Hammill Institute on Disabilities

Intervention in School and Clinic 2015, Vol. 50(5) 291–296

DOI: 10.1177/1053451214560890
isc.sagepub.com
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Cognitive Strategy Instruction for Teaching Word Problems to Primary-Level Struggling Students

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Abstract

Students with mathematics difficulties and learning disabilities (LD) typically struggle with solving word problems. These students often lack knowledge about efficient, cognitive strategies to utilize when solving word problems. Cognitive strategy instruction has been shown to be effective in teaching struggling students how to solve word problems that employ specific word problem types. The cognitive strategy, Math Scene Investigator (MSI), is an example of a cognitive strategy for word problem solving. The MSI strategy described in this paper is suitable for primary-level students with mathematics difficulties and LD. Instructional steps are provided along with an example of an interactive lesson.

Keywords

mathematics, word problem solving, cognitive strategy instruction, mathematics difficulties, learning disability

Mathematical problem-solving abilities are necessary for more advanced mathematics (National Council of Teachers of Mathematics, 2000, 2006; National Mathematics Advisory Panel [NMAP], 2008; Woodward et al., 2012) and are emphasized in the Common Core State Standards for Mathematics (National Governors Association Center for Best Practices, 2010) as part of their mathematical process practices. Yet, for primary-level students with mathematics difficulties and learning disabilities (LD), solving word problems represents a challenging endeavor because of the need to understand how problems are represented and executed (Mayer, 1998). For example, students must be able to translate linguistic (syntax) and schematic (problem structure) information into a quantitative, graphic, or symbolic representation and use a solution strategy to execute or solve the problem (Montague, Enders, & Dietz, 2011; NMAP, 2008). Students must be able to recognize the types of word problem structures and apply an appropriate solution strategy to solve the problem (Powell, 2011); unfortunately, for students with mathematics difficulties, these tasks often prove troublesome.

Difficulties in solving word problems can be a "major impediment for [students'] future success in any math-related discipline" (Gersten, Chard, et al., 2009, p. 26). Students with mathematical difficulties and LD often struggle with word problems because they (a) lack understanding of the language within the problems (Bryant, 2005; Fuchs et al., 2010; Gersten, Jordan, & Flojo, 2005), (b) are unable to apply multiple steps within word problems (Parmer, Cawley & Frazita, 1996; Shin & Bryant, 2013), (c) experience difficulty in selecting and using the correct algorithms to solve the problems (Hecht, Close, & Santisi, 2003), and (d) have an inability to generalize strategies across different types of word problems (Gersten, Beckmann, et al., 2009). To foster success in solving word problems, students with mathematical difficulties and LD benefit from explicit instruction in identifying types of word problems, understanding how to represent them, and applying a solution strategy (Gersten, Beckman, et al.,

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Table 1. Word Problem Types.

Problem Type	Description
Part–part–whole	A word problem where the whole is composed of two parts
Join	A word problem with two quantities that are combined
Separate	A word problem in which a whole is given and one part is taken away
Change	A word problem in which the beginning (part or whole) or middle (part) is unknown
Compare	A word problem with two quantities and the difference between the quantities

2009; Jitendra et al., 2009; Jitendra, DiPipi, & Perron-Jones, 2002; Montague & Dietz, 2009).

This paper presents a cognitive solution strategy, the Math Scene Investigator (MSI), which educators can use to help students with mathematics difficulties and LD solve word problems. Cognitive strategy instruction has been identified as an effective way for students to solve different types of word problems (Gersten, Chard, et al., 2009; Jitendra et al., 2002, 2009; Montague & Dietz, 2009; van Garderen, 2007).

Types of Word Problems

Word problems are a combination of numbers and words in which students apply mathematics instruction in the context of problem solving (Wyndhamm & Saljo, 1997). The types of word problems taught in Grades 1 and 2 are typically addition and subtraction and begin with simple *part-part-whole* and *join* and *separate* problems where the resulting quantity is unknown and then progress to more difficult problems, including *change* (i.e., beginning or middle quantity unknown) and *compare* problems (i.e., how many more, difference in amounts; Fuchs, Fuchs, & Prentice, 2004; Riley & Greeno, 1988). As Gersten, Beckmann, et al. (2009) found, teaching the progression of problem types is essential, and when problems are taught from easier to more difficult using explicit instruction with multiple representations, students attain higher achievement levels. Table 1 provides word problem types and descriptions, typical of primary-level instruction (Riley & Greeno, 1988; Van de Walle, Karp, & Bay-Williams, 2012).

The following is an illustration, as an example, of how word problems might be presented in first grade. In this case, a *join* word problem type is presented. Instruction begins when the teacher verbally provides the problem to students: "Jenny planted three flowers. Then she planted five more flowers. How many flowers did Jenny plant?" Students identify the unit of the problem, in this example, flowers, and the question being asked. Using a graphic or picture, students visualize the information by drawing a schematic representation for solving the problem. Students make three circles to represent three flowers and then add another five circles to represent the additional five flowers. Students are encouraged to verbalize their understanding about the problem representation through questioning by the teacher (e.g., "Tell me why you made three circles and then another five circles." "How can you answer the question?"). Next, problem execution is accomplished as students write a simple equation illustrating the action of the type of word problem type (i.e., addition) to arrive at the answer. To aid further instruction, a cognitive strategy can be used to teach young students with mathematics difficulties and LD a solution strategy for the types of word problems found at the primary level. The goal is to teach students a strategy to help them become more independent learners.

Cognitive Strategy Instruction

Cognitive strategy instruction consists of teaching cognitive and metacognitive strategies to enhance learning and improve performance (Montague et al., 2011). Numerous studies (Montague, 2007; Swanson, Orosco, & Lussier, 2014) have taught cognitive strategies in problem solving that include teaching students how to apply a cognitive strategy (e.g., strategy, visual strategy) to specific types of word problems, how to complete all steps within a problem, and how to increase self-regulation. A cognitive strategy is important to help students keep track of information and promote understanding of the structure of the word problem type. Cognitive strategy instruction helps students focus their attention on the linguistic and semantic information of the problem's structure (e.g., *join, separate* problems) and provides a way for solving the problem, thus potentially increasing student understanding of the meaning of the problem and ability to solve the problems (Swanson & Beebe-Frankenberger, 2004; Swanson & Jerman, 2006).

Additionally, metacognitive strategies (i.e., "thinking about thinking"), such as self-regulation, help students with "planning, monitoring, and modifying" (Pintrich & DeGroot, 1990, p. 33) their approach to solving a problem. Metacognitive strategies paired with cognitive strategies (i.e., read, plan, solve) have been shown to increase students' understanding and their ability to solve problems (Montague et al., 2011). The MSI is one example of a cognitive strategy that can be used to teach primary-level students with mathematics difficulties and LD how to solve primary-level word problems. The MSI is part of the Early Numeracy Intervention program (Bryant, Pfannenstiel, & Bryant, 2014), which was validated in studies showing overall positive findings (see Bryant et al., 2011, for more information about the findings).

Table 2. Math Scene Investigator Strategy.

Step	Actions Within Each Step
Step 1: Inspect and find clues	Read the problem. Underline the question and the unit. Circle important information. Cross out distractible information.
Step 2: Plan and solve	Write the equation. Draw a picture to solve.
Step 3: Retrace	Write the inverse equation. Recount picture drawn. Check to see if question was answered.

MSI Cognitive Strategy

The MSI is a cognitive strategy for primary-level students that can be utilized across the types of word problems typically found in mathematics textbooks. The strategy includes both verbal and visual (e.g., manipulatives) strategies that have been found effective in helping students with serious mathematics difficulties solve word problems (Swanson et al., 2014). The MSI strategy addresses six components of word problem solving: (a) State the question being asked and the important units in the question, (b) identify important numbers, (c) explain what the question is trying to answer, (d) select the operation needed to solve, (e) create the picture or computational strategy used to solve, and (f) discern distractible or unimportant information (Swanson & Beebe-Frankenberger, 2004).

The MSI strategy is based on solving a mystery as the student acts as the detective. There are three main steps aligned with the six components of word problem solving (see Table 2). Each step has specific actions to assist the student in identifying the type of problem and the solution strategy.

The first step is *inspect and find clues*, a verbal strategy. When students inspect, they read the word problem; underline the question, including the unit; circle important words and numbers; and cross out distractible information. The students identify the important words to circle based on the unit in the question. The unit is what the word problem is about; for example, the unit is flowers if the question asks, "How many flowers are in the garden?"

The second step is *plan and solve*, a visual strategy. *Plan and solve* has two actions, write an equation and draw a picture. Students write an equation once they have circled the important information. In writing an equation after they read, students identify how to solve the problem based upon the relationship between parts and whole. Also, the students are instructed to insert a question mark, similar to a variable, to identify the missing component (either a part or a whole) in the equation; this is intended to build algebraic readiness skills. Although the term *variable* is not used, the concept of solving for an unknown quantity is part of MSI.

The final step is *retrace*, or check work. In this step, the student writes the inverse fact equation and recounts the picture drawn to see that the question was answered.

How Do I Teach the MSI Strategy?

Teachers should begin by focusing on teaching the steps of the MSI strategy. Teachers can teach the MSI strategy by engaging in interactive modeling (modeling as students initially work through the strategy) to teach the strategy using multiple examples across 2 to 3 days of instruction. The purpose of each instructional day is to focus specifically on the actions within each step, rather than immediately applying the entire strategy to solve a word problem.

Day 1. Introduce the first two steps, *inspect and find clues* and *plan and solve.*

- Students complete the actions identified within each step (e.g., read the problem, underline the question and state the unit, circle important information, cross out any distractible [irrelevant] words).
- Students practice writing an equation (2 + 2 = 4) and drawing circles by the action to represent the problem's information. See Figure 1 for a sample MSI activity sheet completed by the students.

Day 2. Review *inspect and find clues* and *plan and solve* and explicitly teach the final step, *retrace*.

- Students first review the first two steps from Day 1, filling in the four actions for Step 1 and the two actions within Step 2.
- Students check their work by writing the inverse equation and checking the picture to determine whether it is the correct representation.
- Teacher has student read the question and determine if the question was answered. See Figure 2 for a sample MSI activity sheet completed by the students.

Using Explicit Instruction to Teach MSI

By explicitly teaching one cognitive strategy, MSI, students become more proficient problem solvers and have the ability to "understand, analyze, represent, execute and evaluate problems" (Montague & Dietz, 2009, p. 286). Explicitly teaching MSI is vital and is supported by the research. For example, in a meta-analysis conducted by Swanson (1999), cognitive strategy instruction and direct instruction were found to be the most highly effective teaching methods for students with LD; thus, direct instruction is an important component for teaching the cognitive strategy MSI. Once

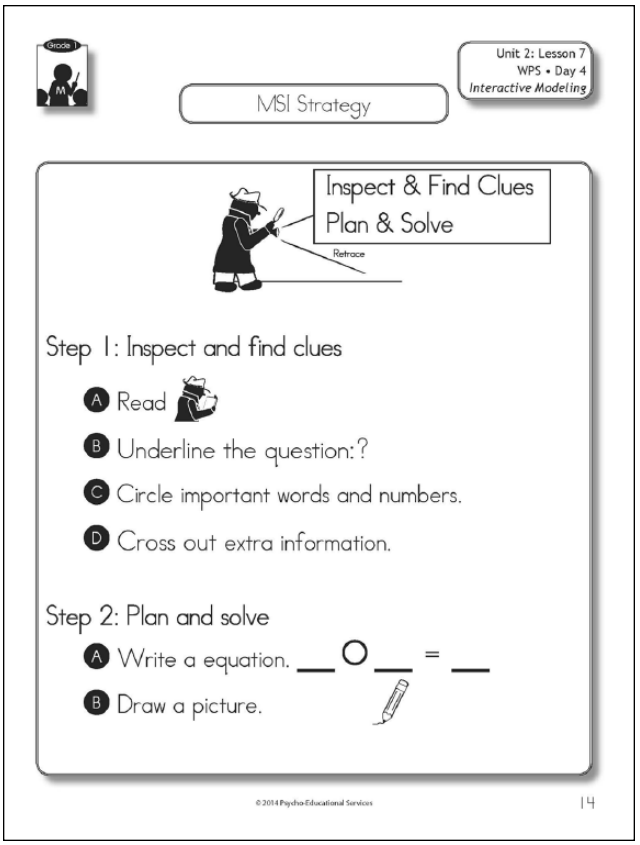

Figure 1. Day 1 sample activity sheet to teach Math Scene Investigator strategy. Reprinted by permission of Psycho-Educational Services.

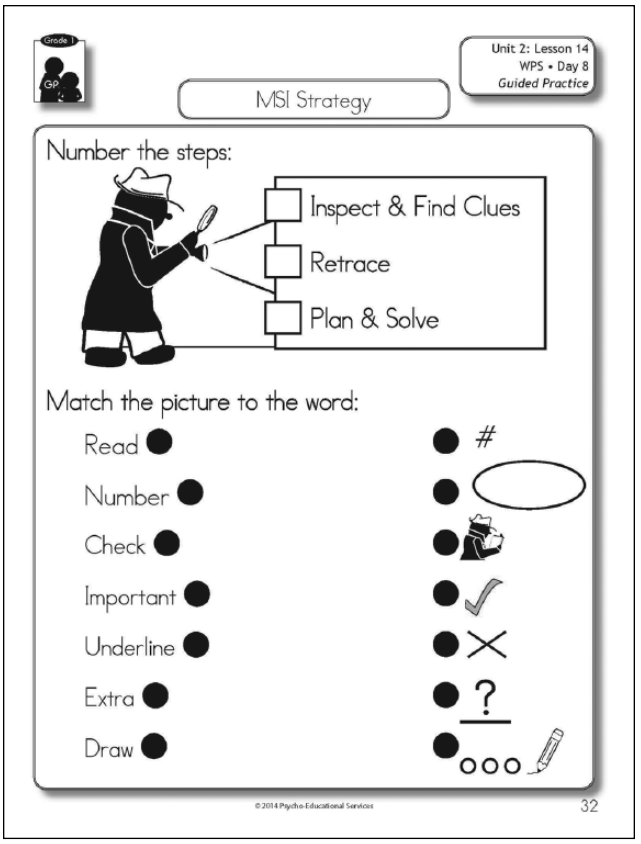

Figure 2. Day 2 sample activity sheet to teach Math Scene Investigator strategy. Reprinted by permission of Psycho-Educational Services.

students have mastered the MSI strategy, one type of cognitive strategy, the word problem–solving lessons are explicitly taught. By teaching the MSI strategy to mastery prior to instruction on specific word problem types, teachers provide students with a means to build a deeper understanding of word problems (Vilkomir & O'Donoghue, 2009).

The purpose of using explicit instruction in teaching the MSI strategy is to focus specifically on mathematically precise language while developing conceptual understanding and procedural knowledge of how to solve word problems. Mathematical vocabulary (e.g., *equation, minus, add, equal, unit*) is taught as part of instruction with the expectation that students use the terms as part of their explanations of their work. This practice is essential to increase mastery of the strategy and use of mathematically precise language. According to Archer and Hughes (2011), elements of explicit instruction, such as sequencing skills, reviewing previously taught concepts, using precise language, reducing complexity of skills, and constructing examples and practice, aid struggling students in the learning process. These elements are embedded in the MSI strategy.

Table 3 presents an example of the language—"teacher talk" and typical student responses—used during guided practice of an MSI lesson where a new word problem type is taught for the first time (i.e., part-part-whole). There are several parts to the MSI lesson routine. First, the Preview/Engage Prior Knowledge part provides an objective or goal for the students and connects to previously taught skills. The lesson then moves to Interactive Modeling, where the first time a new word problem type is introduced, more teacher talk is present. Table 3 outlines the questions that can be used across lessons that focus on questioning and more opportunities for student verbalizations. Guided practice is the next part of the lesson, where students use the MSI strategy in a supported environment with the teacher taking the role of a mediator and facilitator by correcting student misconceptions, adjusting levels of questionings, and promoting deeper understanding of the material.

Concluding Thoughts

Cognitive strategy instruction is a vital component of instructional packages for students in the younger grades, including the area of word problem solving (Montague & Dietz, 2009; Powell, 2011; Swanson et al., 2014). Developing a cognitive strategy, such as MSI, with both

Table 3. Sample Language for Using MSI to Solve Part-Part-Whole Word Problems.

Teacher Talk	Student Response
What is the action of *inspect and find clues*?	Read
Read the story together. Ready, read.	Students read word problem.
What is the next action?	Underline the question
Underline the question. What is the important unit in the question? Write it on the line.	Students underline and write unit.
What is the next action?	Cross out extra information
What do we circle?	Students circle important numbers from word problem.
Is there any extra information to cross out?	
What is the next step?	Plan and solve
Write the equation.	
What do we know: the whole number and one part, or two small parts? Do we add or subtract? How do we know?	
What is the last step of the Math Scene Investigator strategy?	Retrace
(Write a sentence that is the opposite operation.)	
To retrace, write an *addition* equation. What is one part? What is the other part? Count the two parts together. Do the two parts equal the whole?	
To retrace, write a *subtraction* equation. What is the whole number? Take away one part. What part is left?	

verbal and visual strategies theoretically reduces the cognitive load or demand on solving word problems through carefully designed explicit instruction. The MSI strategy is one method teachers can employ when working with students with mathematics difficulties and LD because it provides a structured way for tackling a skill that often proves problematic for struggling students. When MSI was used as part of an intervention for struggling Tier 2 students in Grades 1 and 2, the students were able to memorize the steps and actions. When it came time to solve word problems, students were able to quickly and accurately apply the steps and solve, as compared to the previous year in which the MSI strategy was not utilized. Classroom teachers also reported that students receiving intervention often solved word problems faster than typical peers and did note students' use of the MSI strategy. The MSI strategy is one more tool teachers have available for teaching a skill that will be required throughout the grades.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research was supported by the Institute of Education Sciences (IES), U.S. Department of Education, through Goal 2 development Grant No. R324A120364 to the University of Texas at Austin, the Meadows Center for Preventing Educational Risk. The opinions expressed are those of the authors and do not represent views of IES or the U.S. Department of Education.

References

Archer, A., & Hughes, C. (2011). *Explicit instruction: Effective and efficient teaching*. New York, NY: Guilford Press.

Bryant, D. P. (2005). Commentary on early identification and intervention for students with mathematics difficulties. *Journal of Learning Disabilities*, *38*, 340–345.

Bryant, D. P., Bryant, B. R., Roberts, G., Vaughn, S., Hughes, K., Porterfield, J., & Gersten, R. (2011). Effects of an early numeracy intervention on the performance of first-grade students with mathematics difficulties. *Exceptional Children*, *78*, 7–23.

Bryant, D. P., Pfannenstiel, K. H., & Bryant, B. R. (2014). *Early Numeracy Intervention Program*. Austin, TX: Psycho-Educational Services.

Fuchs, L., Fuchs, D., & Prentice, K. (2004). Responsiveness to mathematical problem-solving instruction: Comparing students at risk of mathematics disability with and without risk of reading disability. *Journal of Learning Disabilities*, *37*, 292–306. doi:10.1177/00222194040370040021

Fuchs, L., Zumeta, R., Finelli, R., Schumacher, R., Powell, S., Seethaler, P., Hamlett, C., & Fuchs, D. (2010). The effects of schema-broadening instruction on second graders' word problem performance and their ability to represent word problems with algebraic equations: A randomized control study. *Elementary School Journal*, *110*, 440–463.

Gersten, R., Beckmann, S., Clarke, B., Foegen, A., Marsha, L., Star, J. R., & Witzel, B. (2009). *Assisting students struggling with mathematics: Response to intervention (RtI) for elementary and middle school* (NCEE 2009-4060). Washington, DC: National Center for Educational Evaluation and Regional Assistance, Institute of Education Sciences, U.S. Department of Education. Retrieved from http://ies.ed.gov/ncee/wws/publication/practiceguides/

Gersten, R., Chard, D., Jayanthis, M., Baker, S., Murphy, P., & Flojo, J. (2009b). Mathematics instruction for students with learning disabilities: A meta-analysis of instructional components. *Review of Educational Research*, *79*, 1202–1242. doi:10.3102/0034654309334431

Gersten, R., Jordan, N., & Flojo, J. (2005). Early identification and interventions for students with mathematics difficulties. *Journal of Learning Disabilities*, *38*, 293–304. doi:10.1177/00222194050380004030 1

Hecht, S., Close, L., & Santisi, M. (2003). Sources of individual differences in fraction skills. *Journal of Experimental Child Psychology*, *86*, 277–302.

Jitendra, A., DiPipi, C., & Perron-Jones, N. (2002). An exploratory study of schema based word problem-solving instruction for middle school students with learning disabilities: An emphasis on conceptual and procedural understanding. *Journal of Special Education*, *36*, 23–38.

Jitendra, A., Star, J., Starosta, K., Leh, J., Sood, S., Caskie, G., Hughes, C., & Mack, T. (2009). Improving seventh grade students' learning of ratio and proportion: The role of schema-based instruction. *Contemporary Educational Psychology*, *24*, 250–264. doi:10.1016/j.cedpsych.2009.06.001

Mayer, R. E. (1998). Cognitive, metacognitive, and motivational aspects of problem solving. *Instructional Science*, *26*, 49–63.

Montague, M. (2007). Self-regulation and mathematics instruction. *Learning Disabilities Research and Practice*, *22*, 75–83.

Montague, M., & Dietz, S. (2009). Evaluating the evidence base for cognitive strategy instruction and mathematical problem solving. *Exceptional Children*, *75*, 285–302.

Montague, M., Enders, C., & Dietz, S. (2011). Effects of cognitive strategy instruction on math problem solving of middle school students with learning disabilities. *Learning Disability Quarterly*, *34*, 262–272.

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

National Council of Teachers of Mathematics. (2006). *Curriculum focal points for prekindergarten through Grade 8 mathematics: A quest for coherence*. Reston, VA: Author.

National Governors Association Center for Best Practices, Council of Chief State School Officers. (2010). *Common core state standards for mathematics*. Washington, DC: Author.

National Mathematics Advisory Panel. (2008). *Foundations for success: The final report of the National Mathematics Advisory Panel*. Washington, DC: U.S. Department of Education.

Parmer, R. S., Cawley, J. F., & Frazita, R. R. (1996). Word problem solving by students with and without mild disabilities. *Exceptional Children*, *62*, 415–429.

Pintrich, P., & DeGroot, E. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology*, *82*, 33–40.

Powell, S. (2011). Solving word problems using schemas: A review of the literature. *Learning Disabilities Research and Practice*, *26*, 94–108.

Riley, M. S., & Greeno, J. G. (1988). Developmental analysis of understanding language about quantities and of solving problems. *Cognition and Instruction*, *5*, 49–101.

Shin, M., & Bryant, D. P. (2013). A synthesis of mathematical and cognitive performance of students with mathematics learning disabilities. *Journal of Learning Disabilities*. Advance online publication. doi:10.1177/0022219413508324

Swanson, H. L. (1999). Instructional components that predict treatment outcomes for students with learning disabilities: Support for a combined strategy and direct instruction model. *Learning Disabilities Research and Practice*, *14*, 129–140.

Swanson, H. L., & Beebe-Frankenberger, M. (2004). The relationship between working memory and mathematical problem solving in children at risk and not at risk for serious math difficulties. *Journal of Educational Psychology*, *96*, 471–491.

Swanson, H. L., & Jerman, O. (2006). Math disabilities: A selective meta-analysis of theliterature. *Review of Educational Research*, *76*, 249–274. doi:10.3102/00346543076002249

Swanson, H. L., Orosco, M. J., & Lussier, C. M. (2014). The effects of mathematics strategy instruction for children with serious problem-solving difficulties. *Exceptional Children*, *80*, 149–168.

Van de Walle, J. A., Karp, K. S., & Bay-Williams, M. (2012). *Elementary and middle school mathematics: Teaching developmentally* (8th ed.). Boston, MA: Pearson.

van Garderen, D. (2007). Teaching students with LD to use diagrams to solve mathematical word problems. *Journal of Learning Disabilities*, *40*, 540–553.

Vilkomir, T., & O'Donoghue, J. (2009). Using components of mathematical ability for initial development and identification of mathematically promising students. *International Journal of Mathematical Education in Science and Technology*, *40*, 183–199.

Woodward, J., Beckmann, S., Driscoll, M., Franke, M., Herzig, P., Jitendra, A., . . . Ogbuehi, P. (2012). *Improving mathematical problem solving in Grades 4 through 8: A practice guide* (NCEE 2012-4055). Washington, DC: National Center for Education Evaluation and Regional Assistance, Institute of Education Sciences, U.S. Department of Education. Retrieved from http://ies.ed.gov/ncee/wwc/publications_reviews.aspx#pubsearch/

Wyndhamm, J., & Saljo, R. (1997). Word problems and mathematical reasoning: A study of children's mastery of reference and meaning in textual realities. *Learning and Instruction*, *7*, 361–382.