-step word problems, mathematical word problem-solving scores were analyzed. An ANCOVA test was run on both groups' pre-and post-test mathematical word problem-solving scores, using the overall problem-solving assessment's post-test scores as the dependent variable and the pretest scores as the covariate. The condition was the fixed factor. The analysis showed that the students in the treatment group outperformed the students in the comparison group on the overall problem-solving ability assessment by a statistically significant margin, $F(1, 46) = 5.753$, $p = .021$, $\eta^2 = .111$. The effect size between the treatment and control group was large. The sample for the treatment and comparison group can be found in Table 1. The mean and standard deviation can be found in Table 2. Full ANCOVA statistics can be found in Table 3.

Table 1
Between-subjects factors for the treatment and the comparison groups

		Value Label	N
Group	1.00	Treatment	24
	2.00	Control	25

Table 2
Descriptive statistics of the overall problem-solving

Dependent Variable: Post Overall Problem Solving			
Group	Mean	Std. Deviation	N
Treatment	21.7917	8.27242	24
Control	19.9200	8.93924	25
Total	20.8367	8.58134	49

Table 3
ANCOVA Statistical Results of the Overall Problem-Solving Tests

Dependent Variable: Post Overall Problem Solving						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1866.637[a]	2	933.318	25.738	.000	.528
Intercept	3380.669	1	3380.669	93.229	.000	.670
Pre Overall	1823.741	1	1823.741	50.293	.000	.522
Group	208.626	1	208.626	5.753	.021	.111
Error	1668.057	46	36.262			
Total	24809.000	49				
Corrected Total	3534.694	48				

a. R Squared = .528 (Adjusted R Squared = .508)

Problem-Solving Procedural Fluency

A research question was designed to determine if SBI increases students' problem-solving procedural fluency within a given time frame when solving one-step problems after explicit schema-based instruction. An ANCOVA test was run on procedural fluency scores, using the procedural post-test scores as the dependent variable and the pretest scores as the covariate. The condition was the fixed factor. Analysis showed that the students in the treatment group significantly outperformed the students in the comparison group on the procedural fluency assessment, $F(1, 46) = 6.069$, $p = .018$, $\eta^2 = .117$. The effect size between the treatment and control group was again large. The means and standard deviations for this procedural fluency measure can be found in Table 4. The full ANCOVA statistics for this measure can be found in Table 5.

Table 4
Descriptive statistics of the procedural fluency

Dependent Variable: Post Procedural Fluency			
Group	Mean	Std. Deviation	N
Treatment	11.2083	4.18048	24
Control	10.0000	5.43906	25
Total	10.5918	4.85163	49

Table 5
Procedural fluency ANCOVA statistics

Dependent Variable: Post Procedural Fluency						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	450.126[a]	2	225.063	15.231	.000	.398
Intercept	1081.428	1	1081.428	73.187	.000	.614
PreProced	432.248	1	432.248	29.253	.000	.389
Group	89.680	1	89.680	6.069	.018	.117
Error	679.710	46	14.776			
Total	6627.000	49				
Corrected Total	1129.837	48				

a. R Squared = .398 (Adjusted R Squared = .372)

An additional ANCOVA was run to determine if the achievement happened early or late during the intervention, using the pre-test as the covariate and the midpoint assessment as the dependent variable. The condition was the fixed factor. The results indicated that there was no difference in the scores between the treatment and control group after only three weeks, $F(1,46) = 3.367$, $p = .073$, $\eta^2 = .068$. Since there was not a significant difference between groups on problem-solving procedural fluency at the midpoint of the intervention but a significant difference on the posttest, we can surmise that the learning benefits occurred later in the intervention rather than at the outset. These full ANCOVA statistics can be found in Table 6.

Table 6
Procedural fluency pretest and during intervention results

Dependent Variable: Midpoint Procedural Fluency						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	694.753[a]	2	347.376	26.421	.000	.535
Intercept	241.019	1	241.019	18.331	.000	.285
PreProced	694.720	1	694.720	52.839	.000	.535
Group	44.270	1	44.270	3.367	.073	.068
Error	604.798	46	13.148			
Total	4231.000	49				
Corrected Total	1299.551	48				

a. R Squared = .535 (Adjusted R Squared = .514)

Computational Fluency

Another research question was designed to determine if SBI improves the students' basic mathematical computational fluency (numerical equations) after the intervention phase. An ANCOVA test was used to assess learning on the fluency assessment for both the SBI group and the GSI group. The post-test scores were the dependent variable, the pretest scores were the covariate, and the group was the fixed factor. The treatment group scored significantly higher than the control group on the post-assessment, $F(1, 46) = 6.608$, $p = .013$, $\eta^2 = .126$. The effect size between the treatment and control group was large. The mean and standard deviation can be found in Table 7. The full ANCOVA statistics for this measure can be found in Table 8.

Table 7
Computational fluency mean and standard deviation

Dependent Variable: Post Computation Fluency

Group	Mean	Std. Deviation	N
Treatment	17.1250	6.00950	24
Control	17.0000	8.06226	25
Total	17.0612	7.05753	49

Table 8
Computational fluency ANCOVA results

Dependent Variable: Post Computational Fluency

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1140.070[a]	2	570.035	20.965	.000	.477
Intercept	1918.738	1	1918.738	70.567	.000	.605
PreComput	1139.879	1	1139.879	41.923	.000	.477
Group	179.659	1	179.659	6.608	.013	.126
Error	1250.746	46	27.190			
Total	16654.000	49				
Corrected Total	2390.816	48				

a. R Squared = .477 (Adjusted R Squared = .454)

Attitudes Towards Mathematics Survey

The last research question was used to determine if SBI influences students' attitudes towards mathematics. The self-confidence and enjoyment constructs were measured with survey data. An ANCOVA was run to compare the change in each construct. The condition was a fixed factor. The dependent variable for the analysis for each construct was post-survey scores, while the covariate was their pre-survey scores. After analysis, there was no statistically significant difference between students in the control and treatment groups on either measure.

Construct 1- Enjoyment. An ANCOVA was run to compare the change in the students' enjoyment towards mathematics. The dependent variable was post-survey scores, and the covariate was their pre-survey score with condition as the fixed factor. There was not a significant difference between the groups, $F(1,46) = .048$, $p = .827$, $\eta^2 = .001$.

Construct 2-Self-Confidence. An ANCOVA was run to compare the change in the levels of self-confidence. The dependent variable was post-survey scores, and the covariate was their pre-survey score with condition as the fixed factor. There was not a significant difference between the groups, $F(1,46) = .063$, $p = .802$, $\eta^2 = .001$.

DISCUSSION

Many recent studies have explored interventions designed to improve elementary and middle grades students' learning in mathematics (Baker & Cuevas, 2018; McClelland &

Cuevas, 2020) and across a variety of content areas (Dalton & Cuevas, 2019; Jennings & Cuevas, 2021; Liming & Cuevas, 2017; Tankersley & Cuevas, 2019; Zavala & Cuevas, 2019). Some of these have focused specifically on schema-based (Hughes & Cuevas, 2020) and cognitively guided instruction (Moore & Cuevas, 2022). The purpose of this present study was similarly to extend the literature on schema-based instruction and the effects of using the schema-based instructional strategy to solve word problems in a third-grade general education setting. This study was designed to evaluate and compare the use of the SBI strategy and general strategy instruction (GSI) in teaching multi-step word problems to third-grade students in mixed abilities general education classrooms. We examined the effects on 49 third-grade students from two mixed-ability third-grade classrooms over six weeks. During the SBI instruction, a four-step strategy checklist was used to help anchor the students' learning of the schema strategies in change, group, and compare problems: find the problem, organize the information in the problem using the diagram, plan to solve the problem, and solve the problem (FOPS). Schema diagrams were used for the change, compare, and group problem-solving in order to assist the students in solving one and two-step word problems; these diagrams were faded before the end of the intervention.

It was hypothesized that the SBI intervention would have a positive effect on the students' overall problem-solving ability when compared to the GSI comparison group. Following six weeks of word problem-solving instruction, this hypothesis was confirmed. The SBI treatment group outperformed the GSI comparison group on the overall problem-solving ability assessment with a large effect size. These findings support that the SBI intervention is an effective method for improving students' understanding and ability to solve one and two-step novel word problems. One plausible explanation is the emphasis on the explicit use of schema diagrams to structure the problem situation and the connections made when solving novel problems were able to stimulate learning.

These findings are similar to those of many researchers who have studied the effects of SBI as an instructional intervention, such as those of Fuchs, Fuchs, Prentice, et al. (2004), Hughes and Cuevas (2020), Xin et al. (2005), and Jitendra, Sczeniak, et al. (2007), who found the treatment group to have significantly outperformed the comparison group on the overall problem-solving assessment. It is important to note that the effect size of the current intervention on problem-solving assessment was large, indicating the difference between the two scores was substantial, also similar to that of Xin and colleagues. The results show that the hypothesis was correct, that after the six-week intervention, the SBI intervention was effective on the students' procedural accuracy and computational accuracy with mixed computation word problems.

It was hypothesized that after the SBI intervention, the treatment group would outperform the comparison group on their ability to solve word problems using the correct problem-solving procedure. Data was gathered on this research question using an eight-question word problem assessment given to the treatment and comparison groups three times during the six weeks of intervention. The assessment measured the students' ability to answer word problems using the correct procedures (i.e. change, group, compare) using only addition and subtraction, then scored on accuracy and use of correct problem-solving strategy. It was determined that the treatment group outperformed the comparison group after six weeks of intervention. The large effect size between the two groups indicated that the students in the SBI group scored substantially higher on the procedural fluency assessment when compared to the GSI group. Notably, Jitendra, Griffin, et al., (2007) conducted a similar study with 88 third-grade students, in which their findings indicated the SBI group outperformed the GSI group on their procedural fluency assessment.

During the intervention phase, another assessment was used to measure the difference between the treatment groups' post-test scores and comparison groups' scores after only three weeks of intervention. It was determined that there was not a difference between the groups' scores after only three weeks of intervention. These results indicated that for the intervention to be successful, the students needed more than three weeks of the intervention. When Griffin and Jitendra (2009) conducted a similar study that lasted eighteen weeks, it was noted at their six-week mark that students in the SBI group scored significantly higher than their comparison group, which was early in their overall intervention. Fuchs et al. (2003) studied the effects of SBI on students' ability to transfer the information to novel problems after the instructional period had ended (6 weeks after). They also found that the treatment group outperformed the comparison group after a 12-week intervention and 6-week delayed transfer. After the current study, we can conclude that three weeks is not enough time for the intervention to be successful and six weeks or longer is recommended for future studies.

Another research question analyzed the impact that the SBI intervention had on the students' computational fluency. This assessment measured the students' ability to manipulate mathematical equations using whole numbers, and unlike the previous measures that used word problems, this assessment only involved the equations. This data was evaluated, and the results indicated that the treatment group outperformed the comparison group with a large effect size. Like the studies conducted by Jitendra, Sczensniak, et al., (2007) and Griffin and Jitendra (2009), having students use schematic diagrams to solve story problems had a positive effect on the students' overall computational fluency. The National Council of Teachers of Mathematics (NCTM) (2000) has indicated that it is not effective to rely on the use of rote memorization of math facts for improving math scores, so it is encouraging that the SBI instruction improved student performance on word problem scores as well as computational fluency. The findings of this study, including the large effect size, suggest the positive influence that high-quality word problem-solving instruction can have on mathematical computational accuracy.

The final research question analyzed the students' attitudes towards mathematics after implementing real-world word problems into the problem-solving intervention. Students were asked to rate their attitudes towards mathematics before and after the implementation of the strategies. The findings indicated there was not a difference between the treatment and comparison groups' post-survey results. It is important to note that the ATMI did not focus solely on the problem-solving strategies used in each group but on the students' overall feelings toward mathematics. It can be noted that the comparison groups' mean self-confidence and enjoyment scores were higher pre-treatment when compared to the treatment group, indicating that their overall attitudes toward math were higher.

The findings documented the consistency and efficacy of the schema-based instruction intervention over the general-strategy instruction in enhancing word problem-solving in a third-grade general-education setting. These findings suggest that this SBI may be an effective instructional option in heterogeneous elementary classrooms to improve students' understanding of word problem-solving and their computational accuracy. Further studies are needed to determine if lengthier treatments would have a different effect on the students' overall attitudes toward mathematics.

LIMITATIONS

This study was not without limitations. One must consider the possibility of the teacher effect. There was only one teacher for the treatment group, as well as the comparison group. It is possible that the individual teachers influenced performance. It should also be noted that the treatment teacher did not receive professional training on using SBI, unlike most studies by Jitendra and colleagues (e.g. Griffin & Jitendra, 2009; Jitendra, Sczensniak, et al., 2007; Jitendra et al., 2019)

The relatively small sample size and lack of special education students in the sample make it difficult to determine how well the intervention would apply to other populations. The sample was chosen based on convenience. As suggested by Hughes and Cuevas (2020), future studies should include more participants to increase the reliability and generalizability of results. An increase in sample size as well as replication of the study in other mathematics classes, with other teachers, and a more diverse population would provide for more confidence in outcomes.

The short duration of the treatment could have impacted the results of the study, with only six weeks to introduce and master each of the three schema strategies. An extended study is likely to further promote success, rather than dampen the results. Other studies on SBI examined the effects for months or years to drive their conclusions and yielded similar results (Fuchs, Fuchs, Prentice, et al., 2004; Griffin & Jitendra, 2009; Hughes & Cuevas, 2020) so it is promising that in this case SBI appeared to be successful after just six weeks.

IMPLICATIONS AND CONCLUSIONS

While recent research has emerged supporting a variety of instructional approaches to enhance students' mathematical skills in early grades (Doster & Cuevas, 2021; Juandi, et al., 2022; Sides & Cuevas, 2020), further studies are needed to determine if schema-based instruction is an effective strategy, as well as continued study on the effects of using real-world problems within SBI intervention instruction. The intervention did appear to provide promising results for students in a general education setting; however, further testing with larger sample sizes and longer duration is recommended. Future studies on the topic should allow for sufficient time for students to achieve mastery on each problem type before the introduction of the next problem type.

The present findings provide some guidance for teaching mathematical problem-solving in third-grade classrooms. The results of this study indicated a strong connection between using SBI strategies and student learning. The current intervention had a noticeable real-world impact on the students' mathematical problem-solving skills. The findings of this study support the use of SBI as an instructional strategy to teach mathematical problem-solving, promoting positive outcomes in mathematical achievement and computational fluency, and preparing students for a future outside of the classroom. Considering the need for students to develop a higher level of understanding of word problem-solving, Schema-Based Instruction emphasizes conceptual understanding and facilitates higher-order thinking, which makes it an effective and feasible option for teachers. Schema-Based Instruction provides students with a pathway for becoming successful problem-solvers and to ultimately meet the demands of higher academic standards.

REFERENCES

Beating the odds analysis. (n.d). The Governor's Office of Student Achievement. Retrieved June 16, 2020, from https://gosa.georgia.gov/accountability-0/beating-odds-analysis

Baker, A. T. & Cuevas, J. A. (2018). The importance of automaticity development in mathematics. *Georgia Educational Researcher, 14*(2). doi: 10.20429/ger.2018.140202 https://digitalcommons.georgiasouthern.edu/gerjournal/vol14/iss2/2/

Barron, B., & Darling-Hammond, L. (2008). Teaching for meaningful learning: A review of research on inquiry-based and cooperative learning. Furger, R. (Ed.). *George Lucas Educational Foundation.* San Rafael, CA. https://eric.ed.gov/contentdelivery/servlet/ERICServlet?accno=ED539399

Brown, A. L., Campione, J. C., Webber, L. S., & McGilly, K. (1992). Interactive learning environments: A new look at assessment and instruction. In B. R. Gifford & M. C. O'Connor (Eds.), *Changing assessments: Alternative views of aptitude, achievement and instruction.* (pp. 121–211). Kluwer Academic/Plenum Publishers. https://doi.org/10.1007/978-94-011-2968-8_5

Chen, Z. (1999). Schema induction in children's analogical problem solving. *Journal of Educational Psychology, 91*(4), 703–715. https://doi.org/10.1037/0022-0663.91.4.703

Cooper, G., & Sweller, J. (1987). Effects of schema acquisition and rule automation on mathematical problem-solving transfer. *Journal of Educational Psychology, 79*(4), 347–362. https://doi.org/10.1037/0022-0663.79.4.347

Dalton, C. & Cuevas, J. A. (2019). Improving content knowledge in social studies for upper elementary students. *International Journal of Social Sciences and Educational Studies, 5*(3), 18 – 42. http://ijsses.org/index.php/volume-5-issue-3-content/

Didierjean, A., & Cauzinille-Marmèche, E. (1998). Reasoning by analogy: Is it schema-mediated or case-based? *European Journal of Psychology of Education, 13*(3), 385–398. https://doi.org/10.1007/BF03172952

Doster, H. & Cuevas, J. (2021). Comparing computer-based programs' impact on problem solving ability and motivation. *International Journal on Social and Education Sciences (IJonSES), 3*(3), 457 – 488. https://doi.org/10.46328/ijonses.121

Fuchs, L. S., Fuchs, D., Finelli, R., Courey, S. J., & Hamlett, C. L. (2004). Expanding schema-based transfer instruction to help third graders solve real-life mathematical problems. *American Educational Research Journal, 41*(2), 419–445. https://doi.org/10.3102/00028312041002419

Fuchs, L. S., Fuchs, D., Finelli, R., Courey, S. J., Hamlett, C. L., Sones, E. M., & Hope, S. K. (2006). Teaching third graders about real-life mathematical problem solving: A randomized controlled study. *Elementary School Journal, 106*(4), 293–311. https://doi.org/10.1086/503633

Fuchs, L. S., Fuchs, D., Prentice, K., Burch, M., Hamlett, C. L., Owen, R., Hosp, M., & Jancek, D. (2003). Explicitly teaching for transfer: Effects on third-grade students' mathematical problem solving. *Journal of Educational Psychology, 95*(2), 293–305. https://doi.org/10.1037/0022-0663.95.2.293

Fuchs, L. S., Fuchs, D., Prentice, K., Hamlett, C. L., Finelli, R., & Courey, S. J. (2004). Enhancing mathematical problem solving among third-grade students with schema-based instruction. *Journal of Educational Psychology, 96*(4), 635–647. https://doi.org/10.1037/0022-0663.96.4.635

Fuson, K. C., & Willis, G. B. (1989). Second graders' use of schematic drawings in solving addition and subtraction word problems. *Journal of Educational Psychology, 81*(4), 514–520. https://doi.org/10.1037/0022-0663.81.4.514

Griffin, C. C. & Jitendra, A. K. (2009). Word problem-solving instruction in inclusive third-grade mathematics classrooms. *The Journal of Educational Research 102*(3), 187-201. https://doi.org/10.3200/JOER.102.3.187-202

Hegarty, M., & Kozhevnikov, M. (1999). Types of visual–spatial representations and mathematical problem solving. *Journal of Educational Psychology, 91*(4), 684–689. https://doi.org/10.1037/0022-0663.91.4.684

Hegarty, M., Mayer, R. E., & Monk, C. A. (1995). Comprehension of arithmetic word problems: A comparison of successful and unsuccessful problem solvers. *Journal of Educational Psychology, 87*(1), 18–32. https://doi.org/10.1037/0022-0663.87.1.18

Hughes, S., & Cuevas, J. (2020). The effects of schema-based instruction on solving mathematics word problems. *Georgia Educational Researcher, 17*(2). https://digitalcommons.georgiasouthern.edu/gerjournal/vol17/iss2/2/

Jennings, C., & Cuevas, J. A. (2021). Teacher impact on student growth mindset. *Perspectives in Learning*, *19*(1). Retrieved from https://csuepress.columbusstate.edu/pil/vol19/iss1/4

Jitendra, A. K. (2004) *Teaching tutorial 3: Teaching mathematical problem solving using schema-based strategy instruction.* TeachingLD. https://www.teachingld.org/wp-content/uploads/2019/04/math_tutorial.pdf

Jitendra, A. K., Griffin, C. C., Haria, P., Leh, J., Adams, A., & Kaduvettoor, A. (2007). A comparison of single and multiple strategy instruction on third-grade students' mathematical problem solving. *Journal of Educational Psychology, 99*(1), 115–127. https://doi.org/10.1037/0022-0663.99.1.115

Jitendra, A. K., Griffin, C. C., McGoey, K., Gardill, M. C., Bhat, P., & Riley, T. (1998). Effects of mathematical word problem solving by students at risk or with mild disabilities. *Journal of Educational Research*, *91*(6), 345–355. https://doi.org/10.1080/00220679809597564

Jitendra, A. K., Harwell, M. R., Im, S., Karl, S. R., & Slater, S. C. (2019). Improving student learning of ratio, proportion, and percent: A replication study of schema-based instruction. *Journal of Educational Psychology, 111*(6), 1045–1062. https://doi.org/10.1037/edu0000335

Jitendra, A. K., & Hoff, K. (1996). The effects of schema-based instruction on the mathematical word-problem-solving performance of students with learning disabilities. *Journal of Learning Disabilities, 29*(4), 422–431. https://doi.org/10.1177/002221949602900410

Jitendra, A. K., Sczesniak, E., Griffin, C.C., & Deatline-Buchman, A. (2007). Mathematical word problem solving in third-grade classrooms. *Journal of Educational Research, 100*(5), 283–302. https://doi.org/10.3200/JOER.100.5.283-302

Jitendra, A. K., & Star, J. (2011). Meeting the needs of students with learning disabilities in inclusive mathematics classrooms: The role of schema-based instruction on mathematical problem-solving. *Theory into Practice, 50*(1), 12–19. https://doi.org/10.1080/00405841.2011.534912

Jitendra, A. K., & Star, J. R. (2012). An exploratory study contrasting high- and low-achieving students' percent word problem solving. *Learning and Individual Differences, 22*(1), 151–158. https://doi.org/10.1016/j.lindif.2011.11.003

Jonassen, D. H. (2003). Designing research-based instruction for story problems. *Educational Psychology Review, 15*(3), 267-296. https://doi.org/10.1023/A:1024648217919

Juandi, D., Kusumah, Y. S., & Tamur, M. (2022). A meta-analysis of the last two decades of realistic mathematics education approaches. *International Journal of Instruction, 15*(1), 381-400. https://doi.org/10.29333/iji.2022.15122a

Kirschner, P. A. & Hendrick, C. (2020). *How learning happens: Seminal works in educational psychology and what they mean in practice*. Rutledge.

Lim, S., & Chapman, E. (2013). Development of a short form of the attitudes toward mathematics inventory. *Educational Studies in Mathematics, 82*(1), 145–164. https://doi-org.proxygsu-nga1.galileo.usg.edu/10.1007/s10649-012-9414-x

Liming, W., & Cuevas, J. A. (2017). Implicit theories of intelligence: Outcomes on academic achievement, self-efficacy, and effort in science education. In *Student Achievement: Perspectives, Assessment and Improvement Strategies* (pp. 79 – 102). Nova Science Publishers. ISBN-13: 978-1536102055 https://novapublishers.com/shop/student-achievement-perspectives-assessment-and-improvement-strategies/

Marshall, S. P. (1995). *Schemas in problem solving.* New York: Cambridge University Press.

Mayer, R. E. (1982). Memory for algebra story problems. *Journal of Educational Psychology, 74*(2), 199–216. https://doi.org/10.1037/0022-0663.74.2.199

Mayer, R. E., & Hegarty, M. (1996) The process of understanding mathematics problems. In R.J. Sternberg & T. Ben-Zeev (Eds.), *The nature of mathematical thinking* (pp. 29-53). Erlbaum.

McClelland, T., & Cuevas, J. A. (2020). A comparison of computer-based testing and paper and pencil testing in mathematics assessment. *Online Journal of New Horizons in Education, 10*(2), 78 – 89. https://www.tojned.net/journals/tojned/articles/v10i02/v10i02-01.pdf

Moore, S., & Cuevas, J. A. (2022). The effects of cognitively guided phonetic instruction on achievement and self-efficacy in elementary students in a response to intervention program. *Journal of Pedagogical Research*, *6*(4), 20 – 34. https://doi.org/10.33902/JPR.202215063

National Council of Teachers of Mathematics (NCTM). (2000). *Principals and standards for school mathematics.* Reston, VA: Author

National Mathematics Advisory Panel (NMAP) (2008). *Foundations for success: The final report of the national mathematics advisory panel.* Washington, DC: US. Department of Education. https://www2.ed.gov/about/bdscomm/list/mathpanel/report/final-report.pdf

Owen, E., & Sweller, J. (1985). What do students learn while solving mathematics problems? *Journal of Educational Psychology, 77*(3), 272–284. https://doi.org/10.1037/0022-0663.77.3.272

Polya, G. (1990). *How to solve it. A new aspect of mathematical method* (H. Weyl (Ed.). Original work published in 1945 Princeton University Press.

Powell, S. R. (2011). Solving word problems using schemas: A review of the literature. *Learning Disabilities Research & Practice (Wiley-Blackwell), 26*(2), 94–108. https://doi.org/10.1111/j.1540-5826.2011.00329.x

Powell, S. R., & Fuchs, L. S. (2018). Effective word-problem instruction: Using schemas to facilitate mathematical reasoning. *TEACHING Exceptional Children, 51*(1), 31–42. https://doi.org/10.1177/0040059918777250

Rohrer, D., & Pashler, H. (2010). Recent research on human learning challenges conventional instructional strategies. *Educational Researcher*, *39*(5), 406–412. https://doi.org/10.3102/0013189X10374770

Sides, J. D. & Cuevas, J. A. (2020). Effects of goal setting for motivation, self-efficacy, and performance in elementary mathematics. *International Journal of Instruction, 13*(4). http://www.e-iji.net/dosyalar/iji_2020_4_1.pdf

Soderstrom, N. C., & Bjork, R. A. (2015). Learning versus performance: An integrative review. *Perspectives on Psychological Science*, *10*(2), 176-199. https://doi.org/10.1177/1745691615569000

Tankersley, A. K. & Cuevas, J. A. (2019). The effectiveness of cooperative learning in the reading classroom. *Perspectives in Learning, 18*(1), 2–36. https://csuepress.columbusstate.edu/pil/vol18/iss1/2/

Tapia, M. & Marsh, G. E. (2004) An instrument to measure mathematics attitudes. *Academic Exchange Quarterly, 8*(2), 16-21.

Van de Walle, J. A. (2004). *Elementary and middle school mathematics: Teaching developmentally* (5th ed). Allyn & Bacon.

Woodward, J. (2006). Making reformed based mathematics word for academically low achieving middle school students. In M. Montague & A. K. Jitendra (Eds.), *Teaching mathematics to middle school students with learning difficulties* (pp.29-50). Guildford Press.

Xin, Y. P., Jitendra, A. K., & Deatline-Buchman, A. (2005). Effects of mathematical word problem-solving instruction on middle school students with learning problems. *Journal of Special Education, 39*(3), 181–192. https://doi.org/10.1177/00224669050390030501

Zavala, E. & Cuevas, J. A. (2019). Effects of repeated reading and rhyming poetry on reading fluency. *International Journal of Social Sciences and Educational Studies*, *6*(2), 134 – 158. https://ijsses.tiu.edu.iq/index.php/volume-6-issue-2-article-6/