IMPROVING THE PROBLEM SOLVING PERFORMANCE OF STRUGGLING LEARNERS IN MATHEMATICS

by

Andrea M. Palmay

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Abstract

This study investigated the effectiveness of an intervention approach called Cognitive Strategy Instruction (CSI) that was supported with the use of graphic organizers (GOs). The intention of the research was to determine if CSI with the use of GOs could help improve the word problem solving performance of Grade 8 students experiencing difficulties in mathematics. The CSI approach incorporated instructional elements and guidelines from a Cognitive Strategy program called *Solve it!* (Montague, 2003). This study was conducted over 18-weeks. Three, female students participated in a 13-week group instruction. Field observations were collected during instruction to examine students’ mannerisms, such as their positive and negative responses, as well as their understanding of the material. Data were also collected from pre- and post- measures to examine students’: (a) feelings toward math problem solving; (b) knowledge, use, and control of the seven cognitive strategies and processes; and (c) performance in solving math word problems. The students participated in pre- and post- individual interviews (based on the modified MPSA-SF; Montague, 1996), as well as a pre- and post-math word problem solving quiz (based on Grade 6 EQAO assessments).

The results indicated that students’ participation on CSI training with the support of GOs may provide potential benefits to students who struggle in math. Two of the three students improved their performance in solving one-step math word problems on the post-intervention quiz. There was also a general improvement in students’ feelings toward math problem solving and an overall improvement in their knowledge and application of the problem solving strategies. In addition, the field observations provided insight about students’ positive and negative responses during instruction, such as their engagement and motivation. This study provides educators with an instructional program to help struggling students succeed in Ontario’s math
classrooms. Future research is recommended to gain further insights about the perceived benefits of CSI training with the support of GOs.
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Chapter 1

Introduction

Mathematical problem solving is an important life skill to learn before entering the workforce and pursuing postsecondary education. According to the National Council of Teachers of Mathematics (2010), problem solving facilitates the extension of students’ learning and fosters the development of students’ conceptual understanding, communication, and reasoning skills. In the province of Ontario, problem solving plays an important and integrative role in Grades 1 to 12 classrooms. As described by the Ontario Ministry of Education (2005) for the mathematics curriculum in Grades 1 to 8, problem solving is considered the “basis of effective mathematics programs and should be the mainstay of mathematical instruction” (p. 11). All students, regardless of their ability, should be capable of acquiring the necessary knowledge and skills to be successful problem solvers. However, results from the 2013-2014 Education Quality and Accountability Office (EQAO) have reported struggles in problem solving and low math literacy scores among many of Ontario’s students. Most significantly, within the past five years, the percentage of elementary students who perform at or above provincial standards on the EQAO mathematics assessment has dropped from 71 % to 67 % in the Primary Division and from 61 % to 54 % in the Junior Division (EQAO, 2014).

The declining math performance of Ontario’s students is a concern and suggests the collective efforts of teachers, administrators, school board personnel, and the Ministry of Education. Beyond the school community, researchers also need to continue examining evidence-based interventions on effective instructional practices in areas such as mathematical problem solving (English-language Expert Panel on Student Success in Ontario, 2004). Further
investigation on effective instructional practices can provide additional benefits, such as positive and supportive learning environments for students with varying learning needs, and greater levels of student motivation and engagement (English-language Expert Panel on Student Success in Ontario, 2004; The National Mathematics Advisory Panel, 2008).

**Background**

Many students with diverse learning needs struggle in math (e.g., students with learning disabilities (LD) and students who are low-achieving; Jitendra, 2013). The diverse learning needs experienced by struggling students are multifaceted and may range from basic skills, such as memory and computation, to more highly developed skills, such as problem solving and reasoning (Maccini, Mulcahy, & Wilson, 2007). For example, many students with LD, such as those with mathematics learning disabilities (MLD), experience academic difficulties in areas such as problem solving (Garrett, Mazzocco, & Baker, 2006). Students with MLD in general, amount to a range from 5% to 9% of the student population (Shalev, Auerbach, Manor, & Gross-Tsur, 2000) and experience cognitive impairments in areas such as processing speed, executive functioning, and working memory (Fuchs & Fuchs, 2002). Similarly, low-achieving students, who demonstrate less severe although significant learning challenges, also demonstrate academic difficulties in areas such as problem solving (English-language Expert Panel on Student Success in Ontario, 2004).

Teacher awareness of and support for students with diverse learning needs are integral components to foster students’ learning and understanding of math (Gersten, Jordan, & Flojo, 2005). Evidence however, suggests that many teachers find it challenging to tailor their instruction to support these students in today’s classrooms (e.g., DeSimone & Parmar, 2006; Voltz & Collins, 2010). For example, DeSimone and Parmar (2006) investigated middle school
mathematics teachers’ beliefs about inclusivity for students with LD. Surveys were completed by 228 sixth-, seventh-, and eighth-Grade general math teachers. 26 survey respondents also participated in a telephone interview. The findings from DeSimone and Parmar (2006) revealed that an alarming percentage of the interview participants (approximately 5% to 13%) were “not comfortable in meeting the mathematical needs of students with LD” across many math topics, such as arithmetic and multi-step word problems (p. 107). Furthermore, many of the respondents did not understand the differences in support services for accommodating students with varying learning needs in math classrooms (DeSimone & Parmar, 2006).

The findings by DeSimone and Parmar (2006) suggest the need for increase in teacher awareness and teacher training for supporting all students who struggle in math. The National Mathematics Advisory Panel (2008) also recommends further investigation on effective instructional practices to help cater to the large body of students experiencing difficulties in math. As an educator, with Intermediate and Senior qualifications in mathematics and physics, I am also aware of the many learning challenges experienced by today’s struggling students. My varied teaching experiences have confirmed the need and importance in investigating effective instructional practices to further support students’ learning in areas such as math problem solving.

**Purpose of Study**

In this research study, I examined the effectiveness of an intervention approach called Cognitive Strategy Instruction (CSI) that was supported with the use graphic organizers (GOs). The intention of the research was to determine if CSI with the use of GOs could help improve the word problem solving performance of Grade 8 students experiencing difficulties in mathematics. This research incorporated instructional elements and guidelines from a Cognitive Strategy
program called *Solve it!* (Montague, 2003). In addition, students’ mannerisms and students’ feelings toward mathematical problem solving were examined. Students’ mannerisms included their positive and negative responses and their understanding of the material during the group instruction on CSI with GOs. Students’ feelings focused on self-perceptions of their math abilities and their attitudes toward mathematical problem solving. Students’ feelings were measured a few weeks prior to and immediately following the group instruction on CSI with GOs.

To address the purpose of this study, the following research questions were proposed:

1. How did the students perform on the math word problem solving quiz before the instruction and after the instruction on CSI training with GOs?
2. How do students’ feelings toward mathematical problem solving compare before and after receiving training on CSI with GOs?
3. How do students’ knowledge, use, and control of the seven cognitive strategies and processes compare before and after receiving training on CSI with GOs?
4. How do students’ mannerisms compare during the group instruction on CSI with GOs?

In addressing these research questions, the intent was not to disclose the specific and diagnosed learning challenges and learning profiles of each participant (e.g., a student’s Individual Education Plan). Rather, this study provides educators and researchers with instructional tools and strategies to improve students’ learning in math problem solving for those with learning difficulties in math, such as students with LD.

**Rationale**

This research is important for several reasons. First, there presently exists minimal understanding and minimal research on mathematics interventions for supporting students who
struggle in math (The National Mathematics Advisory Panel, 2008). Further, in light of the declining math performance of Ontario’s students (EQAO, 2014), there is pressing need to continue examining evidence-based practices in areas such as problem solving (e.g., The National Mathematics Advisory Panel, 2008). If left unaddressed, the declining academic performance of today’s struggling learners, such as students with LD, may extend to other academic domains and may impact students’ social and emotional well-being (e.g., depression and anxiety, Morrison & Cosden, 1997). The high dropout rates of students who struggle in school also pose a concern for education and the economy as a whole (Morrison & Cosden, 1997). It is estimated that approximately 9.6 billion dollars are spent annually in Canada to cover the costs of high school dropouts (e.g., private health, social assistance, and crime; Hankivsky, 2008).

This research is also important because it gives researchers and educators a better understanding of the potential benefits of the addition of GOs for students who struggle in math. While few studies have examined the impact of GOs for struggling learners in mathematics education (e.g., students with LD; Dexter & Hughes, 2011), the existing literature on GO research has illustrated many potential benefits in fostering students’ learning and understanding of math. For example, studies on GOs have indicated their effectiveness in facilitating students’ thinking process, problem solving skills, and reading comprehension skills (e.g., Braselton & Decker, 1994; Ives, 2007; Ives & Hoy, 2003). Similarly, the studies on CSI training have also indicated its effectiveness in supporting struggling students in areas such as problem solving (e.g., Montague, Applegate, & Marquard, 1993). Based on the existing literature, it was thought that CSI training with the support of GOs may be a valuable addition to further support and improve the word problem solving performance of struggling students. This study was therefore
unique to previous research intervention because of the addition of GOs with CSI training.

Finally, the focus of this research relates directly to my own experiences as a mathematics educator and through my own struggles as a student with a LD. My experiences have enabled me to develop an appreciation and understanding of the many challenges experienced by students with diverse learning needs. It naturally followed that I was inspired to pursue a Master’s degree targeting students who experience difficulties in math in order to provide more classroom awareness and instructional support.

Organized of Thesis

This thesis consists of five chapters. Chapter 1 introduces the thesis and includes the research purpose and rationale. Chapter 2 reviews the literature about: (a) mathematical problem solving; (b) metacognition; (c) struggling learners in math; (d) Cognitive Strategy Instruction; (e) graphic organizers; (f) affective factors; and (g) field observations. Chapter 3 describes the research methodology and includes a description about participants, recruitment limitations, procedures, and measures. Chapter 4 presents the research findings. Chapter 5 provides a discussion on the research findings, study’s limitations, and suggestions for future research.
Chapter 2

Literature Review

The purpose of this study was to examine the effectiveness of an intervention approach called Cognitive Strategy Instruction (CSI) with the support of graphic organizers (GOs). The aim of the research was to determine if CSI with the use of GOs could help improve the word problem solving performance of Grade 8 students experiencing difficulties in mathematics. This study also examined students’ mannerisms and students’ feelings toward mathematical problem solving.

This chapter reviews the relevant literature that guided the research. The first section reviews the literature on mathematical problem solving. The second section describes metacognition. The third section reviews the literature on struggling students in mathematics. The fourth section describes the effectiveness of mathematics interventions, such as CSI, for improving students’ problem solving skills. The fifth section reviews the literature on GOs. The sixth section describes the rationale for using GOs with CSI training. The seventh section describes affective factors (e.g., students’ self-perceptions and attitudes) in math classrooms. The last section describes the importance and success of field observations in identifying students’ math weaknesses.

Mathematical Problem Solving

Mathematical problem solving is a complex and integrative task. First, this task requires a learner to understand the information that is presented in the problem. Further, mathematical problem solving requires a person to select and use cognitive strategies and processes that are necessary for task completion (Mayer, 1985). Cognitive strategies and processes for mathematical problem solving are procedural methods or tools that help individuals plan and
solve a problem. Possible cognitive strategies and processes can include finding the algorithm, estimating the problem, or drawing a diagram (Montague & Bos, 1990).

Many problem-solving models have been developed over the years to determine the components required for successful problem solving. For example, Polya’s (1945) model outlines four problem phases: (a) understand the problem; (b) devise a plan; (c) carry out a plan; and (d) check the solution (as cited in Schoenfeld, 1985). This model also addresses various heuristic strategies or problem rules. Heuristic strategies are techniques that help problem solvers think through the problem when they encounter difficulties. Heuristic strategies are generally posed as questions (Foong, 1991). For example, possible heuristic strategies for the second problem phase (i.e., devise a plan) can include asking oneself the following questions:

1. Do I know a related problem?
2. Do I know a theorem that could be useful?

Mayer (1985) developed a similar model for mathematical problem solving. This model outlines four phases: (a) problem translation; (b) problem integration; (c) solution planning; and (d) solution execution. Problem translation refers to decoding any linguistic and numerical information. Problem integration means understanding the relationship between the components of the problem to the mathematical structure. Solution planning involves selecting appropriate operations, while solution execution means calculating the final solution to the problem. To be a proficient problem solver, individuals must also use metacognitive strategies and processes to monitor their understanding and performance (Sternberg, 1994).

Math Word Problems

The focus of this study was on improving students’ performance in solving math word
problems. Word problems in mathematics education represent a set of exercise or story problems that combine words or phrases with numbers. To be successful in solving math word problems, students must learn how to decode the important information and must understand how to translate the important words or phrases into a mathematical expression or equation. Word problems play an important role in the Ontario mathematics curriculum including problems on the EQAO mathematics assessments (Barwell, 2011).

**Metacognition**

Research on metacognition began in the early 1970s (e.g., Brown, 1978; Flavell, 1976) in education and psychology (Schneider & Artelt, 2010). The theories of metacognition are generally composed of multidimensional and broadly defined constructs (Desoete, Roeyers, & Buysse, 2001). Flavell (1976) defined metacognition as “one’s knowledge concerning one’s own cognitive processes and products or anything related to them.” (p. 232). Metacognition is also referred to as the “active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects or data on which they bear, usually in the service of some concrete goal or objective” (Flavell, 1976, p. 232). In essence, metacognition is often considered an “umbrella category that includes a person’s knowledge about the cognitive task and knowledge about what strategies to use to successfully complete the task” (Schoenfeld, 1985, p. 137). Metacognition is also described as “executive skills relating to monitoring and self-regulation,” of study (Schneider & Artelt, 2010, p. 149). According to Thiede (1999), monitoring means looking over (or evaluating) your approach and behaviour on a cognitive task. Self-regulation requires a person to recognize difficult concepts and be able to decide on the best approach to take (Thiede, 1999).
Metacognition and mathematics education.

Many theorists and researchers during the early 1980s became interested in the role of metacognition for problem solving in mathematics education (Schneider & Artelt, 2010). Schoenfeld (1985), for example, recognized the need for students to reflect on and internalize their control routinely during decision-making tasks. As Schoenfeld (1985) explained, “One of the hallmarks of good problem solvers’ control behavior is that, while they are in the midst of working problems, such individuals seem to maintain an internal dialogue regarding the way that their solutions evolve” (p. 140). That is, to be a proficient problem solver, an individual actively and continuously thinks about and monitors his/her cognitive activity. Good problem solvers also ask questions or argue with themselves (Schoenfeld, 1985).

Within the area of problem solving, many individuals need training on metacognition because they either “fail to apply the knowledge they have” or do not know how to use their resources to complete a cognitive task (Sternberg, 1994, p. 419). Researchers have therefore emphasized the importance of training students on metacognitive strategies and processes during classroom instruction (e.g., Baker & Brown, 1984). Metacognitive strategies and processes for mathematical problem solving are commonly associated with three components: (a) self-instruction; (b) self-monitoring; and (c) self-questioning. Self-instruction refers to selecting and using appropriate problem solving strategies, while self-monitoring refers to regulating one’s performance while completing the task. Self-questioning refers to verifying accuracy in strategy and performance (Montague, Warger, & Morgan, 2000).

Struggling Learners in Mathematics

As described in the previous sections, mathematical problem solving requires a learner to use both cognitive and metacognitive strategies and processes. Evidence suggests that many
students in general, and especially those with learning disabilities, have difficulty using cognitive and metacognitive strategies and processes in areas such as problem solving (Krawec, Huang, Montague, Kressler, & de Alba, 2012) and struggle in manipulating the numeric and linguistic information presented in math word problems (Jitendra, 2013). For example, Montague and Bos (1990) investigated the cognitive and metacognitive characteristics of Grade 8 students with varying abilities: (a) students with learning disabilities (LD; $n = 15$); (b) low-achieving students (LA; $n = 15$); (c) average achieving students (AA; $n = 15$); and (d) high achieving students (HA; $n = 15$). The differences in performance across the four ability groups were compared on measures of: (a) mathematical achievement; (b) reasoning; (c) mathematical problem solving; and (d) strategy knowledge, strategy use, and control. Montague and Bos (1990) defined strategy knowledge as the awareness of problem solving strategies and processes that are necessary for successful problem solving. Strategy use referred to the selection of appropriate strategies, while control referred to one’s ability to evaluate and modify one’s own performance during a cognitive activity (Montague & Bos, 1990).

In the study by Montague and Bos (1990), the participants were individually administered different instruments and assessment tools during two 50-minute sessions. The first session consisted of a mathematical skills questionnaire to measure students’ general perceived performance and interests, as well as, students’ knowledge of mathematical problem solving strategies. During the second session, participants were videotaped while they solved five word problems of varying levels of difficulty. The participants then viewed themselves solving a two-step word problem and were later asked questions about their knowledge, use, and control of mathematical problem solving strategies. Data were coded and were later analyzed through statistical measures (e.g., one-way analyses of variance, ANOVA and multivariate analyses of
variance, MANOVA; Montague & Bos, 1990).

Overall, Montague and Bos (1990) indicated that students with LD and LA students differed significantly in their performance from AA students and HA students with respect to their general mathematics’ achievement and mathematical problem solving ($p < .01$). In addition, students with LD and LA students differed significantly from HA students in the number of control strategies they reported after solving a two-step mathematical word problem ($p < .05$). That is, examinations of mean scores (LD, $M = 8.67$; LA, $M = 8.40$; AA, $M = 9.53$; and HA, $M = 10.20$) suggested that students with LD and LA students appear less aware of problem solving strategies than HA students, and also appear less capable in monitoring and regulating their own performance during mathematical problem solving than HA students (Montague & Bos, 1990).

**Mathematics Interventions**

To cater to the diverse learning needs of students with math difficulties, researchers have stressed the importance of designing and examining effective instructional practices for math classrooms (Jitendra, 2013). Findings across several studies have revealed the effectiveness of mathematics interventions for supporting students with varying difficulties in math, such as students with LD (e.g., Maccini et al., 2007; The National Mathematics Advisory Panel, 2008). For example, a review of 26 research interventions by The National Mathematics Advisory Panel (2008) revealed the effectiveness of explicit systematic instruction for teaching students with LD and students who were low achieving in math. Explicit systematic instruction is a term that means direct instruction. Explicit systematic instruction involves the instructor explaining and demonstrating (or modelling) strategies to solve math problems. This approach also encourages students to ask and answer questions to help them “think about the decisions they make while solving problems” (The National Mathematics Advisory Panel, 2008, p. 48).
**Cognitive strategy instruction.**

Cognitive Strategy Instruction (CSI) is a type of explicit systemic instruction (i.e., direct instruction). CSI incorporates different instructional approaches, such as teaching modeling, guided practice, verbal rehearsal, and scaffolding techniques. This approach also reinforces metacognitive strategies and processes to help students self-regulate their understanding and performance when solving math problems. CSI has been shown to improve students’ problem solving skills (Maccini et al., 2007).

*The solve it! program.*

Montague (2003) developed an intervention program called *Solve It!* to improve students’ word problem solving skills of middle-school and secondary students with LD. The program incorporates Mayer’s (1985) model of problem solving and combines metacognitive strategies and processes. *Solve it!* incorporates a cognitive-metacognitive theoretical framework (see Figure 1 for the diagram of the cognitive-metacognitive model of mathematical problem solving).
Mathematical Problem Solving

*Figure 1. Cognitive-metacognitive model of mathematical problem solving*

The *Solve It!* program incorporates four instructional components: (a) problem solving assessment; (b) explicit systematic instruction; (c) process modeling; and (d) performance feedback (Montague et al., 2000).

The first component, problem solving assessment, includes two types of assessments: (a) a word problem solving test on one-, two-, and three-step math word problems and (b) the Mathematical Problem-Solving Assessment-Short form (MPSA-SF). The MPSA-SF is conducted during individual interviews to assess participants’ knowledge, underlining strengths, self-perceptions, and attitudes towards math problem solving (Montague et al., 2000). The second component, explicit systematic instruction, involves the instructor following scripted lessons on the cognitive and metacognitive skills for math problem solving (Montague et al., 2000). The third component, process modeling, involves the instruction of think aloud protocols to help students verbalize their thinking while solving math problems. During the daily lessons,
the instructor models the correct approaches to solve math word problems. Modeling of incorrect approaches is also provided to teach students how to correct procedural and calculation errors. The instructor also reinforces the three metacognitive strategies and processes (i.e., self-instructing, self-monitoring, and self-questioning; Montague et al., 2000). The last component, performance feedback, involves the instructor providing feedback on students’ progress during the daily instruction. Students are also given personal praise on their accomplishments by the instructor and by their peers (Montague et al., 2000).

The effectiveness of solve it!

The Solve it! program was validated and refined in three intervention studies for students with LD (Montague, 1992; Montague, Applegate, & Marquard, 1993; Montague & Bos, 1986). The research studies did not describe the learning challenges of the student participants. Therefore, the research findings might not be effective for students with mathematics learning disabilities (MLD). Montague and Bos (1986) examined the effectiveness of an eight-step cognitive strategy instruction (CSI) model of math problem solving for six secondary school students with LD (age 15 to 19 years old). Students followed the instructional model and practiced using think aloud protocols. Think aloud protocols involved students verbalizing their knowledge and understanding of the problem solving strategies. The instruction was conducted by the teacher and was conducted over three sessions (with 50 minutes of instruction per session) (Montague & Bos, 1986).

Overall, five of the six students improved their performance in solving math problems after receiving CSI training. The findings were obtained by visually analyzing students’ scores on scattergrams. In addition, four participants achieved the criteria on the generalization test on three-step math word problems (i.e., at least 5 correct responses). The generalization test
contained 10 three-step math word problems. The test was administered on the following day after the final treatment test (Montague & Bos, 1986). Despite the results, Montague and Bos (1986) suggested that additional time might be needed to help struggling students practice and understand certain problem solving steps (Montague & Bos, 1986).

The study by Montague and Bos (1986) was refined and later implemented for six middle school students with LD (Grades 6 to 8; Montague, 1992). This revised study included a four-month intervention, which followed the cognitive-metacognitive model of math problem solving (see Figure 1). Participants were individually instructed by the researcher and received two treatments during 55-minute sessions. The first treatment involved direct instruction on the cognitive or metacognitive skills. The second treatment involved instruction on the complementary skill so that all participants received training on the cognitive and metacognitive skills. The students also participated in individual interviews before and after the intervention. The individual interviews measured students’ attitudes and their self-perceptions of their performance in math problem solving (Montague, 1992).

Overall, a majority of the participants improved their performance in solving one-, two-, and three-step word problems after receiving training on the cognitive-metacognitive model of math problem solving. Additionally, following the intervention, four students increased their attitudes toward math problem solving. Despite these findings, the Grade 6 participants ($N=2$) did not meet the study’s mastery criteria of 70% (i.e., 7 of the 10 problems correct) on the setting generalization test. As well, none of the participants achieved criteria mastery (i.e., at least 70%) on the temporal generalized test that was administered a few months following the second treatment (Montague, 1992). Due to the students’ varying performances, Montague (1992) suggested that classroom instruction be tailored according to students’ age and their academic
strengths and weaknesses. As well, additional techniques should be implemented during classroom instruction to promote maintenance of students’ strategy performance (Montague, 1992).

The third study by Montague, Applegate, and Marquard (1993) examined the effectiveness of CSI training on 72 middle school students with LD (Grades 7 to 9). CSI training focused on one-, two-, and three-step math word problems. The study included three groups: (a) direct instruction with cognitive strategies (COG; n = 25); (b) instruction in metacognitive activities (MET; n = 23); and (c) instruction with the combination of cognitive and metacognitive strategy instruction (COG-MET; n = 24). The study also included two treatment cycles. The first treatment cycle involved 7 days of instruction for each group. The second cycle involved 5 days of instruction on MET training for the first group (COG) and 5 days of instruction on COG training for the second group (MET). The third group (COG-MET) continued with the same type of instruction during the two treatment cycles. The sessions were 50 minutes long. Additionally, 24 normal achieving (NA) students served as the comparison group. The NA students did not participate in the experimental training. Students in the comparison sample completed the same 10-problem test, pre- and post-test as the treatment groups (Montague et al., 1993). Overall, the majority of the participants improved their performances in solving one-, two-, and three-step math word problems after receiving training on CSI. Table 1 provides a summary of the effect sizes for the post-tests and maintenance tests across the pooled experimental groups (COG, MET, and COG-MET).
Table 1  
*Effect sizes across pooled groups (COG, MET, and COG-MET; Montague et al., 1993, p. 228)*

<table>
<thead>
<tr>
<th>Test Period</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ten-problem tests</td>
<td></td>
</tr>
<tr>
<td>Pre-test-Post-test 1</td>
<td>.43</td>
</tr>
<tr>
<td>Pre-test-Post-test 2</td>
<td>1.09</td>
</tr>
<tr>
<td>Pre-test-Maintenance 1</td>
<td>1.08</td>
</tr>
<tr>
<td>Pre-test-Maintenance 2</td>
<td>.74</td>
</tr>
<tr>
<td>Pre-test-Maintenance 3</td>
<td>1.25</td>
</tr>
<tr>
<td>Six-problem tests</td>
<td></td>
</tr>
<tr>
<td>Pre-test/Post-test</td>
<td>.81</td>
</tr>
</tbody>
</table>

The results from Table 1 indicate that students improved their performance over time. However, the mean score performance across three groups declined on the second maintenance test (i.e., $M = 5.64, 5.57,$ and 6.38 for COG, MET, and COG-MET, respectively). The second maintenance test was administered 5 weeks following the first maintenance test. In contrast, the results found an improved performance on the third maintenance test ($M = 6.74, 6.33,$ and 7.78 for COG, MET, and COG-MET, respectfully). The third maintenance test was administered after the students received additional strategy training. The overall findings suggest that students with LD may need additional training on strategy instruction to maintain their performance (Montague et al., 1993).

Montague et al. (1993) also compared the performance between the LD participants and NA students. Statistical analyses (ANOVA) indicated that NA students performed significantly better than LD students on the pre-test ($F(1, 94) = 50.45, p < .0001$) and on the Post-test 2 ($F(1, 94) = 5.46, p < .05$). An exploratory analysis also compared participants’ performances on the first maintenance test to NA students’ performances on Post-test 2. The results revealed no significant difference between the students ($p < .05$). These findings suggest that CSI training
may help students with LD in regular math classrooms (Montague et al., 1993). Despite these results, further researcher is needed to examine different instructional approaches that can promote performance generalization (Montague et al., 1993).

**Graphic Organizers**

In addition to the various instructional practices examined thus far, research on graphic organizers (GOs) has also been shown to support students’ learning (e.g., Stull & Mayer, 2007). GOs are visual displays or charts that depict “spatial arrangements of words (or word groups)” (Stull & Mayer, 2007, p. 810). GOs incorporate symbols (e.g., arrows) and graphic representations (e.g., boxes and lines) to make relationships more apparent (Stull & Mayer, 2007). According to Dunston (1991), GOs can help a student “organize information to be learned, connect it to what is known, and allow the reader to interact with the text” (p. 59). From its broadest definition, GOs include concept maps (Novak & Gowin, 1984), hierarchies (Cook & Mayer, 1988), matrices (e.g., Kiewra, Kauffman, Robinson, Dubois, & Staley, 1999), and flow charts (Chambliss & Calfee, 1998). Figure 2 provides a visual display of GOs.
Early research on graphic organizers.

Ausubel (1960, 1963) developed and examined the use of organizers to support his cognitive theory of meaningful reception learning. His theory argued that students’ existing cognitive structures could impact their learning of a new material (Ausubel, 1963). Ausubel hypothesized that if students’ existing knowledge were organized into clear structures, then their comprehension, retention, and learning of verbal material would be enhanced (Ausubel, 1963). Ausubel (1960) encouraged the use of organizers (or advance organizers) to facilitate students’ learning. The advance organizers consisted of a verbal display of structures. The advance organizers were presented to learners prior to instruction (Ausubel, 1960). In the late 1970s,
different types of organizers were developed for educational purposes (Dunston, 1991). Structured overviews for example, were developed from advance organizers. Structured overviews removed complicated terminology. The complicated terminology was replaced with simpler terms in a visual display. Structured overviews were later called graphic organizers (GOs; Dunston, 1991).

**Administration of graphic organizers.**

GOs can be administered to students in three ways: (a) author-provided; (b) learner-generated; and (c) partial completed (Stull & Mayer, 2007). The first way, author-provided, involves the instructor designing GOs to scaffold students’ learning. During instruction, students use GOs as a guide to see how information from a text can be organized and converted into visual representations (Mayer & Moreno, 2003). Author-provided GOs are explained by two theories: (a) cognitive load theory and (b) activity theory.

Cognitive load theory explains the impact of cognitive overload on students’ learning (Sweller, 1988). Cognitive overload happens “when the total intended processing exceeds the learner’s cognitive capacity” (Mayer & Moreno, 2003, p. 45). Sweller (1988) argued that many instructional activities or designs are ineffective because they impose a cognitive demand on students’ working memory. According to cognitive load theory, author-provided GOs can facilitate students’ learning in three ways: (a) help students stay on task; (b) prevent students from engaging in extraneous processing; and (c) can help free generative processing (Stull & Mayer, 2007). Extraneous processing refers to cognitive processing that is created by ineffective instructional designs or activities (e.g., noise distractions; Sweller, 1993). Germaine processing refers to engagement in deep cognitive processing of a material (Sweller, Van Merrienboer, & Paas, 1998).
GOs can also be explained by activity theory (Mayer, 2003). This theory describes the idea that “deep learning occurs when students are encouraged to engage in productive learning activities” (Stull & Mayer, 2007, p. 810). Unlike cognitive load theory, activity theory suggests that author-provided GOs do not generate germane processing because students are not encouraged to create their own visual diagrams (Stull & Mayer, 2007).

The second approach, learner-generated, involves the students designing their own GOs after receiving instruction on the “use, purpose and construction of graphic organizers” (Dunston, 1991, p. 60). According to activity theory, this approach may encourage germane processing. However, students’ cognitive load may be impacted when students become overwhelmed with the material and do not understand how to design their own GOs. As a result, the task may result in extraneous processing (Stull & Mayer, 2007).

The third approach, partial completed, involves the administration of “partially-filled templates” (Stull & Mayer, 2007, p. 810). The instructor also provides scaffolding techniques (or cues) to help students fill in and complete the GOs. Partial completed GOs are believed to reduce cognitive-load (Stull & Mayer, 2007).

**Research on graphic organizers in mathematics education.**

Research in mathematics education has revealed the importance of the addition of GOs during classroom instruction (e.g., Ives, 2007; Ives & Hoy, 2003). Studies on GOs indicate that these visual aids can support students’ higher-level thinking skills in math (Ives & Hoy, 2003) and improve students’ reading comprehension skills (Braselton & Decker, 1994). Additionally, the inclusion of GOs during math instruction can help students “visually relate elements,” infer the solution to a problem, and can help them communicate their thinking when solving math problems (Braselton & Decker, 1994, p. 276).
Zollman (2009) administered GOs for an action-research study on middle school students in math and science classrooms. In total, 186 students and nine inner-city math teachers participated in the study. The project was based on an evidence-based research study on reading and writing skills (Goeden, 2002; National Reading Panel, 2000). The GOs in the study by Zollman (2009) outlined five problem-solving steps (see Figure 3). The GOs were adapted from a study by Gould and Gould (1999), which focused on students’ writing skills. The purpose of the project by Zollman (2009) was to measure the effect of GOs in improving students’ achievement in math problem solving across three areas: (a) math knowledge; (b) strategic knowledge; and (c) math explanation. The teachers administered pre- and post-tests to measure the effect of the intervention (Zollman, 2009). The time length of the study was not reported.

Overall, the results from the study by Zollman (2009) reported an improved performance in students’ problem solving skills after they received instruction on GOs. Scores increased from “27% average on the pre-test to a 70% average on the post-test” (Zollman, 2009, p. 8). In addition, the percentage of students who scored at or above the mastery criteria demonstrated an improvement on the post-test across the three areas of math (math knowledge = 75%; strategic knowledge = 68%; and explanation = 68%). These results were compared to students’ scores on the pre-test (math knowledge = 4%; strategic knowledge = 19%; and explanation = 8%). The math teachers also reported an improvement in students’ performance for those with varying abilities, such as high achieving students and student who were at-risk failure in math (Zollman, 2009).
Students with math difficulties.

As described in the study by Zollman (2009), the addition of GOs during math problem solving revealed its effectiveness of supporting students with varying abilities, such as students with math difficulties. According to Van Garderen (2006), there are two main reasons for providing instruction on GOs for students with math difficulties. First, research on learning disabilities reveal that many students, such as students with mathematics learning disabilities (MLD), have working memory impairments (e.g., Swanson, Ashbaker, & Lee, 1996). These struggles make it difficult for students to keep track of various task demands during problem solving (Geary 1996; Swanson, Cooney, & O’Shaughnessy, 1998). Visual aids in the form of GOs can facilitate students’ thinking process and can alleviate working memory demands (Diezmann & English, 2001). Second, evidence suggests that visual representations can aid students in self-regulating their performance. That is, the “visibility” of a diagram can help students keep track of their thinking process when solving math problems (Van Garderen, 2006, p. 73).

GOs have been incorporated in a few studies for students with learning disabilities (LD) in math classrooms (Dexter & Hughes, 2011). For example, Ives (2007) investigated the effectiveness of GOs for teaching systems of linear equations to secondary school students with LD and to students with attention disorders (Grades 7 to 12). The research consisted of two
studies. In the first study, 14 participants were randomly assigned to the graphic organizer group (GO) and 16 participants were randomly assigned to the control group (CO). In the second study, a different sample of students participated (i.e., 10 participants in the GO and CO groups). The first study focused on solving two-systems of two variable equations. The second study was an extension of first study, but involved solving systems of three equations. Both strategy instruction (e.g., verbal modelling) and direct instruction (e.g., providing feedback and administering probes) were provided to both groups (Ives, 2007). The graphic organizer was designed as a matrix (see Figure 4).

![Figure 4. Matrix graphic organizer (Ives, 2007, p. 112)](image)

In the first study, different tests were administered to both groups (e.g., prerequisite skills pre-test, post-test, and maintenance test). One-way ANOVAs were conducted to compare the mean scores across the two groups. Due to the small sample size, all ANOVAs were conducted with a level of significance of $\alpha = .10$. Overall, the mean scores on the post-concept test was found to be statistically higher for the GO group than the CO group (e.g., $F = 7.86, p = .009, \eta^2 = .219$). The effect size fell within the medium to large range (i.e., $\eta^2$ between .13 and .26). Despite these results, the mean scores from the GO group on solving systems of equations was not significantly different to the CO group’s performance on the post-test ($F = 0.19, p = .664, \eta^2 = .219$).
nor on the follow up or maintenance test ($F = 0.00, p = 1.000, \eta^2 = .000$; Ives, 2007).

In the second study, separate one-way ANOVAs were performed to compare the mean scores on the prerequisite skills test and post-test. Unlike the results from the first study, students’ mean scores from the GO group on the post-test for solving systems of equations were significantly different to students’ performance in the CO group ($F = 11.26, p = .100, \eta^2 = .585$). The effect size fell within the large range (i.e., > .26). This finding was based on an on an alpha level of .10 (Ives, 2007).

Overall, Ives (2007) reported an improvement in students’ conceptual understanding of systems of linear equations in both studies after they received instruction on GOS. In addition, the results for solving systems of equations in the second study were found to be significantly more effective for the GO group than the CO group. Despite these results, a lack of research on GOS also exists in this domain. In addition, majority of the participants had a diagnosed language-related and reading and writing disability. Thus, the results from the study by Ives (2007) might not be able to be generalized to students with mathematics learning disabilities (MLD).

**Limitations of graphic organizers.**

Despite the research on GOS, there are many concerns about the effectiveness of GOS in supporting students’ learning in K to 12 and postsecondary classrooms (Dunston, 1991; Griffin & Tulbert, 1995; Jiang & Grabe, 2007). First, there exist inconsistencies across studies regarding research designs (Jiang & Grabe, 2007). In many studies for example, GOS were represented in different ways and the general definitions of GOS varied across studies. As explained by Griffin and Tulbert (1995), “GOS have taken the form of anything from hierarchical listing of vocabulary terms to elaborate visual-spatial displays with accompanying descriptors and
phrases” (p. 86). As a result, it is unclear which type of GO is the most effective for teaching and learning. In addition, the training times on GOs that was offered to student participants pose a concern. Training on GOs in some studies for example, lasted for a few days or a few weeks (e.g., Alvermann & Boothby, 1986; Simmons, Griffin, & Kameenui, 1988). Certainly, differences in the training time on GOs may have impacted students’ readiness in adapting to new learning tasks. Future research should examine the appropriate time length for training students on GOs (Jiang & Grabe, 2007).

**Addition of Graphic Organizers with Cognitive Strategy Instruction**

As previously noted above, the Solve it! program was validated and refined in three intervention studies for students with LD (Montague, 1992; Montague, Applegate, & Marquard, 1993; Montague & Bos, 1986). Two of the three research studies (Montague, 1992; Montague, Applegate, & Marquard, 1993) used a Venn diagram during instruction. The diagram outlined the cognitive-metacognitive model of math problem solving (see Figure 1). The student participants were required to recite by memory (i.e., 100 % mastery) all cognitive components before they received strategy training on math problem solving. The cognitive-metacognitive model of math problem solving was later removed from instruction after the students recited all strategies and processes by memory (Montague, 1992; Montague, Applegate, & Marquard, 1993). While building on such previous research, my research study was also unique to the aforementioned interventions because of the addition of partially completed GOs with CSI training. I administered GOs during the intervention to help the Grade 8 participants solve math word problems.

**Affective Factors in Mathematics Education**

Proficiency in math is not restricted to content knowledge and skill development (The
Affective factors, such as students’ self-beliefs and their attitudes, also play a critical role in math classrooms (Schoenfeld, 1983, 1989, 1992). Student self-beliefs, such as their self-perceptions in ability or performance, refer to a person’s “cognition and feelings about the self” (Elbaum & Vaughn, 2001, p. 304). These self-beliefs can create positive or negative responses. For example, a person with a positive self-belief in math can say: “I am able to solve problems” (McLeod, 1992, p. 578).

Many students with LD are vulnerable to low self-perceptions (Meltzer, Katzir, Miller, Reddy, & Roditi, 2004) and lack the confidence to persist in tasks (Montague & Applegate, 2000). Similarly, the continued struggles in math experienced by low-performing students in math can decrease their self-concept (i.e., perceptions of self-worth and competence), attitudes (i.e., interest), and engagement (Kajander, Zuke, & Walton, 2008). Such struggles can further exacerbate levels of stress and feelings of frustration.

**Student academic self-perceptions.**

Various interventions on students with varying abilities (e.g., students with LD) have examined students’ academic self-perceptions (e.g., Meltzer, Katzir-Cohen, Miller, & Roditit, 2001). For example, Meltzer et al., (2004) examined the changes in students’ and teachers’ perceptions of students’ “effort, strategy use, and academic difficulties” after implementing strategy instruction in a language-arts curriculum (p. 99). The study occurred within a six-month period and included 201 students with LD, 210 average achieving students, and 57 teachers from Grades 4 to 9. The study also incorporated a comparison sample of teachers and students. The teachers and students in the comparison group only completed the same pre- and post-questionnaires as the experimental group (e.g., Student Self-Report System and Teacher Rating Scale). The teachers in the comparison group did not receive training on strategy instruction...
To determine the impact of strategy instruction, the results were analyzed through repeated measures MANOVAs and ANOVAs. Overall, the results indicated a positive impact on teachers’ and students’ perception of students’ academic abilities after participating in the six-month intervention on strategy instruction. For example, all students in the strategy instruction group reported significant decreases in their academic difficulties in reading \( (F = 8.34, p < .01, \eta^2 = .03) \), spelling \( (F = 7.13, p < .01, \eta^2 = .03) \) and writing \( (F = 11.33, p < .01, \eta^2 = .04) \). In addition, the teachers perceived that all students in the strategy training group (i.e., students with and without LD) applied more strategies and were more willing to work hard than students in the control group \( (e.g., F = 4.63, p < .05, \eta^2 = .02) \). Despite the results from the study, Meltzer et al. (2004) suggested using video-analyses in order to provide more accurate documentations of classroom behaviours (Meltzer et al., 2004).

Students’ attitudes.

Students’ attitudes toward math are another important construct in math education. Attitudes toward math can display positive or negative responses to various tasks. For example, a student could say: “I enjoy math problem solving. I dislike geometry” (McLeod, 1992). Within the area of math problem solving, evidence suggests that a supportive learning environment can change students’ attitudes \( (e.g., Schoenfeld, 1985) \). For example, Mohammad Yusof and Tall (1999) examined the change in university students’ attitudes before and after taking a six-month course that emphasized cooperative problem solving. The course encouraged the students to think deeply about all aspects of mathematical problem solving \( (e.g., formulating and modifying) \). In total, 24 males and 20 females participated in the study \( (ages 18 to 21 years) \). Data were collected through anecdotal classroom observations, individual interviews, as well as
through teacher and student questionnaires. Overall, the results found a positive directional change in students’ attitudes before and after completing the course. For example, before the intervention, a majority of the students reported negative responses, such as “fear, anxiety, and lack of confidence” (Mohammad Yusof & Tall, 1999, p. 67). However, after completing the course on cooperative problem solving, majority of the participants displayed more positive attitudes toward math. Thus the results from the study suggest that students’ attitudes are dependent on the learning environment that is provided during instruction (Mohammad Yusof & Tall, 1999).

Field Observations

Teachers’ understandings and their responses to the diverse needs of students are important in establishing supportive learning environments (Stough & Palmer, 2003). Teachers’ ratings and observations of students’ behaviours are considered appropriate practices to monitor students’ understandings and to address students’ needs (e.g., Bryant, Bryant, & Hammill 2000). Bryant et al. (2000) examined the success of teachers’ observations in identifying math weaknesses of students with LD. The findings were compared to literature on mathematics learning disabilities. The study collected observations on 1724 students with LD from 391 special education teachers. The overall findings validated the existing literature on math weaknesses identified by researchers. For example, general math weaknesses identified by the teachers included: (a) students’ not recognizing math operation signs, such as addition or subtraction; (b) students’ reversing numbers in problems; and (c) students taking a long time to solve multi-step calculations (Bryant et al., 2000). The overall findings by Bryant et al. (2000) revealed the success of teacher observations in identifying student difficulties in math classrooms. As an educator, with Intermediate and Senior in mathematics and physics, I
therefore decided to collect field observations on students’ mannerisms in order to identify students’ positive/negative responses and their understanding of the material. The field observations were collected during the group instruction on CSI and GOs.

Summary of Literature

A review of literature has revealed the importance of cognitive and metacognitive strategies and processes for mathematical problem solving (e.g., Mayer, 1985; Sternberg, 1994). Cognitive strategies and processes for mathematical problem solving are procedural methods or tools that help individuals plan and solve a problem (e.g., finding the algorithm; Montague & Bos, 1990). Metacognitive strategies and processes for mathematical problem solving include: (a) self-instruction; (b) self-monitoring; and (c) self-questioning (Montague et al., 2000). Evidence suggests that many students in general, and especially those with learning disabilities, have trouble using cognitive and metacognitive strategies and processes in areas such as problem solving (Krawec et al., 2012). Research on mathematics interventions has therefore stressed the importance of examining effective instructional practices to support students with math difficulties (Jitendra, 2013).

Research on mathematics interventions has indicated the effectiveness of Cognitive Strategy Instruction (CSI) for supporting students with math difficulties in areas such as problem solving (Maccini et al., 2007). For example, Montague (2003) developed a Cognitive Strategy program called Solve it! to improve students’ math word problem solving skills (see also Montague, 1992; Montague, Applegate, & Marquard, 1993; Montague & Bos, 1986). Additionally, research on graphic organizers (GOS) has also been shown to support students with math difficulties (e.g., Ives, 2007). GOS are visual displays or charts that depict “spatial arrangements of words (or word groups)” (Stull & Mayer, 2007, p. 810). However, the three
studies, which contributed to the design of the Solve it! program (Montague, 1992; Montague, Applegate, & Marquard, 1993; Montague & Bos, 1986), did not provide GOs to the student participants. Therefore, the purpose of this research study was to determine if CSI with the use of GOs could help improve the word problem solving performance of Grade 8 students experiencing difficulties in mathematics.

Supporting students’ learning in math classrooms is not restricted to skill development and knowledge (The National Mathematics Advisory Panel, 2008). It is also important to understand students’ affective factors (e.g., student feelings and self-beliefs) in order to promote student engagement and confidence (Schoenfeld, 1983, 1989, 1992). Research on strategy-focused instruction has revealed its effectiveness in fostering students’ academic self-perceptions in curriculum classrooms (e.g., Meltzer et al., 2004). Additionally, providing a supportive learning environment has been shown to improve students’ attitudes toward math (e.g., Mohammad Yusof & Tall, 1999). In addition to the aforementioned, conducting teacher observations is considered a successful approach in identifying student math weaknesses (e.g., Bryant et al., 2000).
Chapter 3

Methodology

The purpose of this study was to examine the effectiveness of an intervention approach called Cognitive Strategy Instruction (CSI) with the support of graphic organizers (GOs). The intention of the research was to determine if CSI with the use of GOs could help improve the word problem solving performance of Grade 8 students experiencing difficulties in mathematics. Student mannerisms and student feelings toward mathematical problem solving were also examined in this study. The following research questions were investigated: (1) How did the students perform on the math word problem solving quiz before the instruction and after the instruction on CSI training with GOs? (2) How do students’ feelings toward mathematical problem solving compare before and after receiving training on CSI with GOs? (3) How do students’ knowledge, use, and control of the seven cognitive strategies and processes compare before and after receiving training on CSI with GOs? (4) How do students’ mannerisms compare during the group instruction on CSI with GOs?

This research was initially designed as a quantitative study. I initially proposed a two-group comparison study of approximately 20 Grade 9 students with significant difficulties in mathematics. Students from the first group were to receive training on CSI with the use of GOs. Students from the second group were to receive training only in CSI. Due to the small sample size of my research ($N = 3$), this study later transitioned into a qualitative-based study. Qualitative-based studies allow researchers to examine multiple perspectives to help them better understand the complex nature of human behaviour. Qualitative-based studies also allow researchers to document information directly from the source and the opportunity to discover and explain patterns or themes related to the phenomena (McMillan & Schumacher, 2010).
Due to the qualitative nature of this study, the findings were not analyzed through statistical measures, such as effect sizes and ANOVAs. Instead, the findings were interpreted based upon teacher observations and teacher perceptions of students’ math performance and on students’ perceptions of their math performance during the intervention training on CSI with the use of GOS.

**Data Collection**

**Recruitment and Participants**

Three female, Grade 8 students (mean age 13.3 years) participated in this study. The students were recruited from one Public Elementary School in Eastern Ontario through convenience-sampling methods. They were selected with the help of the school’s Principal, Vice Principal, and two classroom math teachers. The recruitment procedure for this study was important for several reasons. First, most classroom teachers regularly monitor students’ progress and understanding by using a variety of assessments (e.g., classroom discussions, peer interactions, and formal evaluations). Classroom teachers can thereby, provide an understanding of students’ underlying academic strengths and weaknesses. Additionally, many school Principals and Vice Principals gather information about each student’s individual learning needs in order to provide additional classroom support (Bennett, Dworet, & Weber, 2013).

The three students had an Individual Education Plan and demonstrated significant learning difficulties in mathematics. The students’ performances in mathematics were identified by the Public Elementary School to be either at or below the Ontario Grade 6 level mathematics curriculum expectations. The three students received a modified mathematics course at the Public Elementary School that addressed their individual needs. For this study, the three students were given the following pseudonyms: Britney, Jena, and Megan.
Ethical clearance was obtained from the Education Research Ethics Board and General Research Ethics Board at Queen’s University in Kingston, Ontario. Ethical clearance was also received from the participating District School Board. Written consent was received from all student participants and from all students’ parents/guardians. Participation was voluntary. See Appendix A for a copy of the letter of information and consent form that was submitted to all student participants and to students’ parents/guardians.

**Recruitment Limitations**

The recruitment of students for my study was very challenging. This research initially proposed a two-group comparison study of approximately 20 Grade 9 students with difficulties in mathematics.

From October 2014 to January 2015, I approached ten schools from one District School Board and two schools from one Separate School Board in Eastern Ontario. I also approached a tutoring centre and an organization that catered to students with learning disabilities. I approached many math teachers, Principals, and Vice Principals. I also spoke to a school official from the District School Board and a representative from the Ontario Ministry of Education. Despite my many efforts, it became clear that most of the teachers were unwilling to support my research. Many teachers felt that my study was an overwhelming undertaking and would pose a potential challenge in recruiting participants. I was even told by a math teacher from a low-performing school, that she did not have any struggling students in her class. It was disillusioning to have received minimal support and cooperation from schools.

I was only able to recruit one Grade 9 student who decided to leave the study after one session. I therefore had to open my study to students from Grades 7 to 10. With the help of an interested and cooperative Vice Principal of a Public Elementary School, I was able to recruit
three Grade 8 students. Admittedly, the small sample size of this research \((N = 3)\) is a limitation. Large sample sizes are generally encouraged for intervention studies because it increases the power and lowers the error of measurement (Vogt, 2007). I however, exhausted all possible options in recruiting students.

**Study Duration**

Data collection occurred over the course of 18-weeks from January 26, 2015 to May 25, 2015. This study was conducted three times a week (Monday, Wednesday, and Friday) with approximately 50 minutes of class time per session. For each 50-minute session, the instruction was approximately 40 minutes long. On a few occasions, the study’s schedule changed to one or two sessions per week because the students were either absent or were away on school field trips or holidays. This study was divided into three parts: (a) a 2-week period for pre-tests and one session introducing the study; (b) a 13-week intervention; and (c) a 3-week period for post-tests immediately following the intervention. I administered all instruction. Figure 5 provides a schematic diagram of the study (see also Appendix B for a complete outline of the instructional components of the study).

<table>
<thead>
<tr>
<th>2 weeks</th>
<th>13 weeks</th>
<th>3 weeks</th>
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<tbody>
<tr>
<td><strong>Pre-tests</strong></td>
<td><strong>Intervention</strong></td>
<td><strong>Post-tests</strong></td>
</tr>
<tr>
<td>• Individual Interviews (Entrance) *</td>
<td>(32 sessions)</td>
<td>• Math word problem solving quiz **</td>
</tr>
<tr>
<td>• Math word problem solving quiz**</td>
<td></td>
<td>• Individual Interviews (Exit)*</td>
</tr>
</tbody>
</table>

*Figure 5. Outline of study with included measures.*

*Note. *Based on Mathematical Problem Solving Assessment-Short Form (MPSA-SF, Montague, 1996). ** Based on Grade 6, Education Quality and Accountability Office assessments (EQAO)*
The time length of the instructional sessions (i.e., 50 minutes of class time per session) was selected for this research because it closely models a typical instructional period in today’s Grades 1 to 12 classrooms. In addition, a review of cognitive interventions in mathematics for middle school and secondary school students with learning disabilities (LD) have reported the effectiveness of short, instructional class periods to support students’ learning (Maccini et al., 2007). For example, Xin, Jitendra, and Deatline-Buchman (2005) examined the differential effects of Schema Based Instruction (SBI) and General Strategy Instruction (GSI) on 22 middle school students who had LD or who were at risk for failure in mathematics. Maccini and Ruhl (2000) included 12 sessions of instruction with 60 minutes of instruction per session. Likewise, a multi-probe design study examined the effectiveness of a type of cognitive instruction called STAR strategy instruction to three Grade 8 students with LD. The study included 18 to 21 sessions with 20 to 30 minutes of instruction per session (Maccini & Ruhl, 2000).

**Study Location**

The three participants were pulled out of their mathematics and music classrooms three times a week. The study was mainly held in the resource room. The resource room was a quiet space in the school, which contained a large table with chairs, large windows, and tall bookcases with teaching resources. On a few occasions, the study was held in the staff room or in the Vice Principal’s office.

**Materials**

I provided the materials during the study. The three participants were administered graphics organizers (GOs), individual booklets, and school supplies (e.g., calculators and pencils). Table 2 and Table 3 outline all materials that were provided during the study. I collected all materials at the end of each session (e.g., student booklets and GOs). All feedback
regarding students’ progress and understanding was provided during the daily lessons. I did not mark students’ work after the lessons.

Table 2

*Materails for the 13-week intervention*

<table>
<thead>
<tr>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>32 sessions</td>
</tr>
<tr>
<td>Daily lesson plans</td>
</tr>
<tr>
<td>Math exercises (one-step and two-step word problems)</td>
</tr>
<tr>
<td>Handout of metacognitive prompts on the seven cognitive strategies and processes</td>
</tr>
<tr>
<td>Graphic organizers (GOs)</td>
</tr>
<tr>
<td>Posters of metacognitive prompts on the seven cognitive strategies and processes</td>
</tr>
<tr>
<td>Handout on rules for rounding</td>
</tr>
<tr>
<td>Student booklets</td>
</tr>
<tr>
<td>Whiteboard</td>
</tr>
<tr>
<td>School supplies (e.g., calculators and pencils)</td>
</tr>
</tbody>
</table>

Table 3

*Materails for pre-tests and post-tests*

<table>
<thead>
<tr>
<th>Pre-tests</th>
<th>Post-tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual Interview</td>
<td>Interview questions (modified MPSA-SF)</td>
</tr>
<tr>
<td></td>
<td>Audio-recording devises</td>
</tr>
<tr>
<td></td>
<td>School supplies (e.g., calculators and pencils)</td>
</tr>
<tr>
<td>Word Problem Solving Quiz</td>
<td>Mini-quizzes (7 one-step, 7-two-step, and 7 three-step word problems)</td>
</tr>
<tr>
<td></td>
<td>School supplies (e.g., calculators and pencils)</td>
</tr>
<tr>
<td></td>
<td>Interview questions (modified MPSA-SF)</td>
</tr>
<tr>
<td></td>
<td>Audio-recording devises</td>
</tr>
<tr>
<td></td>
<td>Graphic organizers (GOs)</td>
</tr>
<tr>
<td></td>
<td>Handout of metacognitive prompts on the seven cognitive strategies and processes</td>
</tr>
<tr>
<td></td>
<td>Posters of metacognitive prompts on the seven cognitive strategies and processes</td>
</tr>
<tr>
<td></td>
<td>Handouts on rules for rounding</td>
</tr>
</tbody>
</table>
Graphic organizers.

Handouts of partially completed graphic organizer (GOs) were administered to the three participants during each lesson and on the post-tests. The GOs displayed the seven cognitive strategies and processes within a flow chart template. Cues were also provided on the GOs to help the students monitor their performance and to help them make connections between the problem solving steps (see Appendix F).

Measures

Two different measures were administered a few weeks before and immediately following the 13-week intervention: (a) individual interviews and (b) math word problem solving quiz. The individual interviews were based on a modified version of the Mathematical Problem Solving Assessment-Short Form (MPSA-SF; Montague, 1996). The math word problem solving quiz was based on Grade 6 Education Quality and Accountability Office (EQAO) assessments. A summary of the pre- and post-tests are reported in this section.

Pre-tests.

Individual interviews.

A modified version of the MPSA-SF (Montague, 1996) was administered as a baseline measure to assess students’ self-perceptions of their math performance, attitudes toward mathematical problem solving, and their knowledge, use, and control of the seven cognitive strategies and processes. Students’ knowledge referred to their awareness of problem solving strategies and processes (Montague & Bos, 1990). Students’ use referred to the selection of appropriate strategies, while students’ control referred to their abilities to evaluate and modify their performance (Montague & Bos, 1990).

The MPSA-SF is a shorter version of the MPSA. The MPSA was used in four
interventions on Cognitive Strategy Instruction (CSI) for middle school students with LD (e.g., Montague & Applegate, 1993; Montague & Bos, 1990; Montague, Bos, & Doucette, 1991; Montague, Marquard, & LeBlanc, 1993). It is considered an effective tool for examining students with varying abilities in mathematical problem solving (e.g., average and above-average students and students with LD; Montague, 1996). MPSA-SF is a two part standardized open-ended interview. It contained 5 Likert-type items, 35 open-ended questions, and three word problems (1 one-step, 1 two-step, and 1 three-step word problem). In total, MPSA-SF measures eight variables: (a) perceptions of math performance; (b) attitudes towards math; (c) attitudes toward math problem solving; (d) general knowledge of math problem solving skills before the interview; (e) knowledge of problem solving strategies; (f) use of problem solving strategies; (g) control of problem solving strategies; and (h) general knowledge of strategies and processes after the interview (Montague, 1996).

Before starting data collection, five components of the MPSA-SF were revised. First, three of the eight variables were removed from the MPSA-SF: (a) attitudes toward math; (b) general knowledge of math problem solving skills before the interview; and (c) general knowledge of strategies after the interview. These variables were removed in order to make the interview align more with the research focus. Second, the grammatical structure (i.e., text written in past tense as opposed to present tense) and the wording of the questions were changed to accommodate any difficulties participants might have in comprehending the information. These questions were modified following the original MPSA questions that were administered in an intervention study on CSI in math problem solving to students with varying abilities (e.g., low-achieving students, high achieving students, and students with LD; Montague & Bos, 1990). For example, the question regarding students’ knowledge of computation (“What goes on in your
head as you compute?”) was rephrased to: “What did you think about when you solved the word problem?” Third, the three word problems, which are shown to participants at the start of interview, were removed to provide additional time for participants to think about and answer the interview questions. Fourth, to make the instructions understandable to the participants, the scoring procedure for the third Likert-type question was changed from a four-point scale (i.e., Not at all; ¼ of the time; ½ of the time; and always) to a five-point scale (i.e., 1 = Strongly Disagree to 5 = Strongly Agree). Fifth, the scoring scale for the 29-open ended responses was removed to make the questions easier to interpret.

In total the modified version of the MPSA-SF for this study contained 3 Likert-type questions, 3 types of word problems (1 one-step, 1 two-step, and 1 three-step word problem), and 29 open-ended responses. The 3 types of word problems (1 one-step, 1 two-step, and 1 three-step) were based on Grade 6 EQAO, mathematics assessments. The individual interviews were conducted by me and occurred before and after the 13-week intervention. The individual interviews were audio-recorded and took approximately 40 minutes to complete. After the interview sessions, the individual interviews were transcribed verbatim and analyzed.

*Revisions of interview questionnaire during data collection.*

During the first individual interview, I had to rephrase 10 of the 29 open-ended response questions to help the participant (Jena) comprehend the instructions and answer the questions. For example, the question regarding student’s knowledge of the first cognitive strategy (Read; “As you read the problem, how did you help yourself understand the problem?”) was rephrased to: “As you read the problem, did you do anything to help you understand the problem?” In addition, I provided prompt questions to gather additional information about Jena’s knowledge, use, and control of the seven cognitive strategies. For example, when I asked Jena how she
solved the math problems (“How did you make a plan to solve the math word problem?”), I guided her to look at their answer sheets and asked her the following prompt questions: (a) What did you do to solve the math problem? and (b) Did you have a plan for Question 1? This same approach was applied to the other two participants (Britney and Megan) in the individual interviews. See Appendix C for final version of modified MPSA-SF.

Before administering the individual interviews, I gave the students a calculator and explained how to use the calculators. I informed them that they would use calculators during the study to help them solve math problems. The reasons for administering calculators are two-fold. First, many students with significant difficulties in math demonstrate poor computational skills and are unable to recall number facts proficiently (Bryant et al., 2000). Second, calculators are permitted to all students during the EQAO assessments.

Math word problem solving quiz.

Following the individual interviews, I introduced the study to the participants in a group setting and explained students’ roles and responsibilities. I then explained what is math problem solving and why it is important. In addition, I provided a review on how to use calculators. Questions and comments about the study were addressed during the introductory session. Once everything was explained and understood, the math word problem solving quiz was administered. The quiz took approximately 30 minutes to complete and was based on Grade 6 EQAO mathematics assessments. A total of 21 questions (i.e., 7 one-step, 7 two-step, and 7 three-step word problems) were administered (see Appendix D).

To support increased variability in scores on the math word solving quiz, I administered the quiz in three parts. Each part focused on one type of word problem (i.e., one-, two-, or three-step problems). Students were given 10 minutes to complete each part. To ensure that the
students did not rush when answering the math problems, I advised them to take their time and to solve as many of the questions they could within the time provided. Students were reminded that their performance on the quiz would not affect their class grade.

Post-tests.

Following the 13-week intervention, the math word problem solving quiz and individual interviews were conducted. The post-tests covered one-step and two-step math words problems. The one-step and two-step word problems were reworded on the post-tests to avoid practice effects. Practice effects refer to a “bias that is introduced at a second test session, due to familiarity with the test procedure and also the specific test items” (Bird, Papadopoulou, Ricciardelli, Rossor, & Cipolotti, 2003, p. 409). The post-tests did not include three-step math word problems because the intervention did not include an instruction on three-step problems.

The math word problem solving quiz was administered immediately following the 13-week instruction. The one-step and two-step math problems were administered to the students on separate days in order to provide them with enough time to answer the questions. Each quiz contained seven questions in total and took approximately 30 minutes to complete. Following the math word problem solving quiz, the individual exit interviews were then administered. The individual interviews were based on the modified MPSA-SF format. The individual interviews were conducted in the same manner as the pre-individual interviews. Refer to Appendix E for a copy of the post-individual interview and post-math word problem solving quiz.

Intervention

During the 13-week intervention, the three students (Britney, Jena, and Megan) participated in a group instruction for a total of 32 sessions and with a total of 1600 minutes of class time (approximately 3 sessions per week with each session containing 50 minutes of class
time). The participants received instruction on Cognitive Strategy Instruction (CSI) with graphic organizers (GOs) applied to one- and two-step math word problems. The one- and two-step word problems were based on math word problems from the Grade 6, EQAO mathematics assessments. Due to time constraints, the study did not provide instruction on three-step math word problems (see Appendix B for an outline of 13-week intervention).

The one- and two-step word problems were simple division problems. The math problems followed a tiered approach. The one-step word problems contained one procedural step to solve the final solution. The two-step word problems modeled one-step problems, but contained an additional procedural step. Figure 6 provides an example of a one-step and two-step math word problem.

A. One-step word problem: John buys 2 ice-cream cones for $2.86. How much does one ice-cream cone cost?

B. Two-step word problem: Emily buys 6 ice-cream cones for $8.76. At this rate, how much will it cost to buy three ice-cream cones?

Figure 6. Examples of word problems

One-step word problems.

Sessions 1 to 23 focused on the cognitive-metacognitive model for solving one-step word problems. Each session focused on at least two cognitive strategies and processes and their associated metacognitive components. Figure 7 provides an outline of the metacognitive prompts for the two cognitive strategies and processes (see also Appendix G for an outline of the metacognitive prompts describing the seven cognitive strategies and processes). The
metacognitive prompts were adapted from Montague (1996) and were reworded before data collection to accommodate any difficulties participants might have in comprehending the instructions. For example, the prompt under Read (“Check: For understanding as I solve the problem”) was rephrased to: “Check: Do I understand all information and instructions as I solve the problem?”

<table>
<thead>
<tr>
<th>Metacognitive Prompts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Read</strong></td>
</tr>
<tr>
<td><strong>SAY (self-instruction):</strong> Read the problem. If I don’t understand, read it again.</td>
</tr>
<tr>
<td><strong>Ask (self-question):</strong> Have I read and understood the problem?</td>
</tr>
<tr>
<td><strong>Check (self-monitor):</strong> Do I understand all information and instructions as I solve the problem?</td>
</tr>
<tr>
<td><strong>Paraphrase</strong></td>
</tr>
<tr>
<td><strong>SAY (self-instruction):</strong> Underline the important information. Put the problem in my own words.</td>
</tr>
<tr>
<td><strong>ASK (self-question):</strong> Have I underlined the important information? What is the question? What am I looking for?</td>
</tr>
<tr>
<td><strong>CHECK (self-monitor):</strong> Does the information go with the question?</td>
</tr>
</tbody>
</table>

*Figure 7. Metacognitive prompts for Read and Paraphrase*

The following sections describe the instructional sessions of CSI training with GOs for one-step math word problems (see Appendix H for individual lesson plans on one-step word
problems that I designed for the study).

**Session 1 to 5: read & paraphrase.**

During Sessions 1 to 5, the students learned the two cognitive strategies and processes (Read and Paraphrase) and the three associated metacognitive prompts for one-step word problems. The GOs included a single-page handout with the two cognitive strategies (Read and Paraphrase).

In Session 1, I demonstrated on the whiteboard how to use GOs. I also modeled how to use the metacognitive prompts for each cognitive strategy and process. For example, I explained how to identify the important words and phrases in the problems and how to rephrase the math problems. Overall, Session 1 included 40 minutes of instructor modeling with guided practice. The participants copied the notes from the whiteboard and recorded the information on the GOs. The participants had the opportunity to answer questions directed by me. Questions and comments were addressed. I provided feedback. This same approach was followed in Sessions 2 and 3.

In Session 4, I reviewed the previously taught skills and provided instructor modeling with guided practice for 10 minutes. Participants were then provided a second worksheet to practice the two cognitive strategies and processes (Read and Paraphrase) during an independent practice exercise. The participants were advised to use the metacognitive prompts to monitor their understanding. During this time, I monitored the students’ progress and provided feedback. For example, I asked the students different prompt questions to monitor their understanding of the material (e.g., “Did you put the problem in your own words?” and “How did you check your work?”). If frequent errors or misunderstandings were noticed across participants, I stopped the independent study and modeled the correct approach on the whiteboard. I attempted to provide
similar attention to each participant. Following 30 minutes of independent practice, 10 minutes of class discussion was provided. The students volunteered modeling the strategies and processes on the whiteboard. I provided feedback and addressed all questions and comments. This same approach was followed in Session 5.

**Sessions 6 to 10: read, paraphrase, visualize, & hypothesize.**

In Sessions 6 to 10, I reviewed the previously taught skills and introduced the next two cognitive strategies and processes (Visualize and Hypothesize). Participants were given a two-page GO, which outlined the four cognitive strategies and processes: Read, Paraphrase, Visualize, and Hypothesize. The sessions followed the same instructional approach as Sessions 1 to 5 (i.e., instructional modeling with guided practice, independent practice, and class discussions). In Session 6, I provided a lesson on the four types of operations (addition, subtraction, multiplication, and division). The participants did not respond positively to the instruction. The students understood the concepts of addition and subtraction, but did not understand the difference between division and multiplication.

To alleviate the students’ frustration and to help them understand the material, I changed my instructional approach. I used simpler language and taught the participants tricks. I informed the students that the phrases in the word problems “How much does each item cost?” or “What is the cost of each item?” meant division. These phrases or cues reminded the students to use division to solve the math word problems.

**Sessions 11 to 16: read, paraphrase, visualize, hypothesize, & estimate.**

In Sessions 11 to 16, participants learned the fifth cognitive strategy and process (Estimate). The participants were taught two rules for rounding: (a) if the cost has zero cents, round the number up or down by counting by 10’s and (b) if the total cost has cents, round the
number up or down by counting by 1’s. For example, if the total cost was $11.00, then we would round the number down to $10.00 (Rule a). However, if the total cost was $3.99, then we would instead round the number up to $4.00 (Rule b). The participants were not expected to memorize the rules for rounding. They were provided during the lessons and on the post-tests (See Appendix I).

During Sessions 11 to 16, I administered a three-page GO to the three participants. The GO handouts outlined the five cognitive strategies and processes: Read, Paraphrase, Visualize, Hypothesize, and Estimate. The sessions followed the same instructional design as described above (i.e., instructional modeling with guided practice, independent practice, and class discussion).

**Sessions 17 to 23: read, paraphrase, visualize, hypothesize, estimate, compute, & check**

Sessions 17 to 23 introduced the last two cognitive strategies and processes (Compute and Check). The participants learned how to calculate the final solutions and learned how to check their work. The GOs contained the seven cognitive strategies and processes: Read, Paraphrase, Visualize, Hypothesize, Estimate, Compute, and Check.

**Two-step word problems.**

During the remaining sessions, students learned how to solve two-step word problems. I followed the same instructional approach that was applied for one-step word problems (e.g., instructor modeling with guided practice, independent study, and class discussions). The students used the same GOs that were provided during the instruction on one-step word problems. One student (Megan) learned the seven cognitive strategies and processes for two-step word problems. Due to time constraints, Britney and Jena were not taught the last two cognitive strategies and processes (Compute and Check) for two-step word problems.
Field Observations

During the 13-week intervention, I recorded field observations on students’ mannerisms. Students’ mannerisms included students’ positive and negative responses and their understanding of the material during the group instruction. As explained by McMillan and Schumacher (2010), field notes are important to assure the fidelity of the intervention because “extraneous variables can affect not only the results but also the nature of the intervention” (p. 263). This procedure is also a form a triangulation, which has the effect of enhancing the credibility and trustworthiness of the research findings and analysis (McMillan & Schumacher, 2010).

One-to-One Tutoring

On a few occasions, some participants were absent from school. In addition, one student (Britney) required additional one-to-one tutoring to help her solve one-step word problems. To support these students’ learning, I met with them individually for 50 minutes at different times during the week. I followed the same instructional approach that was used during the group instruction (e.g., instructional modeling with guided practice, independent practice, and class discussions).

Motivation

To motivate the students’ engagement throughout the study, they received various incentives. First, at the end of every lesson, the students received a sticker to decorate their individual booklets. Second, I provided snacks on one or two sessions per week. Third, the students each received a $15 gift certificate to McDonalds for participating after completing the post-tests.

After School Practice Exercises

The three students asked for additional practice exercises while they were away on March
Break. One student (Megan) also asked for practice exercises during a week of no instruction. I prepared individual booklets with practice exercises for each student. Students’ work was taken up during class time.

**Data Analysis**

Data were examined from the pre- and post-measures: (a) individual interviews and (b) math word problem solving quiz. In addition, the field observations from the 13-week intervention were examined. Data were analyzed to answer the four research questions: (1) How did the students perform on the math word problem solving quiz before the instruction and after the instruction on CSI training with GOs? (2) How do students’ feelings toward mathematical problem solving compare before and after receiving training on CSI with GOs? (3) How do students’ knowledge, use, and control of the seven cognitive strategies and processes compare before and after receiving training on CSI with GOs? (4) How do students’ mannerisms compare during the group instruction on CSI with GOs? Due to the small sample size, data were not analyzed using statistical measures. This study instead used a qualitative approach to interpret the research findings.

**Pre- and Post-Intervention Math Word Problem Solving Quiz**

To examine students’ performances on the math word problem solving quiz before the instruction and after the instruction on CSI training with GOs, students’ individual scores on the pre- and post-math intervention quiz were tallied. Student scores represented the total number of problems solved correctly on the pre- and post-intervention quiz. Student scores were visually displayed through bar charts. The results were examined to determine if there were any changes in students’ performances on the pre- and post-intervention quiz.
**Students’ Feelings toward Mathematical Problem Solving**

To compare students’ feelings toward mathematical problem solving before and after receiving training on CSI with GOs, students’ responses from the three, Likert-type questions in the pre- and post-individual interviews (modified MPSA-SF; Montague, 1996) were examined. Students’ feelings focused on students’ self-perceptions of their math ability and their attitudes toward mathematical problem solving. In addition, students’ written responses regarding their enjoyment in solving math word problems were recorded verbatim to examine if there existed any changes in students’ attitudes toward mathematical problem in the pre- and post-individual interviews.

**Students’ Knowledge, Use, and Control of the Seven Cognitive Strategies and Processes**

To compare students’ knowledge, use, and control of the seven cognitive strategies and processes before and after receiving training on CSI with GOs, the 29 open-ended responses from the pre- and post-individual interviews (modified MPSA-SF; Montague, 1996) were categorized and examined (see Table 4) following guidelines from the original MPSA-SF.

Table 4

*Table for categorizing the 29-open ended responses*

<table>
<thead>
<tr>
<th>Metacognitive Components</th>
<th>Knowledge</th>
<th>Use</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paraphrase</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visualize</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypothesize</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compute</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Students’ Mannerisms during CSI and GO Training

To examine students’ mannerisms during the group instruction on CSI with GOs, the field observations were analyzed using an inductive approach. This approach identified patterns, themes, and categories of three participants (Patton, 2002). Students’ mannerisms focused on their positive and negative responses and their understanding of the material during the CSI with GO’s instruction.
Chapter 4

Results

The purpose of this study was to examine the effectiveness of an intervention approach called Cognitive Strategy Instruction (CSI) with the support of graphic organizers (GOs). This study aimed to determine if CSI with the use of GOs could help improve the word problem solving performance of Grade 8 students experiencing difficulties in mathematics. This study also examined student mannerisms and student feelings toward mathematical problem solving.

The focus of this chapter is to examine the following research questions: (1) How did the students perform on the math word problem solving quiz before the instruction and after the instruction on CSI training with GOs? (2) How do students’ feelings toward mathematical problem solving compare before and after receiving training on CSI with GOs? (3) How do students’ knowledge, use, and control of the seven cognitive strategies and processes compare before and after receiving training on CSI with GOs? (4) How do students’ mannerisms compare during the group instruction on CSI with GOs?

Pre- and Post-Intervention Math Word Problem Solving Quiz

The results in Figure 8 provide a visual representation of students’ scores from the pre- and post-intervention quiz on one-step math word problems. All three participants achieved a score of zero on the pre- and post-intervention quiz on two-step math word problems, therefore these results are not graphed.
As shown in Figure 8, Britney received a score of zero on the pre- and post-quiz on one-step math word problems. Jena also received a score of zero on the pre-quiz, one-step math word problems; however, following the 13-week intervention, Jena obtained a score of three on the post-quiz. That is, Jena solved three, one-step math word problems correctly on the post-quiz. Likewise, Megan improved her performance in solving one-step math word problems after the 13-week intervention. Megan received a score of one on the pre-quiz (i.e., solved one problem correctly) and achieved a score of three on the post-quiz (i.e., solved three problems correctly). Figure 9 provides a sample of students’ answers on the pre-intervention quiz for one-step math word problems (see also Appendix J for a sample of students’ answers on the post-intervention quiz for one-step word problems).
A. Word problem given: A store sells 10 apples for $1.50. How much does one apple cost?

Britney’s incorrect answer

\[
\begin{align*}
\text{I think it is$8.5 because I took away$1.50 from$1.50.}
\end{align*}
\]

B. Word problem given: A store sells 10 apples for $1.50. How much does one apple cost?

Jena’s incorrect answer

\[
\begin{align*}
\text{I think the answer is$8.5 because if you do} \, 10 - 1.50 \, \text{it is$8.5 one apple is$8.5 cents.}
\end{align*}
\]

C. Word problem given: A store sells 10 apples for $1.50. How much does one apple cost?

Megan’s incorrect answer

\[
\begin{align*}
10 \div 1.50 &= 6.7 \\
\text{So one apple costs 67¢.}
\end{align*}
\]

D. Word problem given: John buys 2 ice cream cones for $2.86. How much does one ice cream cone cost?

Megan’s correct answer

\[
\begin{align*}
2 \div 2 = 1.43 \\
\text{So for one ice cream cone it would be$1.43.}
\end{align*}
\]

Figure 9. Students’ answers on the pre-intervention quiz for one-step math word problems

Students’ Feelings toward Mathematical Problem Solving

Students’ responses from the three, Likert-type questions in the pre- and post-individual interviews (modified MPSA-SF; Montague, 1996) were examined to investigate if there were
any changes in students’ feelings toward mathematical problem solving. Students’ feelings focused on their self-perceptions of their math ability and their attitudes toward mathematical problem solving. Students’ responses are presented in Table 5.

Table 5

*Students’ feelings toward mathematical problem solving in the pre- and post-individual interviews*

<table>
<thead>
<tr>
<th></th>
<th>Pre-Individual Interview</th>
<th>Post-Individual Interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Describe your math skills</td>
<td>Britney “Poor”</td>
<td>Britney “Poor”</td>
</tr>
<tr>
<td></td>
<td>Jena “Poor”</td>
<td>Jena “Poor”</td>
</tr>
<tr>
<td></td>
<td>Megan “Average”</td>
<td>Megan “Average”</td>
</tr>
<tr>
<td>Describe how well you solve</td>
<td>Britney “Average”</td>
<td>Britney “Good”</td>
</tr>
<tr>
<td>math word problems</td>
<td>Jena “Poor”</td>
<td>Jena “Average”</td>
</tr>
<tr>
<td></td>
<td>Megan “Good”</td>
<td>Megan “Good”</td>
</tr>
<tr>
<td>I enjoy solving math word</td>
<td>Britney “Somewhat Disagree”</td>
<td>Britney “Agree”</td>
</tr>
<tr>
<td>problems</td>
<td>Jena “Somewhat Disagree”</td>
<td>Jena “Somewhat Disagree”</td>
</tr>
<tr>
<td></td>
<td>Megan “Neither Agree or</td>
<td>Megan “Strongly Agree”</td>
</tr>
<tr>
<td></td>
<td>Disagree”</td>
<td></td>
</tr>
</tbody>
</table>

Regarding students’ self-descriptions of their math skills, all three students did not change their responses in the pre- and post-individual interviews. Britney and Jena both reported that their math skills were “poor” in the pre- and post-individual interview (see Table 5). Likewise, Megan reported that her math skills were “average” in the pre- and post-individual interviews. Both Britney and Jena however, reported a change in the post-individual interview about how well they solve math word problems. Britney reported that she was “average” in solving math word problems in the pre-individual interview, but in the post-individual interview Britney reported that she was “good” in solving math word problems. Similarly, Jena reported that she was “poor” in solving math word problems in the pre-individual interview, but stated
that she was “average” in solving math word problems in the post-individual interview. Megan did not change her response in the pre- and post-individual interviews. Megan reported that she was “good” in solving math word problems in the pre-individual interview as well as in the post-individual interview.

The three students also answered a five-point, Likert-scale question about their attitudes toward mathematical problem solving. The students provided a written response to explain their answers in the pre- and post-individual interviews. Britney reported a change in attitude in the pre- and post-individual interviews. In the pre-individual interview, Britney reported that she “somewhat disagreed” with the statement, “I enjoy solving math word problems.” She wrote, “Because I sometimes don’t understand the question that it asks me.” However, in the post-individual interview Britney stated that she “agreed” with the statement. Her written response was, “I choose 4 because it is fun solving math problem.” Jena however, did not change her response in the pre- and post-individual interviews. Jena reported that she “somewhat disagreed” with the statement, “I enjoy solving math word problems” in the pre- and post-individual interviews. In the pre-individual interview, Jena stated, “I don’t like solving math word problems because sometimes they are too hard.” In the post-individual interview her written response was, “I chose number two because sometimes the question I get is hard and I don’t understand.” Similar to Britney, Megan also reported a change in attitude in the pre- to post-individual interviews. In the pre-individual interview, Megan responded “neither agree or disagree” with the statement, “I enjoy solving math word problems.” She wrote, “I can’t exactly agree or disagree because I have not done many math word problems but if I did them more often I would agree.” However, in the post-individual interview Megan reported to “strongly agree” with the statement. Her written response was, “I chose number 5 because when I use grafic [sic]
organizers it helps me solve the word problems and this study has helped me by the posters, white board and all the lessons.”

Students’ Knowledge, Use, and Control of the Seven Cognitive Strategies and Processes

The 29 open-ended response questions from the pre- and post-individual interviews (modified MPSA-SF; Montague, 1996) were examined to determine if there were changes in students’ knowledge, use, and control of the seven cognitive strategies and processes when solving one-step and two-step math word problems. Students’ knowledge referred to their awareness of problem solving strategies and processes (Montague & Bos, 1990). Students’ use referred to the selection of appropriate strategies, while students’ control referred to their ability to evaluate and modify their performance (Montague & Bos, 1990). A summary of students’ responses for each of the seven cognitive strategies and processes from the pre- and post-individual interviews is reported in this section. The pre- and post-interview recordings from Britney are reported first in the section below, followed by the recordings from Jena and Megan. See Appendix K for an outline of all students’ responses in the pre- and post-individual interviews.

Britney’s item responses.

Britney was asked questions about her knowledge of the first cognitive strategy and process, Read. In both the pre-individual interview and the post-individual interview, Britney reported that she did not know how she read the word problems. In addition, in the pre-individual interview Britney explained that she tried to understand the information in the word problems while reading the problems. She stated, “Well I thought what was it trying to say.” Likewise, in the post-individual interview Britney stated that while she was reading the word problems, she asked herself, “how I was going to answer the questions?”
Britney was then asked questions about her use of the first cognitive strategy and process, Read. Britney stated that she read the word problems two or three times in the pre-individual interview. In the post-individual interview Britney reported that she read the word problems only two times. Britney also reported that she re-read the word problems when she did not understand anything in both the pre- and post-individual interviews.

Britney only answered one question (Question 8) about her control of the first cognitive strategy and process, Read, in both the pre- and post-individual interviews. The question stated, “What questions did you ask yourself while you were reading the word problems?” In the pre-individual interview Britney reported that she asked herself, “What was it trying to say?” In the post-individual interview Britney explained, “I didn’t really ask myself questions because I knew what to do.”

Following the response questions about Britney’s knowledge, use, and control of the first cognitive strategy and process, Read, she was then asked question about her knowledge of the second cognitive strategy and process, Paraphrase. Britney gave different responses in the pre-individual interview and the post-individual interview about how she helped herself remember what the word problems said. In the pre-individual interview Britney stated, “I just like put it in my mind…what the question said.” On the post-individual interview Britney could not explain how she helped herself remember what the problems said. She explained, “It all came back to me.”

In regards to Britney’s use of the second cognitive strategy and process, Paraphrase, Britney stated that she did not put the word problems in her own words in the pre-individual interview. In the post-individual interview she said she paraphrased the one-step and two-step math word problems.
Britney’s control of the second cognitive strategy and process, Paraphrase, (Question 14) was skipped in the pre-individual interview because she did not paraphrase the word problems. In the post-individual interview Britney answered the paraphrase question “When you put the problems in your own words, how did you know what you said was correct?” Britney stated, “I looked back at the question sheet.” She did not provide further explanation.

Britney’s knowledge, use, and control of the third cognitive strategy and process, Visualize, (Questions 15 to 18) were skipped in the pre-individual interview because she did not draw pictures to solve the word problems. In the post-individual interview Britney drew pictures of the word problems on the graphic organizers (GOs). She explained that the pictures helped her check her work when she made a plan to solve the word problems (i.e., Hypothesize step). Britney also explained that she remembered the instructions I gave her during the 13-week instruction. She stated, “…when I was doing Hypothesize, you always told me to look back up here.” Britney pointed to her picture in the “Visualize” box on her GO. She then explained, “I looked back at the pictures. So like for number one at Hypothesize, it was $3.96 divided by two…and that finds the cost of one chocolate bar.”

Britney was then asked questions about her knowledge about the fourth cognitive strategy and process, Hypothesize. In the pre-individual interview, Britney stated, “I used my fingers and then I subtracted the question…what it was saying.” In the post-individual interview Britney explained that she wrote down “$1.92 divided by six equals…finds the cost of one apple” for the one-step word problem. She also explained that the phrase, “how much” meant division. Britney used these same responses to answer the interview questions about her use of the fourth cognitive strategy and process, Hypothesize.

Britney provided relatively basic explanations of her control of the fourth cognitive strategy
strategy and process, Hypothesize. She rarely provided deeper explanations. In the pre-individual interview Britney explained that she decided to use subtraction to solve the word problems because the problems asked, “how much does...” In the post-individual interview, Britney said that she used division to solve the one-step problem because the use of division finds the cost of one item. She stated, “Division… because you are trying to find out what is the cost.” Britney also mentioned that she used division and addition to solve the two-step word problem.

Britney stated that she understood what the fifth cognitive strategy and process, Estimate, meant in the pre-individual interview. However, the questions about estimation (Questions 24 to 26) were skipped in the pre-individual interview because Britney did not find an estimate. In the post-individual interview Britney answered the response questions about her knowledge, use, and control of this strategy and process. For example, in regards to her use of estimation, Britney stated that she rounded the numbers to help her predict the answers before calculating the final answer to the problems. For the one-step word problem she explained, “In Estimate, I circled one apple is about 33 cents and then I circle it and put an arrow… kind of… and then down to compute it’s like 32 cents… and that’s the answer.” Britney then stated, “My estimate is bigger than my answer because I rounded up.”

Britney provided relatively basic explanations about her knowledge, use, and control of the sixth cognitive strategy and process, Compute, in the pre-individual interview. Britney stated, “I used my fingers and subtracted the numbers.” Britney did not provide further explanation. In the post-individual interview Britney stated, “I need to look at instruction sheet.” The instruction sheet outlined the metacognitive prompts of the seven cognitive strategies and processes (see Appendix G).

For the remaining interview questions (Questions 30 to 32), Britney was asked questions
about the last cognitive strategy and process, Check. She understood what checking meant in both the pre- and post-individual interviews. In the pre-individual interview Britney could not answer the last questions because she did not check her solutions (Questions 31 and 32). In the post-individual interview, Britney explained that she used a calculator to check her solutions. For example, for the one-step word problem she stated, “I used a calculator… what I did was $1.92 divided and that finds the cost of one apple.”

**Jena’s item responses.**

Jena did not provide a clear explanation about her knowledge, use, and control of the first cognitive strategy and process, Read, in the pre-individual interview. Jena stated that she did not know how she understood the word problems (Question 6) and reported that she read the word problems five or six times (Question 5). However, in the post-individual interview Jena reported, “I wrote down what six apples mean and what four chocolate bars mean.” This approach helped her understand the one-step and two-step math word problems. Jena also stated that she read the word problems two times in the post-individual interview.

Jena was then asked questions about her knowledge of the second cognitive strategy and process, Paraphrase. In the pre-individual interview Jena stated that she kept “looking back” at the word problem in order to help her remember the information in the problems. The interview questions about paraphrase (Questions 12 to 14) were skipped in the pre-individual interview because Jena did not paraphrase the word problems. In the post-individual interview, Jena paraphrased the one-step and two-step math word problems. She also stated, “I kept it beside me…the question sheet and the steps on the other side.” This approach helped her remember the information in the word problems. Jena explained that “the steps” referred to the instruction sheet she used to solve the word problems. The instruction sheet outlined the metacognitive
prompts of the seven cognitive strategies and processes. Jena also explained, “I highlighted the numbers… six and $1.92 and four and $3.96.” This method helped Jena remember the information in the post-individual interview.

The interview questions regarding Jena’s knowledge, use, and control of the third cognitive strategy and process, Visualize, (Question 15 to 18) were skipped in the pre-individual interview because she did not draw pictures to solve the word problems. In the post-individual interview Jena drew pictures for the one-step and two-step math word problems on the GOs.

Jena stated that she “did not know” how to answer the questions about her knowledge and use of the fourth cognitive strategy and process, Hypothesize, in the pre-individual interview. In the post-individual interview however, Jena explained how she used the GOs to help her make a plan to solve the math problems. For the one-step word problem she stated, “I went to Hypothesize…I wrote down what division means and I said how much equals division. And $1.92 divided by six equals finds the cost of one apple.” For the two-step word problem Jena stated, “How much equals division? $3.96 divided by four equals the cost of one and…” Jena stopped talking and did not provide further explanation about how she solved the two-step word problem.

Jena was then asked questions about her control of the fourth cognitive strategy and process, Hypothesize. In the pre-individual interview she stated that she used subtraction to solve the word problems. Jena also explained why she chose subtraction instead of addition. She explained, “If you did addition on this question…it would be too big.” In the post-individual interview Jena reported that she used division to solve the one-step word problem. She stated, “I did how much equals division. $3.96 divided by four and then…the cost of one.” Jena also stated that she used division and addition to solve the two-step word problem.
The interview questions about Jena’s knowledge, use, and control of the fifth cognitive strategy and process, Estimate, (Questions 23 to 26) were skipped in the pre-individual interview because she did not find an estimate. In the post-individual interview Jena found an estimate to the math word problems. She however, stated that she “did not know” how she compared her estimate with her answer in the post-individual interview (Question 26).

Jena did not answer the questions about her knowledge and control of the sixth cognitive strategy and process, Compute, (Questions 27 and 29) in the pre-individual interview. She did answer the question about her use of computation in the pre-individual interview (Question 28). Jena explained that used addition and subtraction to solve the word problems. She stated, “I added them and subtracted them…I did addition and subtraction.” In the post-individual interview Jena stated that she used the calculator and used the GOs to help her solve the word problems.

The remaining questions, regarding Jena’s knowledge, use, and control of the last cognitive strategy and process, Check, were skipped in the pre-individual interview because she did not check her solutions. In the post-individual interview Jena reported that she compared her answer with the word problems to make sure she had correctly solved the problems.

**Megan’s item responses.**

Megan was able to answer more questions than Britney and Jena in both the pre-individual interview and the post-individual interview. Megan gave similar responses about her knowledge of the first cognitive strategy and process, Read, in both the pre- and post-individual interviews. Megan stated that she selected the numbers that were important in the word problems. For example, in the pre-individual interview she stated, “I… like… took the numbers… and then when I took the numbers, I figured out if it was subtracting, adding,
multiplying, and dividing.” In the post-individual interview Megan stated that she also looked at the posters and the instruction sheet. The posters and instruction sheet outlined the metacognitive prompts of the seven cognitive strategies and processes. Jena explained, “I went and looked at the question and looked at the step sheet and then looked at the posters.”

Regarding Megan’s use of the first cognitive strategy and process, Read, she stated that she read the word problems once or twice in the pre-individual interview. In the post-individual interview Megan stated that she read the word problems two or three times. In addition, in both the pre- and post-individual interviews, Megan reported that she continued reading the word problems and looked back at the information if she did not understand something. For example, in the post-individual interview she explained, “I went back and looked at it again…Like the question and what I did not understand.”

Megan also gave similar responses about her control of the first cognitive strategy and process, Read, in the pre-individual interview and post-individual interview. In the pre-individual interview Megan stated that she asked herself, “…which numbers are the most important?” while she read the word problems. In the post-individual interview Megan stated that she asked herself, “Have I read and understood the problem?”

Following the response questions about the first cognitive strategy and process, Read, Megan was then asked questions about her knowledge of the second cognitive strategy and process, Paraphrase. In the pre-individual interview she explained how she helped herself remember what the word problems said. She stated, “I took bits of pieces of it and like stuck it in my head to the back of my head.” In the post-individual interview Megan stated, “I just went back to the question if I forgot something instead of like trying to figure it out. So I went back and looked at the question.” Megan also stated that she looked at her work on the GOs to help
her remember the information in the word problems. She stated, “And I also looked back like if I was on Hypothesize, I went to Visualize and then Read and Paraphrase.”

Megan was then asked questions about her knowledge and use of the second cognitive strategy and process, Paraphrase. In the pre-individual interview she stated that she paraphrased the two-step math word problem. In the post-individual interview Megan stated that she paraphrased the one-step and two-step math word problems.

Megan did not provide a clear explanation about her use of the second cognitive strategy and process, Paraphrase, in the pre-individual interview. For example, for the paraphrase question “When you put the problems in your own words, how did you know what you said was correct?” (Question 14), she stated, “Well I don’t know. I just like figured it out if it was right…and I wrote it down.” In the post-individual interview Megan explained, “I just kind of like…checked everything. Like going from the questions to the graphic organizers to the information sheet and the posters.”

The interview questions regarding Megan’s knowledge, use, and control of the third cognitive strategy and process, Visualize, (Questions 15 to 18) were skipped in the pre-individual interview because she did not draw pictures of the one-step and two-step math word problems. In the post-individual interview Megan drew pictures to help her solve the word problems. She explained how her pictures on the GOs helped her solve the problems (Question 18). She stated, “Because I knew I had to find the cost of one apple. So I just drew six items because that’s how many items there are.” She then explained, “The numbers here are the same numbers here.” Megan pointed to her solutions on the GO under the “Visualize” and “Hypothesize” boxes on the GO.

Megan provided relatively basic explanations about her knowledge, use, and control of
the fourth cognitive strategy and process, Hypothesize, in the pre-individual interview. For the one-step word problem she stated, “Well for question 1, I pulled out the numbers and did the math obviously” (Question 19). Megan also stated that “did not know” why she decided to use division for the one-step problem and multiplication for the two-step word problem (Question 21). In the post-individual interview Megan understood how she made a plan to solve the problems. For example, for the one-step word problem she stated, “Well how much means division. So I wrote how much means division and then it was a one-step word problem. So I wrote it as a one-step problem. And then I had to figure out the cost of one. So I divided $1.92 divided by six and that finds you the cost of one item.”

The interview questions regarding Megan’s knowledge, use, and control of the fifth cognitive strategy and process, Estimate, (Questions 24 to 26) were skipped in the pre-individual interview because she did not find an estimate. She however, understood what estimation meant in the pre-individual interview (Question 23). In the post-individual interview Megan found an estimate. She also stated that her estimate helped her find the final solutions to the word problems (Question 24). She stated, “It just kind of helped me find the actual answer, which is obviously what you have to do.”

Megan overall provided relatively basic explanations about her knowledge, use, and control of the sixth cognitive strategy and process, Compute, in the pre-individual interview. She rarely provided further or deeper explanations. For example, she stated, “I just picked out the numbers and chose multiplication with the one I wanted to use or the one that fit more appropriately. I guess.” She also stated that she did not check her solutions (Questions 28 and 29). In the post-individual interview Megan stated that she checked her answers by referring to the posters and information sheet, which outlined the metacognitive prompts of the seven
cognitive strategies and processes. Megan also explained that she double-checked all her work on the GOs. She explained, “I double-checked by going to the information sheet and the posters and the steps ahead of the one-step.”

Following the response questions about the sixth cognitive strategy and process, Compute, Megan was then asked questions about her knowledge, use, and control of the seventh cognitive strategy and process, Check. In the pre-individual interview she stated that she checked her answers by “looking over” her work (Question 32). In the post-individual interview Megan stated that she used a calculator to check her solutions and double-checked her work on the GOs. For the one-step word problem she explained, “I used a calculator….I went from box to box. I went to Hypothesize. I did 1.92 divided by six and then found the cost. And then went to Estimate and did all the calculations.”

**Students’ Mannerisms during CSI and GO Training**

Field observations about students’ mannerisms were analyzed using an inductive approach. This approach identified patterns, themes, and categories of the three participants (Patton, 2002). Students’ mannerisms included their positive and negative responses and their understanding of the material during the CSI with GO’s instruction (see Table 6 for the complete list that was generated for each participant). The codes were then collapsed and were placed into broader, thematic groups. Initially, the relationship between the codes was not clear. However, after closely examining the connections among codes, six key themes emerged from the data across all three students: (a) students’ learning struggles; (b) supportive instructional strategies; (c) coping skills; (d) student engagement and motivation; (e) student retention of material taught; and (f) additional factors which may have impacted students’ learning. These themes and classified codes are summarized in Table 7.
### Table 6

**Generated code list for Britney, Jena, and Megan**

<table>
<thead>
<tr>
<th>Codes</th>
<th>Britney</th>
<th>Jena</th>
<th>Megan</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Witnessed that student experienced difficulties in explaining what methods she used to solve the word problems</td>
<td>• Witnessed that student experienced difficulties in explaining what methods she used to solve the word problems</td>
<td>• Witnessed that student demonstrated poor math skills (e.g., made frequent calculation errors and did not understand the difference between division and multiplication)</td>
<td>• Witnessed that student demonstrated poor math skills (e.g., made frequent calculation errors and did not understand the difference between division and multiplication)</td>
</tr>
<tr>
<td>• Witnessed that student experienced difficulties in following new instructions and guidelines</td>
<td>• Witnessed that student cried when she did not understand how to complete a task</td>
<td>• Witnessed student’s tiredness</td>
<td>• Witnessed student’s tiredness</td>
</tr>
<tr>
<td>• Witnessed that student required additional instructional support to reinforce key concepts (e.g., one-to-tutoring, guided practice, independent practice, and feedback)</td>
<td>• Witnessed that student demonstrated poor math skills (e.g., made frequent calculation errors and did not understand the difference between division and multiplication)</td>
<td>• Witnessed that student required additional instructional support to reinforce key concepts (e.g., modeling, guided practice, independent practice, and feedback)</td>
<td>• Witnessed that student required additional instructional support to reinforce key concepts (e.g., modeling, guided practice, independent practice, and feedback)</td>
</tr>
<tr>
<td>• Witnessed that student required additional instructional support to reinforce key concepts (e.g., one-to-tutoring, guided practice, independent practice, and feedback)</td>
<td>• Witnessed student’s inability to focus on the task at hand because of external noise distractions (e.g., due to class location and time of class (e.g., morning lesson))</td>
<td>• Witnessed student’s inability to retain certain concepts taught (e.g., after field trip)</td>
<td>• Witnessed student’s inability to retain certain concepts taught (e.g., after March Break)</td>
</tr>
<tr>
<td>• Witnessed student’s tiredness</td>
<td>• Witnessed student’s inability to retain certain concepts taught (e.g., after field trip)</td>
<td>• Witnessed student’s tiredness</td>
<td>• Witnessed student’s inability to focus on the task at hand because of external noise distractions (e.g., due to class location and time of class (e.g., morning lesson))</td>
</tr>
<tr>
<td>• Witnessed an improvement in student’s ability to retain certain concepts taught (e.g., after March Break)</td>
<td>• Witnessed student’s enjoyment in using GOs to solve math word problems</td>
<td>• Witnessed student’s enthusiasm in following new instructions and guidelines</td>
<td>• Witnessed student’s enthusiasm in following new instructions and guidelines</td>
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<tr>
<td>• Witnessed student’s willingness to complete practice exercises after school</td>
<td>• Witnessed an improvement in student’s ability to retain certain concepts taught (e.g., after March Break)</td>
<td>• Witnessed good student participation</td>
<td>• Witnessed student’s ability to retain certain concepts taught</td>
</tr>
<tr>
<td>• Witnessed improvement in student’s participation after March Break</td>
<td>• Witnessed good student participation</td>
<td>• Witnessed student’s enthusiasm in following new instructions and guidelines</td>
<td>• Witnessed good student participation</td>
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<tr>
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<tr>
<td>Themes</td>
<td>Classified Codes</td>
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<td>---------------------------------------------</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>A. Students’ learning struggles</td>
<td>• Witnessed that students demonstrated poor math skills (e.g., made frequent calculation errors and did not understand the difference between division and multiplication)</td>
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<tr>
<td></td>
<td>• Witnessed that Britney experienced difficulties in explaining what methods she used to solve the word problems</td>
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<tr>
<td></td>
<td>• Witnessed that Britney experienced difficulties in following new instructions and guidelines</td>
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<tr>
<td>B. Supportive instructional strategies</td>
<td>• Witnessed that students required additional instructional support to reinforce key concepts (e.g., instructor modeling, guided practice, independent practice, and feedback)</td>
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<td></td>
<td>• Witnessed that Britney required one-to-one tutoring for additional support</td>
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<td>C. Coping skills</td>
<td>• Witnessed that Britney and Megan stopped working when they did not understand how to complete a task</td>
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<td></td>
<td>• Witnessed that Jenna cried when she did not understand the material</td>
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<tr>
<td>D. Student engagement and motivation</td>
<td>• Witnessed an improvement in students’ participation</td>
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<td></td>
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<tr>
<td></td>
<td>• Witnessed students’ enthusiasm in following new instructions and guidelines</td>
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<tr>
<td></td>
<td>• Witnessed students’ enjoyment in using GOs</td>
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<tr>
<td></td>
<td>• Witnessed students’ willingness to complete practice exercises after school</td>
<td></td>
<td></td>
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<tr>
<td>E. Student retention of material taught</td>
<td>• Witnessed good student retention of material taught after March Break</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Witnessed poor student retention of material after March Break</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Witnessed students’ ability to retain certain concepts after school field trips</td>
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<tr>
<td>F. Additional factors which may have impacted students’ learning</td>
<td>• Students’ tiredness</td>
<td></td>
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<tr>
<td></td>
<td>• External distractions (e.g., noise and time of class)</td>
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</table>
The following analysis provides a description of the field observations about students’ mannerisms with respect to the generated themes. My observations and quotations from the students were used to describe and interpret the themes more closely.

**Students’ learning struggles.**

During the 13-week instruction, I noticed that the three students demonstrated poor math skills. For example, they understood the concept of addition and subtraction, but did not know the difference between division and multiplication. Even after teaching them when to divide and multiply, they looked confused and were unable to grasp the concepts. They stated in class, “This is confusing!” To alleviate the students’ frustrations and to help them understand this concept, I changed my instructional approach. I used simpler language and taught the students tricks. I informed the students that the phrases in the word problems “How much does each item cost?” or “What is the cost of each item?” meant division. These phrases or cues reminded the students to use division to solve the math word problems.

During the 13-week study, I also observed that the students did not understand the concept of decimal place value. For example, I asked the students to use their calculators to find the cost of one chocolate bar if two chocolate bars cost $1.00 in total. All three students got the correct answer on their calculators (0.5). However, when I asked them what is the cost of one chocolate bar, the three students said the cost was 5 cents not 50 cents. To help them understand this concept, I taught the students to put a zero after the number 0.5. This in turn, helped the students remember that an answer of $0.5 can be expressed as $0.50 or 50 cents.

I also witnessed that all three participants struggled in applying the cognitive strategies and processes for solving one-step and two-step math word problems. The three students specifically struggled learning the last four cognitive strategies and processes for one-step math
word problems, Hypothesize, Estimate, Compute, and Check, and struggled on the fourth and fifth cognitive strategies and processes, Hypothesize and Visualize, for two-step math word problems. For example, they took a longer time learning how to find an estimate and how to calculate the final answer to the problems. They also asked what steps they needed to use to solve the problems and asked for help to complete the in class exercises. For example, Britney asked me, “How do I do Compute?” during an independent practice exercise. To help the students understand the strategies, I provided additional class support (e.g., instructor modeling, guided practice, independent practice, and feedback). Due to time constraints, Britney and Jena were not taught the last two cognitive strategies and processes, Compute and Check, for two-step math word problems.

During the instructional sessions, Britney also demonstrated difficulties in explaining what strategies she used to solve the math word problems. For example, I asked Britney to explain how she completed the step “Hypothesize” on her graphic organizer (GO). She stated, “I don’t know.” To help Britney, I guided her to look at her GO and asked her specific questions (e.g., What did you write here? And why did you write that?).

Britney also struggled in following new instructions and guidelines. For example, I asked all three students to take out their booklets and to answer the first two cognitive strategies and processes, Read and Paraphrase, on their GOs. Britney looked confused and told me that she did not know what she had to do. To help Britney complete the task, I provided additional assistance to help her follow the instructions. Jena and Megan did not demonstrate difficulties in explaining the methods they used to solve the word problems and did not struggle in following new instructions and guidelines.

The students also demonstrated difficulties in checking their work. Jena for example,
forgot to check to see if she transposed the same numbers from the word problem to the GO. Jena wrote, “$19.8” instead of “$1.98” on her GO. Megan also did not complete the last cognitive strategy and process, Check, correctly. Megan found the correct cost of one item ($4.50) if two items cost $9 in total. She however, wrote $9 + $9 instead of $4.50 + $4.50. Although the students were given constant reminders to check their work, they continued to forget this strategy. As a result, their final solutions were incorrect. Figure 10 provides an example of an error Jena made during the 13-week instruction.

Figure 10. An example of an error Jena made on a one-step math word problem

Note. Jena wrote $19.8” instead of “$1.98” on her GO. The circle in the “Paraphrase” box is the error Jena made. Jena wrote the correct answer at the top after I showed her the mistake.

Supportive instructional strategies.

All three students required additional support to help hone their skills. These strategies included: instructor modeling, guided practice, independent practice, and feedback. Britney required the most support during the 13-week instruction. She specifically struggled in applying
the four cognitive strategies and processes, Hypothesize, Estimate, Compute, and Check. She took a longer time learning the strategies and processes, and asked what steps she needed to use to solve the problems. Britney also asked for help to complete the in class exercises. I provided additional assistance to support her learning. For example, to complete the step “Estimate,” I demonstrated how to draw a number line and how to round numbers. I also directed her attention to the posters, which outlined the metacognitive prompts of the seven cognitive strategies and processes. She was provided guided practice and independent practice opportunities. Britney also did not understand how to compare her estimate with the final solution. To help her complete this task, I had her point to or circle the final solution and point to or circle her estimate. I then asked Britney to answer following question, “Is my estimate bigger or smaller than the final answer?” She was then provided additional practice opportunities to complete the task successfully. Britney was also provided three, one-to-one tutoring sessions to help her complete the remaining cognitive strategies and processes for one-step word problems, Compute and Check.

Jena and Megan were also provided instructor modeling, guided practice, and feedback to help them solve one-step and two-step word problems. For example, Megan was assigned more practice opportunities to help her understand the last three cognitive strategies and processes for one-step word problems, Estimate, Compute, and Check. Likewise, Jena required more instructional modeling and guided practice opportunities to understand the fourth and fifth cognitive strategies and processes, Estimate and Hypothesize, for two-step word problems.

Coping skills.

The three students continuously demonstrated personal struggles and frustrations while learning how to solve one-step and two-step math word problems. Britney for example, gave up
during some sessions when she became confused and did not understand how to complete a task. For example, Britney explained during some lessons, “This is confusing!” Jenna cried during one lesson after she told me, “I don’t understand what to do!” Megan stopped working on a task when she was confused and after explaining, “I don’t know how to solve this question.”

**Student engagement and motivation.**

Megan was the most engaged throughout the study. She attended every session and continuously participated in class discussions and activities. For example, Megan was always active in answering teacher posed questions and was willing to help the other two students when they experienced difficulties understanding and solving problems. Britney and Jena however, were quiet and participated less, especially during the first few weeks of instruction. Their participation however, improved during the course of the study after they started gaining confidence in their abilities and when they started understanding the concepts taught. Britney for example, struggled learning the cognitive strategies and processes for one-step word problems before March Break. However, after receiving practice exercises during March Break, Britney’s progress improved. She displayed more confidence, participated more in class, and enjoyed solving math word problems. Britney stated during one lesson, “Estimating is fun!”

During the 13-week intervention, the students were enthusiastic in following new instructions and guidelines. The students responded favorably toward the instruction and were respectful in class. They also helped set up the class materials (e.g., posters and whiteboard) during the lessons. All three students also enjoyed using the GOs to solve math word problems. During one session, Britney wrote, “I like using graphic organizer because it is understandable and easy to do.” Similarly, Megan wrote, “Yes I do enjoy using grafic [sic] organizers because it helps me keep my work together.”
In addition to the aforementioned, all three participants asked for additional practice exercises while they were away on March Break. The students asked me to prepare individual booklets for them to take home. All three students successfully completed the exercises during March Break. Similarly, Megan completed an additional set of exercises during a week of no instruction.

**Student retention of material taught.**

The three students demonstrated an ability to retain certain concepts taught after returning from school field trips and holidays. The school field trips and holidays ranged between 3 days to 14 days long. Britney remembered how to apply the two cognitive strategies and processes, Hypothesize and Estimate, for one-step word problems during an independent practice exercise after returning from a one-week March Break. Megan also remembered how to apply the four cognitive strategies and processes for one-step word problems, Read, Paraphrase, Visualize, and Hypothesize. Similarly, Jena remembered how to use the three cognitive strategies and processes for solving two-step math word problems, Read, Paraphrase, and Visualize, after returning from a two-week school field trip. Megan however, had difficulties finding an estimate for one-step word problems after the March Break. Jena also struggled completing the fourth and fifth cognitive strategies and processes, Hypothesize and Estimate, for two-step word problems after her two-week field trip.

**Additional factors which may have impacted students’ learning.**

The students were tired during some sessions and were unable to concentrate on the tasks at hand. They yawned, walked slowly to class, and squirmed in their seats. This was a particular challenge when instruction occurred during the early mornings. Likewise, the students were unable to focus during instruction when there was a lot of commotion in the school (e.g., band
rehearsals). The students told me that they could not concentrate because there was a lot of noise in the school hallway or classroom next door. The location in which the study took place also impacted students’ learning. The students looked distracted and had trouble following instructions. On a few occasions, the study took place in the staff room or in the Vice Principal’s office. The students were unable to concentrate and be productive during instruction because of the noise level in the staff room and because of the cramped quarters in the Vice Principal’s office.

**Summary of Results**

The main set of analyses examined the effectiveness of CSI that was supported with the use of GOs. This study aimed to improve the word problem solving performance of three, Grade 8 students experiencing difficulties in mathematics. In addition, the following set of analyses explored students’ mannerisms and feelings toward mathematical problem solving.

The purpose of the first research question was to compare students’ performance in solving math word problems before and after a 13-week intervention on CSI with GOs. The overall findings revealed that two of the three participants improved their performance in solving one-step math word problems on the post-intervention quiz (Jena and Megan). All three students however, did not demonstrate an improvement in solving two-step math word problems on the post-intervention quiz.

The purpose of the second research question was to compare students’ feelings toward mathematical problem solving before and after they received training on CSI with GOs. The findings found a general improvement in students’ self-perceptions of their math ability and attitudes toward math problem solving. For example, two of the three students (Britney and Megan) increased their attitudes toward math problem solving following the intervention. All
three students however, did not change their responses in the pre- and post-individual interviews about their self-perceptions of their math skills.

The focus of the third research question was to compare students’ knowledge, use, and control of the seven cognitive strategies and processes before and after the 13-week intervention. The overall findings found an improvement and growth in students’ ability to explain what methods they used to solve the word problems. The three students also applied more cognitive strategies and processes to solve the word problems in the post-individual interviews. Two of the three students (Britney and Jena) however, struggled in answering some response questions in the pre-individual interview and post-individual interview.

The focus of the fourth research question was to compare students’ mannerisms during the 13-week instruction. The field observations generated different sets of codes for each student. After closely examining the relationships between the codes, six themes emerged from the field note observations: (a) students’ learning struggles; (b) supportive instructional strategies; (c) coping skills; (d) student engagement and motivation; (e) student retention of material taught; and (f) additional factors which may have impacted students’ learning. Each theme described similarities and differences among the three participants.
Chapter 5

Discussion

The purpose of this study was to examine the effectiveness of an intervention approach called Cognitive Strategy Instruction (CSI) that was further supported with the use of graphic organizers (GOs). The aim of the research was to determine if CSI with the use of GOs could help improve the word problem solving performance of Grade 8 students experiencing difficulties in mathematics. Student mannerisms and student feelings toward mathematical problem solving were also examined. This study addressed the following research questions:

1. How did the students perform on the math word problem solving quiz before the instruction and after the instruction on CSI training with GOs?
2. How do students’ feelings toward mathematical problem solving compare before and after receiving training on CSI with GOs?
3. How do students’ knowledge, use, and control of the seven cognitive strategies and processes compare before and after receiving training on CSI with GOs?
4. How do students’ mannerisms compare during the group instruction on CSI with GOs?

This chapter begins with a discussion of the research findings for each research question. The later sections describe the limitations of the study, as well as the implications for future research and practice. The final section provides a concluding statement about the present study.

Pre- and Post-Intervention Math Word Problem Solving Quiz

As illustrated in the earlier chapters of the thesis, previous studies on CSI training and on GOs have been conducted independently to examine their effectiveness in improving students’ problem solving skills for students with math difficulties (e.g., Montague, Applegate, &

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Marquard, 1993; Zollman, 2009). These investigations have indicated their study’s effectiveness in supporting students with math difficulties, such as students with learning disabilities (LD). The present study was unique to previous research interventions because of the addition of GOs with CSI training.

The tallying of students’ scores from the present study revealed that two of the three participants (Jena and Megan) improved their performance on the post-intervention quiz on one-step math word problems. The third student (Britney) did not improve her performance in solving one-step math word problems on the post-intervention quiz. The findings also revealed that all three students did not improve their performance in solving two-step math word problems after completing the intervention.

These findings suggest that the training on CSI with GOs may have positive effects on students’ performance while solving one-step math word problems. Hence it is important to explore how this intervention may have provided useful learning supports. First, the students in the present study used GOs to solve the math problems on the post-intervention quiz, but not on the pre-intervention quiz. It is possible that the GOs may have facilitated students’ thinking processes and fostered their self-regulation during problem solving (Van Garderen, 2006). The students also received metacognitive prompts on the post-intervention quiz, but not on the pre-intervention quiz. Data from the post-individual interviews indicated that the students looked at the metacognitive prompts while solving the math problems. Based on these findings, it is possible that the administration of the metacognitive prompts may have also fostered students’ self-regulation and improved their performance in math problem solving. According to Sternberg (1994), successful problem solvers must use the combination of cognitive and metacognitive strategies and processes to complete a cognitive task.
Students’ engagement and motivation during the study may have also impacted their performance on the post-interview quiz. My field observations on students’ mannerisms revealed that Megan continuously participated in the class instruction and that Jena’s participation improved during the course of instruction. While solving math problems, these students also demonstrated confidence while using GOs as a guide. As stated by Megan, “Yes I do enjoy using grafic [sic] organizers because it helps me keep my work together.” The students also asked for practice exercises while they were away on March Break. These results relate closely to previous studies regarding student motivation and academic achievement (e.g., Tella, 2007). The study by Tella (2007) for example, investigated the motivation and academic performances in mathematics of 450 secondary school students (ages 15 to 22 years). Tella (2007) concluded that, “highly motivated students perform better academically than the low motivated students” (p. 154). According to Tella (2007), improved student performance in math can be achieved by different motivating factors, such as students’ interests in the math instruction.

Despite the positive gains in students’ performances on the post-intervention quiz, there are also possible reasons why the students in the present study may not have improved their performance in solving one-step math word problems (Britney) and two-step math word problems (Britney, Jena, and Megan). First, my field observations on students’ mannerisms revealed that the students struggled learning the material during the intervention. For example, I noticed that all three students had difficulties applying the cognitive strategies and processes for one- and two-step math word problems. To support their learning, I provided additional class support (e.g., instructor modeling, guided practice, and feedback) and held one-to-one tutoring sessions. Second, the time constraint of the study may have also impacted the students’ achievement. Britney and Jena were not taught the last two cognitive strategies and processes,
Compute and Check, for two-step math word problems. My research aligns with the research findings from Montague and Bos (1986), who examined the effectiveness of an eight-step CSI model of math problem solving for six secondary school students with LD. Due to the varying performances of the participants, Montague and Bos (1986) suggested that additional time might be needed to help struggling students practice and understand certain problem solving steps. It is also possible that the students in the present study may have needed additional training sessions on GOs. It remains, however, unclear to existing research on GOs what is the appropriate time length for training students on GOs (Jiang & Grabe, 2007).

The testing environment may have also impacted students’ performances in the present study. I noticed there was a lot of noise in the school during the testing sessions (e.g., due to band rehearsal). My field observations on students’ mannerisms during the intervention indicated that the students were unable to concentrate on the instruction and on tasks because of noise distractions in the school and because of cramped quarters in the classrooms. The student participants became agitated and looked distracted; at other times they appeared tense. They squirmed in their chairs and looked around the room instead of focusing on the tasks at hand. The testing for the post-intervention quiz was also held in the Vice Principal’s office. The space was very small and confining. The students were sitting very close together and they told me they felt very closed in. These findings suggest that these students may not have been able to fully concentrate during the quizzes that served as the outcome measures for my research. Additionally, test anxiety may have also impacted students’ performances on the pre- and post-intervention quizzes. According to Ashcraft and Moore (2009), students who are at-risk of math anxiety include students with low-ability math skills, students who are unmotivated, and student with working memory impairments. Evidence suggests, that in testing situations, the low
achievement scores of students who are math-anxious are more attributable to their math anxiety than their mastery of math (Ashcraft & Moore, 2009).

**Students’ Feelings toward Mathematical Problem Solving**

Students’ responses from the Likert-type questions in the pre- and post-individual interviews (modified MPSA-SF; Montague, 1996) revealed a general improvement in students’ self-perceptions of their math abilities and attitudes toward math problem solving. Britney and Jena reported a positive change in their self-perceptions about how well they solve math word problems after completing the intervention. Britney and Megan also reported a positive change in their attitudes toward math problem solving after completing the intervention. Additionally, the students’ written responses about their attitudes toward math problem solving provided an understanding on the reasons why they enjoyed solving math problems. Britney reported in the post-individual interview, “I chose 4 because it is fun solving math problems.” Megan’s written response in the post-individual interview was, “I chose number 5 because when I use grafic [sic] organizers it helps me solve the word problems and this study has helped me by the posters, white board and all the lessons.”

The overall findings from my research suggest the effectiveness of CSI training with GOs in changing students’ feelings toward math problem solving. These findings also align with previous research on students’ academic self-perceptions and attitudes (e.g., Meltzer et al., 2004; Mohammad Yusof & Tall, 1999). Meltzer et al. (2004) examined the success of a strategy-focused intervention in fostering students’ academic self-perceptions. Similarly, Mohammad Yusof and Tall (1999) studied the improvement in students’ attitudes toward math problem solving after the students completed a course on cooperative problem solving. My results also align with the research findings from Montague (1992), who implemented a four-month
intervention on CSI training in math problem solving for six middle school students with LD (Grades 6 to 8). Montague (1992) revealed that four of the six students increased their attitudes toward math problem solving after completing the four-month intervention.

Contrary to previous research on students’ attitudes (e.g., Mohammad Yusof & Tall 1999), Jena did not report a change in attitude toward problem solving following the 13-week intervention. In the pre-individual interview Jena stated, “I don’t like solving math word problems because sometimes they are too hard.” Her written response in the post-individual interview was, “I chose number two because sometimes the question I get is hard and I don’t understand.” These findings are interesting given that Jena improved her performance in solving one-step math word problems on the post-intervention quiz. These results suggest that Jena may have low self-confidence in her abilities. Student low self-confidence is typical of low-performing students in math classrooms (e.g., Kajander et al., 2008).

Despite the positive gains in students’ feelings toward math problem solving, all three students did not change their responses in the pre- and post-individual interviews about their self-perceptions of their math skills. Britney and Jena for example, reported having poor math skills in the pre- and post-individual interviews. These findings are also consistent with previous studies on learning disabilities and on low-performing students (e.g., Kajander et al., 2008; Meltzer et al., 2004). Many students who struggle in math commonly experience negative or decrease self-concepts of their math ability (i.e., perceptions of self-worth and competence), and these perceptions persist over time (Kajander et al., 2008).

Students’ Knowledge, Use, and Control of the Seven Cognitive Strategies and Processes

Students’ responses from the pre- and post-individual interviews support the value of CSI training with GOs to improve students’ knowledge, use, and control of the seven cognitive
strategies and processes for math problem solving. In their interviews the students described greater use of cognitive steps and demonstrated more knowledge of the strategies and processes after completing the intervention. For example, the students found an estimate and drew pictures of the math problems in the post-individual interviews, but not in the pre-individual interviews.

The findings from the present study also described the students’ approaches to solving the math word problems. In the pre-individual interview the students wrote their solutions on lined paper. Britney and Megan explained that they relied on their memory to help them remember the information in the word problems. Britney explained in the pre-individual interview, “I just like put it in my mind… what the question said.” Megan explained, “I took bits of pieces of it and like stuck it in my head to the back of my head.” In the post-individual interview the three students only used GOs to solve the math problems. Jena for example, explained how she used the GOs to help her make a plan. For the one-step word problem she stated, “I went to Hypothesize… I wrote down what division means and I said how much equals division.” The three students also stated that they used their GOs to either check their work or to remember the information in the word problems.

Overall, my findings suggest there are benefits of GOs for facilitating students’ learning and success during math problem solving. Previous studies on GOs indicated that these visual aids can help students “visually relate elements” and can help them communicate their thinking when solving math problems (Braselton & Decker, 1994, p. 276). It is also possible that the GOs may help reduce students’ working memory demands during problem solving (Diezmann & English, 2001). Data from the post-individual interviews also indicated that the students looked at the metacognitive prompts while solving the math problems. The findings indicate the importance in administering guidelines on the metacognitive strategies and processes to help
students monitor and self-regulate their performance.

Despite the positive responses from the post-individual interviews, Britney and Jena struggled in answering some questions in the pre- and post-individual interviews. The interviews revealed that their responses tapered off when the cognitive steps become more involved and sophisticated (i.e., cognitive strategies and processes: Hypothesize, Compute, and Check). The findings suggest these students may have needed additional training on the individual cognitive strategies and processes before administering instruction on CSI with GOs.

**Students’ Mannerisms during CSI and GO Training**

The field observations on students’ mannerisms focused on their positive and negative responses and also their understanding of the material during the intervention. The observations generated different sets of codes for each student. Six themes emerged after examining the relationship between the codes: (a) students’ learning struggles; (b) supportive instructional strategies; (c) coping skills; (d) student engagement and motivation; (e) student retention of material taught; and (f) additional factors which may have impacted students’ learning.

The observations, in regards to the first theme, described students’ learning struggles during the intervention on CSI training with GOs. I noticed that the students did not understand decimal place values and struggled in applying the cognitive strategies and processes for one-step and two-step math word problems. I also noticed they struggled while checking their work. These findings relate closely with existing research on teacher-identified math weaknesses of students with LD (Bryant et al., 2000). General math weaknesses identified by the teachers in the study by Bryant et al. (2000) included: (a) students having difficulty with word problems and with multi-step problems; (b) students not copying numbers correctly; (c) students reaching “unreasonable” answers; and (d) students disregarding decimals.
My field observations with respect to the second theme described the instructional strategies that were implemented to support students’ learning. Britney required the most support during the intervention. She required additional practice opportunities to understand the cognitive strategies and processes. Such practice opportunities included one-to-one support, review sessions of material taught, as well as continuous instructor modelling and feedback. Jena and Megan were also assigned additional practice exercises during the daily lessons. Not surprisingly, there is support for the use of additional practice, and such practice is likely even more beneficial for struggling students to better understand and practice certain problem solving steps (e.g., Montague & Bos, 1986).

The field observations in regards to third theme described students’ struggles in handling personal frustrations and stress during the intervention. Britney and Megan gave up during some sessions when they did not understand how to complete a task. Jena cried during one lesson. These results indicate the students may have experienced symptoms that are similar to math anxiety. According to Ashcraft and Moore (2009), math anxiety reactions “can range from mild to severe, from seemingly minor frustration to overwhelming emotional (and physiological) disruption,” such as crying (p. 197).

The field observations, in regards to the fourth theme, revealed the possible benefits of CSI training with GOs in promoting students’ engagement and motivation. Megan attended every session and was always active in answering teacher posed questions. Jena and Britney’s participation improved during the course of the study when they started understanding the concepts taught and after they started gaining confidence in their abilities. The three students were also enthusiastic in following new instructions and enjoyed using the GOs. Additionally, the students asked for practice exercises while they were away on March Break. Such results
relate favourably to the recommendations by The National Mathematics Advisory Panel (2008) in promoting students’ self-beliefs, engagement, and motivation through evidence-based interventions. My findings however, may also be explained by additional factors. One possible explanation of students’ engagement and motivation may have been due to the administration of extrinsic rewards during the study (e.g., stickers, snacks, and gift cards; Hutchinson, 2010).

The field observations in regards to the fifth theme described the potential benefits of CSI training with GOS in fostering students’ retention of the material taught. Britney remembered how to apply the cognitive strategies and processes (i.e., Hypothesize and Estimate) for one-step word problems after she returned from March Break. Despite these findings, the students demonstrated some difficulties in applying certain problem solving steps. These findings align with the work of Montague, Applegate, and Marquard (1993), who examined the effectiveness of CSI training on 72 middle school students with LD (Grades 7 to 9). Montague et al. (1993) found a decline in participants’ mean score performance on the second maintenance test. Even though my research did not measure the maintenance of students’ knowledge and understanding of problem solving strategies, the overall findings by Montague et al. (1993) suggested the need to provide additional training on strategy instruction for students who struggle in math.

The final theme from the field observations revealed students’ inability to concentrate on the instruction because of noise distractions in the school, student tiredness, and class location. These findings highlight the importance in providing a large and quiet-free room where students are able to concentrate on instruction and class activities.

**Limitations**

The present study poses a number of limitations that warrant discussion. The main set of limitations is in regards to the obtained sample, participants’ demographics, and the methods
used for data collection. The study recruited three participants from one Public Elementary School. Due to the small class sizes, the demographics of the participating school were less diverse than at other Ontario elementary schools. Additionally, the study’s sample only had female participants. It is therefore difficult to generalize the findings to the general population of students in Ontario experiencing math difficulties. Recruiting students from a variety of schools across Ontario could find larger variations in students’ performance. Large variations could make it easier to compare the findings to the general population of students in Ontario with math difficulties.

The small sample size (N = 3) also posed a challenge in analyzing the results and obtaining sufficient statistical power. I was unable to use statistical measures to detect the effects of the intervention. Additionally, the present study did not include comparison groups. Comparison groups are valuable because they help address the potential influence of other factors that may impact change. As one example, it would be worthwhile to compare the effectiveness of CSI training with GOs to a sample of students receiving only CSI training, a sample of students receiving only GOs, and a group of students receiving neither (control group). This approach would determine if the treatment group (CSI with the support of GOs) is more effective than the comparison groups (CSI group, GO group, control group). It would also be beneficial to compare the effectiveness of CSI training with the support of GOs between a sample of LD students and low-performing students, who demonstrate less severe learning challenges. This investigation would allow researchers to determine if the intervention may benefit a classroom of students with varying learning needs. In addition to the presented limitations, the present study did not measure the maintenance of participants’ knowledge and their understanding of the problem solving strategies. It is difficult to determine if the positive
effects of the intervention will be maintained after completing the study.

Another limitation is in regards to the participants’ individual learning challenges. Britney, Jena, and Megan all demonstrated poor math skills before starting the intervention. It is possible that the students many have experienced learning difficulties in other academic subjects. For example, during the individual interviews and 13-week intervention, I noticed that I had to provide instruction in simpler language in order to help them understand the information. It is possible that the participants’ performance may have been affected by other learning struggles.

A final limitation may also be linked to my participation in the intervention, both as a researcher and an instructor. I developed a good rapport with the students throughout the course of the study. I recognize that my ongoing participation may have caused the students to behave in a certain way and to respond positively about the intervention. It is also possible that my interpretations of the results may have been influenced by own perceptions of students’ learning. Through my personal experiences with a LD, my predisposed beliefs may persuade me from recording what I “want to see rather than what is actually there” (Bodgan & Bilklen, 1998, p. 33).

**Directions for Future Research**

The purpose of the present study was to examine the effectiveness of an instructional approach called Cognitive Strategy Instruction (CSI) that was supported with the use of graphic organizers (GOs). This study sought to improve the word problem solving performance of Grade 8 students experiencing difficulties in mathematics. In addition, I (the researcher and instructor) examined students’ mannerisms and feelings toward mathematical problem solving. The present study was unique to previous research interventions because of the combination of GOs with CSI training. The overall findings indicated the potential benefits of CSI training with GOs for
improving the word problem solving performance of struggling learners in math. The improvement in students’ performances was evident after comparing students’ scores on the pre- and post-intervention quiz for one-step math word problems. There was also a general improvement in students’ feelings toward math word problem solving after completing the intervention. Additionally, the field observations provided an understanding about students’ positive and negative responses and their understanding of the material during the intervention. These findings align with previous studies and interventions on student math difficulties in problem solving.

After examining my active role as a joint teacher and researcher, it is possible that my participation in this study may have provided additional benefits in supporting students’ learning during the intervention training on CSI with the use of GOs. I developed a good rapport with the students throughout the intervention. It is possible that my close interactions and long-term connections with the students may have helped create a positive and caring learning environment. According to Gersten et al. (2005) teacher awareness of and support for students with diverse learning needs are integral components to foster students’ learning and understanding of math. Within the area of qualitative-based research, maintaining interpersonal skills with the participants, such as “building trust, maintaining good relations, being nonjudgmental, and respecting the norms of the situation,” are integral components for data collection (McMillan & Schumacher, 2010, p. 332). It is therefore important that future researchers continue emphasizing the important role of the teacher in providing positive and supportive learning environments for students who struggle in math.

Although the present study found promising results, the findings cannot be generalized to Grade 8 math classrooms. Certainly the small sample size prevents this. Nevertheless, the
intensive nature of the intervention with these three students provides an important opportunity to understand how such students with math difficulties respond to and interact with a CSI and GO math intervention. Admittedly, the short timeframe of the intervention made it difficult to examine these students’ maintenance of their knowledge and their understanding of math problem solving. Hence there is a need for future research to build on the promising early findings of my work. Such studies would include interventions with larger sample sizes, longer intervention periods, and longitudinal studies to determine if students’ achievement and feelings are maintained subsequent to the intervention. Based on findings from previous research interventions on math problem solving (e.g., Montague, Applegate, & Marquard, 1993), it is possible that additional strategy training would be needed to maintain students’ positive effects from the intervention.

Another possible direction for future research would be to examine the effectiveness of CSI training with different types of GOs, such as Venn diagrams and matrices. This approach would help researchers determine what is the most effective visual aid in problem solving for students experiencing math difficulties. In addition, it would be beneficial to investigate the appropriate time length required to train students successfully on GOs. These investigations would help researchers address two of the present limitations on GO research (Jiang & Grabe, 2007).

Finally, to control research bias, future studies could recruit external researchers to review the data independently to find patterns and themes. The external researchers could then compare their analyses to generate final themes. The study by Butler, Beckingham, and Lauscher (2005) used this approach to analyze the effectiveness of Strategic Content Learning for three Grade 8 students struggling in math.
Implications for Future Practice

The present study provides preliminary but potentially valuable benefits of CSI training with the support of GOs for improving the word problem solving performance of struggling students in math. Although I did not assess nor provide the specific learning difficulties and profiles of the student participants (e.g., a student’s Individual Education Plan), my work provides educators with a structured program for teaching math word problem solving that has support in the literature and in my early findings. Classrooms teachers can use various elements from the intervention to help cater to small groups of students with math difficulties.

Conclusion

My work adds to the existing literature on research interventions for math problem solving, providing insights on the potential benefits of Cognitive Strategy Instruction (CSI) that is supported with the use of graphic organizers (GOs) for students experiencing math difficulties. Such an intervention has the potential to:

1. Contribute to improved performance in solving math word problems
2. Improve students’ feelings toward math problem solving
3. Improve students’ knowledge, use, and control of the seven cognitive strategies and processes for math problem solving
4. Provide insight about students’ mannerisms, such as their engagement and motivation, during the instruction

As illustrated in the previous chapters of the thesis, many students with math difficulties struggle in problem solving. Student struggles in problem solving presently exist in many Ontario math classrooms (EQAO, 2014). The need of future research and implementation of CSI training with GOs would benefit the performance of students struggling in math. This could help
our ongoing efforts to support those students struggling to develop and master valuable problem solving skills in mathematics and perhaps other areas of learning as well.
References


10.1177/0731948712455337


Xin, Y. P., Jitendra, A. K., & Deatline-Buchman, A. (2005). Effects of mathematical word...


Appendix A

Letter of Information

Dear Parent/Guardian,

I, Andrea Palmay, a graduate student in the Faculty of Education at Queen’s University and a high school math teacher, will be conducting a study on problem solving in math titled, “Improving the Problem Solving Performance of Struggling Learners in Secondary School Mathematics,” at <name of school>. I have experience teaching and tutoring middle school and high school math. I hope the results of this study will provide teachers with more classroom instructional support to help all students who struggle in math. In this study, teacher recommendation at <name of school> was used to identify students from Grades 7 and 8 who would benefit from participating. No access to school records was used to select the students. This study has been granted permission according to the recommended principles of Canadian ethics guidelines and Queen’s policies, as well as the <name of District School Board>.

The goal of this research is to examine the effectiveness of an instructional approach called Cognitive Strategy Instruction with graphic organizers (e.g. visual displays and charts) for improving students’ math word problem solving skills. This study will also examine students’ feelings towards math problem solving (attitudes and self-perceptions of their math ability) and students’ use of strategies when solving math word problems. This research will compare students’ performance in math word problem solving between two groups. Students in Group 1 will receive instruction in Cognitive Strategy Instruction. Students in Group 2 will receive instruction in Cognitive Strategy Instruction with graphic organizers. This study will be conducted over 13-weeks. Total participation will be approximately 20 hours throughout the 13-weeks. The instruction will occur within seven weeks and with a total time of 17.5 hours (3 sessions per week with 50 minutes of instruction per session). As well, during the three weeks before the instruction and the three weeks after the instruction, students will be asked to participate in individual interviews (each totaling approximately 25-minutes of participation) and a math word problem solving quiz (totaling 30-minutes of participation). A 30-minute introductory session will also be held before to the seven-week instruction to describe the study, explain students’ roles and address any questions. In this study, I will be administering all instruction. Instruction will take place during the school day at <insert name of school>. The scheduled dates and times for this study will be arranged with the school’s principal and classroom teacher to minimize any disruption to students’ learning. The study’s schedule, including dates and times, will be sent to all participants.

Your child’s participation is voluntary. Your son/daughter is free to withdraw from the study at any time without reason and with no consequences. I do not see any risks for students being involved in this study. Participant’s performance will not affect a student’s class standing. If you request your son/daughter to withdraw from the study or he/she wishes to withdraw from the study, you or your son/daughter may request removal of all or part of his/her data. Students may choose not to participate in any activities they find uncomfortable or disagreeable. All participants will be entered in a draw for one of three gift certificates to McDonalds.
Student’s anonymity will be protected to the extent possible. Students will be asked not to talk about the study outside instructional sessions. Only my supervisor and I will have access to the interview, instructional materials, and quiz data collected during the study. Students’ work will be secured in a locked cabinet. The individual interviews will be audio recorded and transcribed verbatim. All electronic files will be protected with a password. In accordance with Queen’s policy, the data will be retained for a minimum of five years, after this time, all data will be destroyed. If the results of this research are published in professional journals or presented at academic conferences, the identity of the school board, schools, and participants will be kept confidential.

Any questions about study participation, a request to withdraw from the study, and removal of any data may be directed to Andrea Palmay at andrea.palmay@queensu.ca or my supervisor, Dr. Derek H. Berg at (613) 533-6000 ext. 77413 or derek.berg@queensu.ca. Any ethical concerns about the study may be directed to the Chair of the General Research Ethics Board at (613) 533-6081 or chair.GREB@queensu.ca.

If you wish your son/daughter to participate in this study, please have your son/daughter read the letter of information and discuss the study with him/her. Two consent forms are included in this package. Please sign one consent form. Please return the signed consent form, with your son’s/daughter’s signature, to the school’s main office within one week.

I thank you for your time and consideration.

Regards,

Andrea Palmay  M.Ed. Candidate. B.Sc. B.Ed. OCT.
Consent Form
Improving the Problem Solving Performance of Struggling Learners in Secondary School Mathematics
Andrea Palmay *M.Ed. Candidate* Faculty of Education, Queen’s University

Name of Student Participant (please print clearly): ____________________________________
("Student")

Name of Parent/Guardian (please print clearly): ____________________________________
("Parent/Guardian" and collectively with the Student “we”)

1. We understand that:
   a. the Student will be participating in the study called *Improving the Problem Solving Performance of Struggling Learners in Secondary School Mathematics* (the “Study”) the purpose of which is to examine the effectiveness of an instructional approach called Cognitive Strategy Instruction with graphic organizers (e.g. visual displays and charts) for improving students’ math word problem solving skills including students’ feelings towards math problem solving (attitudes and self-perceptions of their math ability) and students’ use of strategies when solving math word problems;
   
   b. teacher recommendation was used to identify students who would benefit from participating and no access to school records was used to select the student;
   
   c. the Study consists of: (i) a seven-week instruction consisting of 3 sessions per week with 50 minutes of instruction per session for a total of 17.5 hours; (ii) a 30-minute introductory session to be held prior to this instruction; and (iii) an individual interview (approximately 25-minutes to complete) and a 30-minute word problem solving quiz during the three weeks before and during the three weeks following the instruction - participation in the Study will be approximately 20 hours during 13-weeks;
   
   d. instruction will take place during the school day at <insert name of school> and will be arranged with the school’s principal and classroom teacher in order to minimize any disruption to students’ learning;
   
   e. the Student will receive the study’s schedule, including dates and times; and
   
   f. the researcher, Andrea Palmay, will administer all instruction.

2. We further understand that:
a. participation in this study is voluntary and that the Student is free to withdraw at any time without any reason and with no consequences and the Student may choose not to participate in any activities that he/she finds uncomfortable or disagreeable;

b. the Student’s performance will not affect his/her class standing;

c. the Student might receive one of three gift certificates to McDonalds;

d. if the Student withdraws from the study, we can request removal of all or part of his/her data;

e. individual interviews will be audio recorded and transcribed verbatim and the results from this study may be presented at academic conferences or be published in professional journals; and

f. steps have been taken to maintain the confidentiality of all participants to the extent possible.

3. Any questions about Study participation, a request to withdraw from the Study and/or removal of any data may be directed to Andrea Palmay at andrea.palmay@queensu.ca or her supervisor, Dr. Derek H. Berg at (613) 533-6000 ext. 77413 or derek.berg@queensu.ca. Any ethical concerns about the study may be directed to the Chair of the General Research Ethics Board at (613) 533-6081 or chair.GREB@queensu.ca.

We have read and kept the Letter of Information and all our questions have been answered to our satisfaction. We consent to the Student participating in the Study.

Please sign one copy of this Consent Form and return to the school’s main office within one week. Please retain the second copy for your records.

Signature of Parent/ Guardian: ____________________________ Date: __________________

Signature of Student Participant: ________________________ Date: __________________
## Appendix B

Outline of 18-Week Intervention

### Pretests

**Individual Interviews:** approximately 40 minutes

- Modified Mathematical Problem Solving Assessment-Short Form (MPSA-SF; Montague, 1996)
  - The interview contained 3 Likert-type questions, three word problems (1 one-step, 1 two-step, and 1 three-step word problem), and 29 open-ended responses
  - The three word problems (1 one-step, 1 two-step, and 1 three-step word problem) were based on the Grade 6 EQAO mathematics assessment
  - Interviews were audio-recorded and transcribed verbatim

**Student Introduction + Math Word Problem Solving Quiz**

- Introduction of study. Explained students’ roles and responsibilities
- Explained the importance of mathematical problem solving
- Explained how to use a calculator
- Administered the math word problem solving quiz.
- Quiz took 30 minutes to complete and was based on the Grade 6 EQAO mathematics assessment
- Quiz contained one-step, two-step, and three-step math problems

### Intervention: 32 sessions

**13-weeks**

Cognitive Strategy Instruction with Graphic Organizers

**Session 1:** 50 minutes

Objective: Focused on the first two cognitive strategies & processes (*Read & Paraphrase*) and the three associated metacognitive strategies for one-step word problems (self-instruct, self-monitor, and self-question)

- Classroom set up (10 minutes)
- Instructor modeling with guided practice (40 minutes)

**Session 2: 50 minutes**

*Read & Paraphrase Strategies & Processes*
- Classroom set up and introduction to study (10 minutes)
- Instructor modeling with guided practice of previously taught skills (40 minutes)

**Session 3: 50 minutes**

*Read & Paraphrase Strategies & Processes*
- Classroom set up and discussion of previously taught skills (10 minutes)
- Instructor modeling with guided practice of previously taught skills (40 minutes)

**Session 4: 50 minutes**

*Read & Paraphrase Strategies & Processes*
- Classroom set step. Instructor modeling with guided practice of previously taught skills (10 minutes)
- Independent practice (30 minutes)
- Class discussion (10 minutes)

**Session 5: 50 minutes**

*Read & Paraphrase Strategies & Processes*
- Classroom set up and class discussion of previously taught skills (10 minutes)
- Independent practice (30 minutes)
- Class discussion (10 minutes)

**Session 6: 50 minutes**

*Visualize & Hypothesize Strategies & Processes*
- Classroom set up and discussion of strategies (10 minutes)
- Instructor modeling and guided practice - Visualize & Hypothesize strategies (10 minutes)
- Class discussion on the four types operations: addition, subtractions, multiplication, and division (30 minutes)
<table>
<thead>
<tr>
<th>Session 7: 50 minutes</th>
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</thead>
<tbody>
<tr>
<td>* Read, Paraphrase, Visualize, &amp; Hypothesize Strategies &amp; Processes</td>
</tr>
<tr>
<td>• Classroom set up. Class discussion and guided practices of previously taught skills (Read &amp; Paraphrase) (10 minutes)</td>
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<tr>
<td>• Instructor modeling and guided practice- Visualize and Hypothesize (40 minutes)</td>
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<td>Session 8: 50 minutes</td>
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<tr>
<td>* Read, Paraphrase, Visualize, &amp; Hypothesize Strategies &amp; Processes</td>
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<tr>
<td>• Classroom set up and class discussion of previously taught skills (Read, Paraphrase, Visualize, &amp; Hypothesize) (5 minutes)</td>
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<tr>
<td>• Instructor modeling and guided practice - Visualize and Hypothesize strategies (30 minutes)</td>
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<td>• Independent practice on Read, Paraphrase, Visualize, &amp; Hypothesize (15 minutes)</td>
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<td>Session 9: 50 minutes</td>
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<tr>
<td>* Read, Paraphrase, Visualize, &amp; Hypothesize Strategies &amp; Processes</td>
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<tr>
<td>• Classroom set up and class discussion of previously taught skills (Read, Paraphrase, Visualize, &amp; Hypothesize) (5 minutes)</td>
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<tr>
<td>• Independent practice (30 minutes)</td>
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<td>• Class discussion (15 minutes)</td>
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<td>Session 10: 50 minutes</td>
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<tr>
<td>* Read, Paraphrase, Visualize, &amp; Hypothesize Strategies &amp; Processes</td>
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<tr>
<td>• Classroom set up and class discussion of previously taught skills (Read, Paraphrase, Visualize, &amp; Hypothesize) (5 minutes)</td>
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<tr>
<td>• Independent practice (30 minutes)</td>
</tr>
<tr>
<td>• Class discussion (15 minutes)</td>
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<tr>
<td>Session 11: 50 minutes</td>
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<tr>
<td>* Estimate Strategy &amp; Process</td>
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<tr>
<td>• Classroom set up and class discussion of previously taught skills (Read, Paraphrase, Visualize, &amp; Hypothesize) (10 minutes)</td>
</tr>
<tr>
<td>• Instructor modeling and guided practice - Estimate strategy (40 minutes)</td>
</tr>
<tr>
<td>Session 12: 50 minutes</td>
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<tr>
<td>* Estimate Strategy &amp; Process</td>
</tr>
<tr>
<td>• Classroom set up and class discussion of previously taught skills (Estimate) (5 minutes)</td>
</tr>
<tr>
<td>• Instructor modeling and guided practice- Estimate strategy (30 minutes)</td>
</tr>
<tr>
<td>• Independent practice on Read, Paraphrase, Visualize, Hypothesize, &amp; Estimate (15 minutes)</td>
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<td>Session 13: 50 minutes</td>
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<td>Session 14: 50 minutes</td>
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<td>Session 18: 50 minutes</td>
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<tr>
<td>Session 19: 50 minutes</td>
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</tbody>
</table>
- Classroom set up and review of previously taught skills (10)
- Independent practice on Read, Paraphrase, Visualize, Hypothesize, Estimate, Compute, & Check (40 minutes)

**Session 20:** 50 minutes
* Read, Paraphrase, Visualize, Hypothesize, & Estimate, Compute, & Check Strategies & Processes
  - Classroom set up and review of previously taught skills (10)
  - Independent practice on Read, Paraphrase, Visualize, Hypothesize, Estimate, Compute, & Check (40 minutes)

**Session 21:** 50 minutes
* Read, Paraphrase, Visualize, Hypothesize, & Estimate, Compute, & Check Strategies & Processes
  - Classroom set up and review of previously taught skills (10)
  - Independent practice on Read, Paraphrase, Visualize, Hypothesize, Estimate, Compute, & Check (40 minutes)

**Session 22:** 50 minutes
* Read, Paraphrase, Visualize, Hypothesize, & Estimate, Compute, & Check Strategies & Processes
  - Classroom set up and review of previously taught skills (10)
  - Independent practice on Read, Paraphrase, Visualize, Hypothesize, Estimate, Compute, & Check (40 minutes)

**Session 23:** 50 minutes
* Read, Paraphrase, Visualize, Hypothesize, & Estimate, Compute, & Check Strategies & Processes
  - Classroom set up and review of previously taught skills (10)
  - Independent practice on Read, Paraphrase, Visualize, Hypothesize, Estimate, Compute, & Check (40 minutes)

**Session 24 - Session 32**
- Students learned how to solve two-step math word problems
- The sessions followed the same instructional approach as one-step word problems

### Posttests

**Math Word Problem Solving Quiz**
- Based on the Grade 6 EQAO assessments
- The one-step and two-step math problems were administered to the students on separate days
- Each quiz took approximately 30 minutes to complete

**Individual Interviews**
- Modified Mathematical Problem Solving Assessment-Short Form (MPSA-SF; Montague, 1996)
- Followed similar format as the pre-individual interviews. Post-individual interviews only contained one-step and two-step math problems
- Individual interviews took approximately 40 minutes
- Individual interviews were audio-recorded and transcribed verbatim
Appendix C

Pre- Individual Interview

Modified Mathematics Problem Solving Assessment Form  (MPSA-SF, Montague, 1996)

Name (please print): __________________________________________

PART 1: Read each statement. Circle one number as your answer. Use the scales below to inform your answers.

<table>
<thead>
<tr>
<th>Very Poor</th>
<th>Poor</th>
<th>Average</th>
<th>Good</th>
<th>Very Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

1. Describe your math skills

1  2  3  4  5

2. Describe how well you solve math word problems

1  2  3  4  5
<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Somewhat Disagree</th>
<th>Neither Agree or Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

3. I enjoy solving math word problems

1  2  3  4  5

Explain your answer to Question 3.

_________________________________________________________________

_________________________________________________________________

_________________________________________________________________
PART 2: Answer each question. Show all your work

**Question 1 (one-step):**
A store sells 12 oranges for $3.96. How much does one orange cost?

**Question 2 (two-step):**
Jamie buys 3 ice cream cones for $4.65. At this rate, how much will it cost to buy two ice cream cones?

**Question 3 (three-step):**
Emily buys 3 bags of apples. Each bag has 24 apples. The total cost of the 3 bags of apples is $12.24.

How much does one apple cost?
PART 3: Answer each question. Your responses will be audio-recorded.

4. How did you read the word problems?

5. How many times did you read the word problems?

6. As you read the problem, did you do anything to help you understand the problem? (Can you explain more?)

7. If you did not understand something, what did you do?

8. What questions did you ask yourself while you were reading the word problems?

9. Did you ask yourself any questions after you solved the word problems?

10. Did you do anything when you were reading the word problems?

11. How did you help yourself remember what the problem said? (Side comments: And how many times? For each question?)

12. Did you put the problems in your own words?

13. How did you do this? Now I would like you to put the two-step problem in your own words.
14. When you put the problem in your own words, how did you know what you said was correct?

15. Did you make drawing or pictures of the problems?

16. Examiner: Show me one of the pictures you drew.

17. How did you make the pictures or drawings?

18. How did your drawings or pictures help you solve the math word problems?

19. How did you make a plan to solve the math word problem?

Researcher provides further clarification and asks student: What did you do to solve the math problem?

Researcher points to student’s answer sheet and asks the student: Did you have a plan for Question 1?

20. How did you use your plan to help you solve the math word problems?

21. How did you know to use addition, subtraction, multiplication or division to solve the math word problems?

Researcher points to each question and asks the student what operation he/she used to solve the math word problem. The researcher also asks the student why they choice that operation.
22. How did you decide how many steps are needed to solve the math word problems?

   Research asks the student to look at their answer sheet.

23. What is estimation?

24. Estimation is making a prediction about the answer using the information in the problem.
   Researcher provides clarification and says: This means you are guessing what the answer should be before you solve the word problem.

   Researcher asks: How did estimation help you solve the math word problems?

   Researcher asks the student to look at his/her answer sheet. Researcher asks: Did you guess what the answer should be for Question 1, 2, and 3?

25. How did you estimate or predict the answer before you solved the math word problems?

26. How did you compare your estimate with the answers?

27. What did you think when you solved the word problems?
   For further clarification, researcher asks: Did anything come to your mind while you were solving the math word problems?

28. How did you solve the math word problems?
29. How did you know that your calculations were correct?

30. What does checking mean?

31. Did you check your solutions? How did you check your solutions?

32. How did you check that you have correctly completed the math word problem?
Appendix D

Pre-Math Word Problem Solving Quiz

One-Step Word Problems:

1. A store sells 10 apples for $1.50. How much does one apple cost?
2. Emily buys 3 boxes of chocolates for $10.50. How much does one box of chocolates cost?
3. A store sells 5 candy bars for $6.50. How much does one candy bar cost?
4. John buys 2 ice cream cones for $2.86. How much does one ice cream cone cost?
5. A store sells 3 juice boxes for $3.60. How much does one juice box cost?
6. Sam buys 8 flowerpots for $16.56. How much does one flowerpot cost?
7. A store sells 5 oranges for $2.30. How much does one orange cost?
Two-Step Word Problems:

1. Max buys 3 boxes of chocolates for $10.59. At this rate, how much will it cost to buy two boxes of chocolates?
2. A store sells 5 apples for $1.50. At this rate, how much will it cost to buy three apples?
3. Sara buys 10 flowerpots for $15.50. At this rate, how much will it cost to buy four flowerpots?
4. A store sells 4 oranges for $4.40. At this rate, how much will it cost to buy two oranges?
5. Pat buys 6 juice boxes for $9.60. At this rate, how much will it cost to buy two juice boxes?
6. A store sells 3 candy bars for $5.25. At this rate, how much will it cost to buy two candy bars?
7. Emily buys 6 ice-cream cones for $8.76. At this rate, how much will it cost to buy four ice cream cones?
Three-Step Word Problems:

1. Emily buys 3 bags of oranges. Each bag has 10 oranges. The total cost of the 3 bags of oranges is $10.50. How much does one orange cost?

2. Max buys 4 boxes of chocolate bars. Each box has 5 chocolate bars. The total cost of 4 boxes of chocolate bars is $15.00. How much does one chocolate bar cost?

3. Sam buys 2 boxes of ice-cream bars. Each box has 6 ice-cream bars. The total cost of 2 boxes of ice-cream bars is $13.80. How much does one ice-cream bar cost?

4. A store sells 3 bags of candy bars. Each bag has 10 candy bars. The total cost of 3 bags of candy bars is $15.00. How much does one candy bar cost?

5. A store sells 2 bags of apples. Each bag has 6 apples. The total cost of 2 bags of apples is $5.52. How much does one apple cost?

6. Pat buys 2 boxes of juice packs. Each box has 6 juice packs. The total cost of 2 boxes of juice packs is $8.40. How much does one juice pack cost?

7. A store sells 3 boxes of cookies. Each box has 10 cookies. The total cost of 3 boxes of cookies is $13.50. How much does one cookie cost?
Appendix E

Post-Individual Interview

Modified Mathematics Problem Solving Assessment Form (MPSA-SF, Montague, 1996)

Name (please print): ________________________________

PART 1: Read each statement. Circle one number as your answer. Use the scales below to inform your answers.

<table>
<thead>
<tr>
<th>Very Poor</th>
<th>Poor</th>
<th>Average</th>
<th>Good</th>
<th>Very Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

33. Describe your math skills
   1   2   3   4   5

34. Describe how well you solve math word problems
   1   2   3   4   5
<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Somewhat Disagree</th>
<th>Neither Agree or Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

35. I enjoy solving math word problems

1 2 3 4 5

Explain your answer to Question 3.
PART 2: Answer each question. Show all your work

**Question 1 (one-step):**
A store sells 6 apples for $1.92. How much does one apple cost?

**Question 2 (two-step):**
Jamie buys 4 chocolate bars for $3.96. At this rate, how much will it cost to buy two chocolate bars?
PART 3: Answer each question. Your responses will be audio-recorded.

4. How did you read the word problems?

5. How many times did you read the word problems?

6. As you read the problem, did you do anything to help you understand the problem? (Can you explain more?)

7. If you did not understand something, what did you do?

8. What questions did you ask yourself while you were reading the word problems?

9. Did you ask yourself any questions after you solved the word problems?

10. Did you do anything when you were reading the word problems?

11. How did you help yourself remember what the problem said? (Side comments: And how many times? For each question?)

12. Did you put the problems in your own words?

13. How did you do this? Now I would like you to put the two-step problem in your own
When you put the problem in your own words, how did you know what you said was correct?

14. Did you make drawing or pictures of the problems?

15. Examiner: Show me one of the pictures you drew.

16. How did you make the pictures or drawings?

17. How did your drawings or pictures help you solve the math word problems?

18. How did you make a plan to solve the math word problem?
Researcher provides further clarification and asks student: What did you do to solve the math problem?
Researcher points to student’s answer sheet and asks the student: Did you have a plan for Question 1?

19. How did you use your plan to help you solve the math word problems?

20. How did you know to use addition, subtraction, multiplication or division to solve the math word problems?
Researcher points to each question and asks the student what operation he/she used to solve
the math word problem. The researcher also asks the student why they choose that operation.

22. How did you decide how many steps are needed to solve the math word problems?
Research asks the student to look at their answer sheet.

23. What is estimation?

24. Estimation is making a prediction about the answer using the information in the problem
Researcher provides clarification and says: This means you are guessing what the answer should be before you solve the word problem.
Researcher asks: How did estimation help you solve the math word problems?
Researcher asks the student to look at his/her answer sheet. Researcher asks: Did you guess what the answer should be for Question 1, 2, and 3?

25. How did you estimate or predict the answer before you solved the math word problems?

26. How did you compare your estimate with the answers?

27. What did you think when you solved the word problems?
For further clarification, researcher asks: Did anything come to your mind while you were solving the math word problems?

28. How did you solve the math word problems?
29. How did you know that your calculations were correct?

30. What does checking mean?

31. Did you check your solutions? How did you check your solutions?

32. How did you check that you have correctly completed the math word problem?
Post-Math Word Problem Solving Quiz

One-Step Word Problems:

8. A store sells 6 oranges for $2.40. How much does one orange cost?
9. Emily buys 3 chocolate bars for $2.97. How much does one chocolate bar cost?
10. A store sells 3 ice-cream cones for $6.00. How much does one ice-cream cone cost?
11. John buys two cheeseburgers for $12.00. How much does one cheeseburger cost?
12. You buy 3 hot chocolates for $4.20. How much does one hot chocolate cost?
13. A store sells 4 apples for $1.80. How much does one apple cost?
14. Sam buys two candy bars for $4.00. How much does one candy bar cost?
Two-Step Word Problems:

8. Max buys 3 candy bars for $3.30. At this rate, how much will it cost to buy two candy bars?

9. A store sells 4 t-shirts for $19.00. At this rate, how much will it cost to buy three t-shirts?

10. A store sells 4 ice-cream cones for $4.80. At this rate, how much will it cost to buy three ice-cream cones?

11. Sara buys 5 boxes of chocolates for $17.20. At this rate, how much will it cost to buy two boxes of chocolates?

12. You buy 6 juice boxes for $7.20. At this rate, how much will it cost to buy three juice boxes?

13. A store sells 3 boxes of pencils for $6.60. At this rate, how much will it cost to buy two boxes of pencils?

14. Emily buys 4 cookies for $4.40. At this rate, how much will it cost to buy two cookies?
Appendix F

Read: 1. Write down all information I understand.

Paraphrase:

1. Underline the important information.
2. Circle the question.
3. Write the word problem in your own words.

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**Visualize:** Draw a diagram or picture.

**Hypothesize:** Make a plan to solve the math word problem.
**Estimate:**
Did I round the numbers up or down?
Write the estimate.

**Compute:** Solve the question.
Check:

Have I checked the calculations? Is my answer correct?

Have I checked all steps?

Write the final answer.

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### Appendix G


<table>
<thead>
<tr>
<th>Step</th>
<th>SAY:</th>
<th>ASK:</th>
<th>CHECK:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Read</strong></td>
<td>Read the problem. If I don’t understand, read it again.</td>
<td>Have I read and understood the problem?</td>
<td>Do I understand all information and instructions as I solve the problem?</td>
</tr>
<tr>
<td><strong>Paraphrase</strong></td>
<td>Underline the important information. Put the problem in my own words.</td>
<td>Have I underlined the important information? What is the question? What am I looking for?</td>
<td>Does the information go with the problem?</td>
</tr>
<tr>
<td><strong>Visualize</strong></td>
<td>Make a drawing or a diagram.</td>
<td>Does the picture fit the problem?</td>
<td>Does the picture match the information in the problem?</td>
</tr>
<tr>
<td><strong>Hypothesize</strong></td>
<td>How many steps are needed to solve the problems? What types of operations (+ − × ÷ ) will I use?</td>
<td>Have I included all steps and operations?</td>
<td>Does my plan make sense?</td>
</tr>
<tr>
<td><strong>Estimate</strong></td>
<td>Round the numbers and write your estimate.</td>
<td>Did I round the numbers up or down? Did I write my estimate?</td>
<td>Does my estimate make sense? Have I included the important information?</td>
</tr>
<tr>
<td><strong>Compute</strong></td>
<td>Do the operations in the correct order.</td>
<td>How does the answer compare with my estimate? Does my answer make sense? Are the units included in the answer?</td>
<td>Did I do the operations in the correct order?</td>
</tr>
<tr>
<td><strong>Check</strong></td>
<td>Check my answer.</td>
<td>Have I checked the calculations? Is my answer correct?</td>
<td>Have I checked all steps?</td>
</tr>
</tbody>
</table>
Appendix H

Daily Lesson Plans - Instructor Guidelines

ONE-STEP WORD PROBLEMS: Read & Paraphrase

Read:

-Instructor reads the word problem out loud:

*A store sells 10 apples for $2.50. How much does one apple cost?*

- Research explains SAY, ASK, and CHECK (metacognitive strategies):

1. SAY: Read the problem. If I don’t understand, read it again.

2. ASK: Have I read and understood the problem?
   - What does $2.50 mean? For how many apples?

3. CHECK: Do I understand all information as I solve the problem.
   - Find the question in the word problem. What does the problem ask?

Paraphrase (put in your own words):

Instructor explains SAY, ASK, and CHECK (metacognitive strategies):

1. SAY: Underline the important information. Put the problem in my own words.
   - Instructor states: *First, I need to underline key words or phrases in the word problem.*

   - *Underline the following:*
     o 10 apples for $2.50
     o How much does one apple cost?
     o Circle one apple

2. ASK: Have I underlined the important information? What is the question? What am I looking for?

3. CHECK: Does the information go with the problem?
   - Now paraphrase the word problem: *I am going to buy 10 apples. 10 apples cost $2.50. Find the cost for one apple.*

*Use the Graphic Organizer to follow instructions.*
ONE-STEP WORD PROBLEMS: Visualize & Hypothesize

Visualize:

- Instructor reads the first word problem out loud

A store sells 3 candy bars for $2.40. How much does one candy bar cost?

- Research explains SAY, ASK, and CHECK (metacognitive strategies):
  1. SAY: Make a drawing or a picture.
  2. ASK: Does the picture fit with the problem?
  3. CHECK: Does the information match the information in the problem?

Hypothesize:

- Research explains SAY, ASK, and CHECK (metacognitive strategies):
  1. SAY: How many steps are needed to solve the problems? What types of operations (+ − × ÷) will I use?
     - Instructor explains that the terms “How much” or “What is” mean division.
     - To find the cost of one candy bar, you take the total amount ($2.40) and divide it by 3.
     - This is a one-step problem.
  2. ASK: Have I included all steps and operations?
     - If I divide the total cost ($2.40) by the number of candy bars (3), then I will find the cost of 1 candy bar.
  3. CHECK: Does my plan make sense?
     - Did I copy the numbers correctly?

Use the Graphic Organizer to follow the instructions.
ONE-STEP WORD PROBLEMS: Estimate, Compute & Check

Estimate:

- Instructor reads the math problem out loud:

A store sells 2 candy bars for $2.80. How much does one candy bar cost?

- Research explains SAY, ASK, and CHECK (metacognitive strategies):

  1. SAY: Round the numbers and write your estimate.
     - Round the number $2.80.
     - Apply Rules for Rounding: Round $2.80 to $3.00
  2. ASK: Did I round the numbers up or down? Did I write my estimate?
  3. CHECK: Does my estimate make sense? Have I included the important information?

Use the Graphic Organizer to follow the instructions.

Compute:

- Research explains SAY, ASK, and CHECK (metacognitive strategies):

  1. SAY: Do the operations in the correct order.
  2. ASK: How does the answer compare with my estimate? Does my answer make sense? Are the units included in the answer?

    If I round down, the estimate is smaller than the final answer.
    If I round up, the estimate is larger than the final answer.
  3. CHECK: Did I do the operations in the correct order?

Use the Graphic Organizer to follow the instructions.

Check:

- Research explains SAY, ASK, and CHECK (metacognitive strategies):

  1. SAY: Check my answer.
     - Use the calculator to check your answer.
  2. ASK: Have I checked the calculations? Is my answer correct?
     - Make sure $1.40 + $1.40 is the cost for two candy bars
  3. CHECK: Have I checked all steps?

Use the Graphic Organizer to follow all instructions.
Sample of One-Step Word Problems:

1. A store sells 10 apples for $2.50. How much does one apple cost?

2. Emily buys 5 oranges for $3.50. How much does one orange cost?

3. A store sells 3 candy bars for $2.40. How much does one candy bar cost?

4. John buys two small pizzas for $21.00. How much does one pizza cost?

5. You buy two sweaters for $29.98 at Walmart. How much does one sweater cost?
Appendix I

Rules for Rounding

1. If the total cost has zero cents (e.g., $18.00), then round the total cost either up or down by counting by 10’s (e.g., 10, 20, 30,…)

2. If the total cost has cents (e.g. $3.99), then round the total cost either up or down by counting by 1’s (e.g., 1, 2, 3,…)

Appendix J
Sample of Students’ Answers- Post-Intervention Quiz for One-Step Word Problems

Britney

Word Problem given: A store sells 6 oranges for $2.40. How much does one orange cost?

Britney’s incorrect answer
Estimate:
1. Did I round the numbers up or down?
2. Write the estimate.

\[ \$2.40 \]

\[ \text{estimate} \]

\[ \frac{\$2.40}{6} = 0.33 \]

\[ \text{Rounds down to} \]

\[ \$2.40 \times \frac{1}{6} \]

The cost of one orange is about \( 0.33 \) - estimate

 Compute: Solve the question

\[ \frac{\$2.40}{1} = \$2.40 \]

\[ \text{answer} \]

\[ \text{My estimate is smaller than my answer because} \]

\[ \text{rounded down.} \]

Check:
1. Have I checked the calculations? Is my answer correct? \( \square \)

2. Have I checked all steps? \( \square \)

\[ 0.33 + 0.33 + 0.33 + 0.33 = 1.98 \]

\[ 0.33 \times 6 = 1.98 \]

Write the final answer.

The cost of one orange is \( \$1.98 \)
**Jena**

**Word Problem given:** A store sells 6 oranges for $2.40. How much does one orange cost?

Jena’s correct answer

---

1. **Read:** Write down all information I understand.
   
   6 oranges, $2.40
   
   Find the cost of one orange

2. **Paraphrase:**
   
   1. Underline the important information.
   2. Circle the question.
   3. Write the word problem in your own words.
   
   I bought 6 oranges for $2.40. Find the cost of one orange.

3. **Visualize:** Draw a diagram or picture.
   
   ![Diagram of oranges and cost]
   
   100
   
   $2.40

4. **Hypothesize:** Make a plan to solve the math word problem.
   
   How much = division
   
   What is = division
   
   $2.40 \div 6 = \text{find the cost of one orange}

This is a one step problem.
Estimate:
1. Did I round the numbers up or down?
   - Round down
2. Write the estimate.
   - $2.40
   - $2.00
   - The cost of one orange is about $0.33

Compute: Solve the question.

$2.40 ÷ 6 ≈ 0.40

My estimate is smaller than my answer because I rounded down.

Check:
1. Have I checked the calculations? Is my answer correct?
   - Used the calculator
2. Have I checked all steps?
   - Yes

Write the final answer.

The cost of one orange is $0.40
Megan

Word Problem given: A store sells 6 oranges for $2.40. How much does one orange cost?

Megan’s correct answer
Estimate:
1. Did I round the numbers up or down?
2. Write the estimate.

\[ \$2.40 \]
\[ \frac{2.40}{6} = \$0.33 \]

Rounds down to

\[ \$0.33 \]

The approximate cost of one orange is \$0.33

Compute: Solve the question.

\[ \frac{2.40}{6} = \$0.40 \]

The cost of one orange is \$0.40

Check:
1. Have I checked the calculation? Is my answer correct?

2. Have I checked all steps?

Write the final answer.

The cost of one orange is 40¢ (cents)
## Appendix K
Students’ responses in the pre-individual interview and post-individual interview (modified MPSA-SF; Montague, 1996)

### Britney: Pre-Individual Interview

<table>
<thead>
<tr>
<th></th>
<th>Knowledge</th>
<th>Use</th>
<th>Control</th>
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</thead>
<tbody>
<tr>
<td><strong>Read</strong></td>
<td>4. How did you read the word problems?</td>
<td>5. How many times did you read the word problems?</td>
<td>8. What questions did you ask yourself while you were reading the word problems?</td>
</tr>
<tr>
<td></td>
<td>(“I don’t know.”)</td>
<td>(“About 3 times because for question 3 I did not really get it. And so I read it a couple of times so I can make myself understand it.”)</td>
<td>(“What it was trying to say?”)</td>
</tr>
<tr>
<td></td>
<td>6. As you read the problem, did you do anything to help you understand the problem? (Can you explain more?)</td>
<td>Researcher said: Okay. Good. So how many times did you read question 1? Student said: About 2. Researcher asked: And how about for question 2? Student said: 3 I think. Researcher asked: And how about for question 3? Student said: 3 I think.”</td>
<td>9. Did you ask yourself any questions after you solved the word problems?</td>
</tr>
<tr>
<td></td>
<td>(“Well I thought what was it trying to say.”)</td>
<td></td>
<td>(“I did not really ask any questions.”)</td>
</tr>
<tr>
<td></td>
<td>10. Did you do anything when you were reading the word problems?</td>
<td>7. If you did not understand something, what did you do?</td>
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<td></td>
<td>(“I am not sure. I just re-read it I guess.”)</td>
<td>(“I went back and re-read it.”)</td>
<td></td>
</tr>
<tr>
<td><strong>Paraphrase</strong></td>
<td>11. How did you help yourself remember what the problem said? (Side comments: And how many times? For each question?)</td>
<td>12. Did you put the problems in your own words?</td>
<td>14. When you put the problem in your own words, how did you know what you said was correct?</td>
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<td></td>
<td>(“I just like put it in my mind...like what the question said.”)</td>
<td>(“No.”)</td>
<td><strong>Skipped</strong></td>
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<td></td>
<td>13. How did you do this? Now I would like you to put the two-step problem in your own words.</td>
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<td></td>
<td><strong>Skipped</strong></td>
<td></td>
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<tr>
<td><strong>Visualize</strong></td>
<td>17. How did you make the pictures or drawings?</td>
<td>15. Did you make drawing or pictures of the problems?</td>
<td>18. How did your drawings or pictures help you solve math</td>
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<tr>
<td><strong>Hypothesize</strong></td>
<td><strong>Skipped</strong></td>
<td><strong>“No.”</strong></td>
<td><strong>Skipped</strong></td>
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<tr>
<td>16. Examiner: Show me one of the pictures you drew.</td>
<td>19. How did you make a plan to solve the math word problem?</td>
<td>20. How did you use your plan to help you solve the math word problems?</td>
<td>21. How did you know to use addition, subtraction, multiplication or division to solve the math word problems?</td>
</tr>
<tr>
<td>Skipped</td>
<td>Researcher provides further clarification and asks student: What did you do to solve the math problem?</td>
<td>“I used my fingers.”</td>
<td>Researcher points to each question and asks the student what operation he/she used to solve the math word problem. The researcher also asks the student why they chose that operation.</td>
</tr>
<tr>
<td>Skipped</td>
<td>Researcher points to student’s answer sheet and asks the student: Did you have a plan for Question 1?</td>
<td>“I used my fingers and then I subtracted the question... what it was saying.”</td>
<td>“I used subtraction. Researcher said: Okay. And how did you know to use subtraction? Student said: Because it asked how much does one orange cost. And I wrote that. Researcher asked: And how about for question 2? Did you do subtraction or addition? Student said: Subtraction. And why did you do subtraction? Student said: Because it said...are we on question 2? Researcher said: Yes. Student reads question 2. Student said: So it says how much. So...Researcher said: Okay. And how about for question 3? Did you do subtraction? Student said: Yeah. I did subtraction because it says how much does one apple cost. So you are taking away.”</td>
</tr>
<tr>
<td>22. How did you decide how many steps are needed to solve the math word problems?</td>
<td>“I am not sure. Researcher said: So for question 1, did you know how many steps you needed to calculate to get the</td>
<td></td>
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<tr>
<td>Estimate</td>
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</table>
| 23. What is estimation?  
   “Estimate is where you pick a guess and then you calculate it and find out...what like the answer, the real answer is.” |
| 24. Estimation is making a prediction about the answer using the information in the problem.  
   Researcher provides clarification and says: This means you are guessing what the answer should be before you solve the word problem.  
   Researcher asks: How did estimation help you solve the math word problems?  
   “No.”  
   Skipped | 25. How did you estimate or predict the answer before you solved the math word problems?  
   Skipped | 26. How did you compare your estimate with the answers?  
   Skipped |

answer? Student said: Yeah.  
Researcher asked: And how many steps? Student said: Two.  
Researcher asked: And why two steps? Student said: Actually 3 because you had to figure out what the question was saying and then you had to calculate it with my fingers and then I had to solve it. So this answer was like $1.96  
Researcher: And how about for question 2? And how many steps did you use to solve question? Student: 3 because of the same answer for question 1.  
Researcher: Good. Did you do anything else? Student: No.  
Researcher: And how about for question 3? How many steps did you do to solve the math word problem? Student: The same as question 1 and 2. Researcher: Did you do anything else? Student: No.”
| Compute | 27. What did you think when you solved the word problems?  
For further clarification, researcher asks: Did anything come to your mind while you were solving the math word problems?  
“No.” | 28. How did you solve the word problems?  
“I used my fingers and then I subtracted the numbers.” | 29. How did you know that your computations were correct?  
“Because I did it on my fingers.” |
|---|---|---|---|
| Check | 30. What does checking mean?  
“It means you are checking with your fingers or a calculator and you check if your answers are right and you right the real answer down.” | 31. Did you check your solutions? How did you check your solutions?  
“I forget.” | 32. How did you check that you have correctly completed the math word problem?  
“I forget.” Researcher: That’s okay. Take your time. You did a lot of things for that question. Did you do anything to check your work (for question 1,2 and 3)? Student said: No.” |
<table>
<thead>
<tr>
<th>Knowledge</th>
<th>Use</th>
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</tr>
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<tbody>
<tr>
<td><strong>Read</strong></td>
<td>4. How did you read the word problems?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>“I don’t know.”</td>
<td></td>
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<tr>
<td></td>
<td>6. As you read the problem, did you do anything to help you understand the problem? (Can you explain more?)</td>
<td></td>
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<tr>
<td></td>
<td>“No, not really.”</td>
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<tr>
<td></td>
<td>10. Did you do anything when you were reading the word problems?</td>
<td></td>
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<td></td>
<td>“Well I thought... how I was going to answer the questions?”</td>
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<tr>
<td><strong>Paraphrase</strong></td>
<td>11. How did you help yourself remember what the problem said? (Side comments: And how many times? For each question?)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>“Say...like for Read, it all came back to me...like when I did...um...Researcher: so what came back to you? Student: Like for read my mind just kind of blanked and like when I read the question. Researcher: Is this for question 1? Student: Yeah. Researcher: Okay. So you got stuck? Where did you get stuck? Student: Like I did not know what to do. Researcher: where did you not know what to do? At what step? Student: I think it was compute and I did not know what to do. So it all came back to me.</td>
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<td></td>
<td>12. Did you put the problems in your own words?</td>
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<td></td>
<td>“Yes (to questions 1 and 2).”</td>
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<td></td>
<td>13. How did you do this? Now I would like you to put the two-step problem in your own words.</td>
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<td>“The cost of four chocolate bars is $3.96. Researcher: Okay, what else did you write? Student: I wrote “find the cost of two chocolate bars.”</td>
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<td></td>
<td>14. When you put the problem in your own words, how did you know what you said was correct?</td>
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<td></td>
<td>“Because you are pretty much putting it in your own words. So I wrote: the cost of four chocolate bars is $3.96. Researcher: But how did you know this information was correct? There are no mistakes. Student: I looked back. Researcher: where did you look back? Student: at the question sheet. Researcher: You looked back at the question sheet? Student: Yeah. Researcher: Is there anything else that you did? Student: No.”</td>
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<tr>
<td><strong>Use</strong></td>
<td>5. How many times did you read the word problems?</td>
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<td></td>
<td>“Well if I did not understand it, I read it two times or three times. Researcher: So looking at question 1, let’s flip to question 1 here, question 1 was the one-step problem, how many times did you question 1? Student: I read it twice. Researcher: Twice. And how about question2, how many times did you read the problem? Student: Twice.”</td>
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<tr>
<td><strong>Control</strong></td>
<td>8. What questions did you ask yourself while you were reading the word problems?</td>
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<td>“I didn’t really ask myself questions because I knew what to do. So I didn’t really ask myself questions.”</td>
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<td></td>
<td>9. Did you ask yourself any questions after you solved the word problems?</td>
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<td>“No to questions 1 and 2.”</td>
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<tr>
<td><strong>Visualize</strong></td>
<td>17. How did you make the pictures or drawings?</td>
<td>15. Did you make drawing or pictures of the problems?</td>
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<td>“I did 4 chocolate bars and I circled two because you are trying to find two. And I put an arrow and it has $3.96. Researcher: So what does $3.96 mean? Student: the cost of four chocolate bars. Researcher: Very good. And what does this mean? Student: It means you are trying to find the cost of two chocolate bars.”</td>
<td>“Yes, in visualize.”</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Hypothesize</strong></th>
<th>19. How did you make a plan to solve the math word problem?</th>
<th>20. How did you use your plan to help you solve the math word problems?</th>
<th>21. How did you know to use addition, subtraction, multiplication or division to solve the math word problems?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Researcher provides further clarification and asks student: What did you do to solve the math problem?</td>
<td>“Because you have to find out what $1.92 divided by six is and that finds the cost of one apple. Researcher: So did you use this plan to help you solve it? Student: Yes. Researcher: How? Student: I don’t know. Researcher: That’s ok. Just try your best. How about for question 2? So when you looked at this plan, did you do anything? Student: No.”</td>
<td>Researcher points to each question and asks the student what operation he/she used to solve the math word problem. The researcher also asks the student why they choose that operation.</td>
<td>“Researcher: So look at question 1, what calculation or operation did you use for question 1? Student: Division. Researcher: And why did you use division? Student: because you trying to find out what is the cost. Researcher: the cost of what? Student: Uh...one apple. Researcher: Okay, now for question 2, what calculations did you use? Student: Division. Researcher: Okay. for which step? Student: number 1. Researcher: why for 1? Student: Because......i don’t know. Researcher: So you did division. Why division? Student: Because you are trying to find out what one chocolate bar is.”</td>
</tr>
</tbody>
</table>
Researcher: Okay.”

Researcher: ok. And what calculation did you do for step 2? Student: addition. Researcher: And why addition? Student: Because you are trying to find what two chocolate bars cost."

22. How did you decide how many steps are needed to solve the math word problems?

“I don’t know. Researcher: Okay. So for question 1, how many steps are needed to solve this question? Student: Seven. Researcher: For this graphic organizer, how many steps are needed to solve the question? Student: One. Researcher: Okay. Why one? Student: Because this is a one-step problem. Researcher: and what does a one-step problem mean? Student: you are just figuring out what one step is. Researcher: Okay and here, how many steps are needed to solve the problem? Student: two."
**Estimate**

23. What is estimation?

“It is like guessing what the answer is.”

24. Estimation is making a prediction about the answer using the information in the problem.

Researcher provides clarification and says: This means you are guessing what the answer should be before you solve the word problem.

Research asks: How did estimation help you solve the math word problems?

“Researcher: Did you estimate for question 1? Student: Yeah. Researcher: Okay. How did your estimate help you solve the question? Student: I don’t know. Researcher: Okay. Did you do anything here to help you solve the question? Student: Oh yeah. In estimate I circled one apple is about 33 cents and then I circled it and put an arrow kind of....and then down to compute it’s like 32 cents....and that’s the answer. Researcher: Good. So what did you write down here? Student: My estimate is bigger than my answer because I rounded up.”

25. How did you estimate or predict the answer before you solved the math word problems?


26. How did you compare your estimate with the answers?

“I don’t know. Researcher: So look at question1 closely. Did you compare this estimate to your answer? Student: Oh yeah. Researcher: Good. So what did you do? Student: Well my estimate is bigger than my answer. Researcher: So how did you know that? Student: I don’t know.”

**Compute**

27. What did you think when you solved the word problems?

For further clarification, researcher asks: Did anything come to your mind while you were solving the math word problems?

“No. not really.”

28. How did you solve the word problems?

“I...I don’t know. Researcher: Okay. you can look at your graphic organizer. How did you solve the math word problems? Student: Oh I used the instruction sheet.. Researcher: You used the instruction sheet? Student: Yeah. Researcher: Good. Did you follow all the step? Student: Yeah. Researcher: what else did you do to

29. How did you know that your computations were correct?

“Because I calculated twice on the calculator (question 1). Researcher: Good. And did you do anything else? Student: No.”
solve the word problems? Did you do anything else? Student: No. Researcher: So did you look at the instruction sheet to solve question 2? Student: Not really, just in some parts. Like Hypothesize I needed to look at the instruction sheet for, but for the other parts, I know. Researcher: That’s for question 2. How about for question 1? Did you use it for all the seven steps? Student: No. Researcher: Which steps did you look at? Student: Oh I had to look at check.”

<table>
<thead>
<tr>
<th>Check</th>
<th>30. What does checking mean?</th>
<th>31. Did you check your solutions? How did you check your solutions?</th>
<th>32. How did you check that you have correctly completed the math word problem?</th>
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<tbody>
<tr>
<td></td>
<td>“It means like checking if the answer is right.”</td>
<td>“What I did was...I used a calculator. Researcher: And what did you do on your calculator? Student: what I did was $1.92 divided 6 and that finds the cost of one apple. And did you do anything else to check your answer? Student: Nope.”</td>
<td>“I used a calculator.”</td>
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### Jena: Pre-Individual Interview

<table>
<thead>
<tr>
<th>Knowledge</th>
<th>Use</th>
<th>Control</th>
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<tbody>
<tr>
<td><strong>Read</strong></td>
<td>4. How did you read the word problems?</td>
<td>5. How many times did you read the word problems?</td>
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<tr>
<td></td>
<td>“I don’t know.”</td>
<td>“5 or 6 times.”</td>
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<td></td>
<td>6. As you read the problem, did you do anything to help you understand the problem? (Can you explain more?)</td>
<td>7. If you did not understand something, what did you do?</td>
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<td></td>
<td>10. Did you do anything when you were reading the word problems?</td>
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<td></td>
<td>“Not really.”</td>
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<tr>
<td><strong>Paraphrase</strong></td>
<td>11. How did you help yourself remember what the problem said? (Side comments: And how many times? For each question?)</td>
<td>12. Did you put the problems in your own words?</td>
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<td></td>
<td>“Keep looking back at it.” Research says: “Okay. Good. And how many times did you look back at the problem?” Student says: “4 to 5 times.”</td>
<td>“No.”</td>
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<td></td>
<td>13. How did you do this? Now I would like you to put the two-step problem in your own words.</td>
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<td><strong>Skipped</strong></td>
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<tr>
<td><strong>Visualize</strong></td>
<td>17. How did you make the pictures or drawings?</td>
<td>15. Did you make drawing or pictures of the problems?</td>
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<td></td>
<td><strong>Skipped</strong></td>
<td>“No.”</td>
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<tr>
<td>Hypothesize</td>
<td>19. How did you make a plan to solve the math word problem? Researcher provides further clarification and asks student: What did you do to solve the math problem? Researcher points to student’s answer sheet and asks the student: Did you have a plan for Question 1? “I don’t know.”</td>
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<td></td>
<td>21. How did you know to use addition, subtraction, multiplication or division to solve the math word problems? Researcher points to each question and asks the student what operation he/she used to solve the math word problem. The researcher also asks the student why they choice that operation. “If you did addition on this one (points to question 1), it would be too big.” Researcher says: “too big of what?” Student says:” too big of a number.” Student says: “for this question(points to question three), you don’t minus it, you add it.” Research asks for clarification: “So this question 1, what operation did you do?” Student say:” subtraction.” And researcher asks: “And why did you do subtraction? Why did you not do addition?” Student said: “Because if you added it, would be…” Researcher says: ” It would be too big of a number.” Student said: “Yeah.”</td>
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<td>22. How did you decide how many steps are needed to solve the math word problems? “I am not sure.”</td>
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<tr>
<td>Estimate</td>
<td>23. What is estimation?</td>
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<td></td>
<td>No response from student.</td>
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<td>24. Estimation is making a prediction about the answer using the information in the problem</td>
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<td>Researcher provides clarification and says: This means you are guessing what the answer should be before you solve the word problem.</td>
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<td>Researcher asks: How did estimation help you solve the math word problems?</td>
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<th>27. What did you think when you solved the word problems?</th>
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<td>For further clarification, researcher asks: Did anything come to your mind while you were solving the math word problems?</td>
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<td>“No.”</td>
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<td></td>
<td>28. How did you solve the word problems?</td>
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<td></td>
<td>“I added them and subtracted them.”</td>
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<td></td>
<td>Researcher asked: “So operations did you do? Did you do addition?” Student says: “I did addition and subtraction.” Researcher asked: “For questions 1, 2 and 3?” Student: “for questions 1, 2 and 3.”</td>
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<td></td>
<td>29. How did you know that your computations were correct?</td>
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<td></td>
<td>“I don’t know.”</td>
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<td>“Checking over your work”</td>
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<td>31. Did you check your solutions? How did you check your solutions?</td>
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<td>“I am not sure.”</td>
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<td>32. How did you check that you have correctly completed the math word problem?</td>
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## Jena: Post-Individual Interview

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<td>4. How did you read the word problems?</td>
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<td></td>
<td>“I don’t know. I just read it.”</td>
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<td>6. As you read the problem, did you do anything to help you understand the problem? (Can you explain more?)</td>
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<td>“I wrote down what 6 apples mean and what 4 chocolate bars mean.” Researcher: Good. And where did you write that down? Student: “In Read.” Researcher: Did you do anything else to help you understand? Student: “I put how much does one apple cost in my own words.”</td>
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<td></td>
<td>10. Did you do anything when you were reading the word problems?</td>
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<td></td>
<td>“Not really.”</td>
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<tr>
<td><strong>Paraphrase</strong></td>
<td>5. How many times did you read the word problems?</td>
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<td>7. If you did not understand something, what did you do?</td>
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<td>11. How did you help yourself remember what the problem said? (Side comments: And how many times? For each question?)</td>
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<td>12. Did you put the problems in your own words?</td>
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<td></td>
<td>“Yeah.”</td>
<td></td>
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<td></td>
<td>13. How did you do this? Now I would like you to put the two-step problem in your own words.</td>
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<td>“I said four bars equals…costs $3.96. Find the cost of two.”</td>
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<td>14. When you put the problem in your own words, how did you know what you said was correct?</td>
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<td>“I looked back at the question sheet.” Researcher: Is there anything else that you did in order to make sure this information was correct? Student: “I looked back at Read.”</td>
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<tr>
<th>Visualize</th>
<th>17. How did you make the pictures or drawings?</th>
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<tbody>
<tr>
<td></td>
<td>“I drew 4...no six apples in a box and then... Researcher: What else did you draw here? Student: “I put one apple equals question mark cost.” Researcher: What does this statement mean? Student: “How much does one apple cost?”</td>
</tr>
<tr>
<td>15. Did you make drawing or pictures of the problems?</td>
<td>“I did in Visualize.”</td>
</tr>
<tr>
<td>18. How did your drawings or pictures help you solve math word problems?</td>
<td>“It helps because you know how many apples you have.”</td>
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<tr>
<td>16. Examiner: Show me one of the pictures you drew.</td>
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<tr>
<td>Hypothesize</td>
<td>19. How did you make a plan to solve the math word problem?</td>
</tr>
<tr>
<td>Researcher provides further clarification and asks student: What did you do to solve the math problem? Researcher points to student’s answer sheet and asks the student: Did you have a plan for Question 1? “I went to Hypothesize.” Researcher: Good. And what did you do there? Student: “I wrote what division means and...” Researcher: So what did you write down for question 1? Student: “I said how much equals division. And $1.92 divided by six equals finds the cost of one apple. And then a two-step problem”. Researcher: And for question 2, what did you write there? Student: “How much equals division. $3.96 divided by 4 equals the cost of one.”</td>
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<tr>
<td>21. How did you know to use addition, subtraction, multiplication or division to solve the math word problems?</td>
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<tr>
<td>22. How did you decide how many steps are needed to solve</td>
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</table>
| **Estimate** | 23. What is estimation?  
“Guess the answer.” | 25. How did you estimate or predict the answer before you solved the math word problems?  
Researchers: So how about for question 2? So how did you estimate for question 2?  
Student: “$4 divided 4 equals 1.” Researchers:  
Good. And what else did you do there? Student: “I did $4 divided 4 equals 1 and then… and then… I did the two drawings.” | 26. How did you compare your estimate with the answers?  
“I don’t know.” |
| --- | --- | --- | --- |
|  | 24. Estimation is making a prediction about the answer using the information in the problem.  
Researchers provide clarification and says: This means you are guessing what the answer should be before you solve the word problem.  
Researchers ask: How did estimation help you solve the math word problems?  
“I rounded up or down. And then I divided it.” Researchers: So what was your estimation here?  
Student: “0.33.” Researchers:  
What does that mean? 0.33?  
Student: “The cost of one apple is about 0.33.” |  |  |
| **Compute** | 27. What did you think when you solved the word problems?  
For further clarification, researcher asks: Did anything come to your mind while you were solving the math word problems?  
“No.” | 28. How did you solve the word problems?  
“I used the graphic organizer and calculator.” | 29. How did you know that your computations were correct?  
“I used the calculator.” |
| **Check** | 30. What does checking mean?  
“To check your work.” | 31. Did you check your solutions? How did you check your solutions?  
“I compared it to the question sheet.” | 32. How did you check that you have correctly completed the math word problem?  
“I compared it to the question sheet.” |
# Megan: Pre-Individual Interview

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<td>4. How did you read the word problems?</td>
<td>5. How many times did you read the word problems?</td>
<td>8. What questions did you ask yourself while you were reading the word problems?</td>
</tr>
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<td></td>
<td>“I...like...took the numbers...and then...when I took the numbers, I figured out if it was subtracting, adding, multiplying, and dividing. And then...I put like...for questions one, the numbers were 12 and 3.94. So I did 12 divided by 3.94, and the answer was 30 cents. So that is how I got that answer.”</td>
<td>“I read it like once or twice.”</td>
<td>“Just like...which numbers are the most important.”</td>
</tr>
<tr>
<td></td>
<td>6. As you read the problem, did you do anything to help you understand the problem? (Can you explain more?)</td>
<td>7. If you did not understand something, what did you do?</td>
<td>9. Did you ask yourself any questions after you solved the word problems?</td>
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<td></td>
<td>“No. I just kind of read it.”</td>
<td>“I...like...continued reading it and like went back and then figured it out. Because like it did not make sense at first for question 3 I think with the one I asked you about the apple. So I went back and then it just said one apple and then I was okay well....and that’s one apple.”</td>
<td>“No.”</td>
</tr>
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<td></td>
<td>10. Did you do anything when you were reading the word problems?</td>
<td>12. Did you put the problems in your own words?</td>
<td>14. When you put the problem in your own words, how did you know what you said was correct?</td>
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<td></td>
<td>“No. not really.”</td>
<td>“For question 2, yes. For question 1 and 3, no.”</td>
<td>“Well I don’t know. I just kind of figured it out if it was right and I wrote it down. I thought it was right. So if it’s not then....”</td>
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<td></td>
<td><strong>Paraphrase</strong></td>
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<td>11. How did you help yourself remember what the problem said? (Side comments: And how many times? For each question?)</td>
<td>13. How did you do this? Now I would like you to put the two-step problem in your own words.</td>
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<td>“I took bits of pieces of it and like stuck it in my head to the back of my head.”</td>
<td>“Question two asks that Jamie buys three ice cream cones for 4.65. At this rate, how much will it cost to buy two ice cream cones? So instead of it being Jamie, I”</td>
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<tr>
<td><strong>Visualize</strong></td>
<td>17. How did you make the pictures or drawings?</td>
<td>15. Did you make drawing or pictures of the problems?</td>
<td>18. How did your drawings or pictures help you solve math word problems?</td>
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<td><strong>Skipped</strong></td>
<td></td>
<td>“No.”</td>
<td><strong>Skipped</strong></td>
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<tr>
<td><strong>Hypothesize</strong></td>
<td>19. How did you make a plan to solve the math word problem?</td>
<td>20. How did you use your plan to help you solve the math word problems?</td>
<td>21. How did you know to use addition, subtraction, multiplication or division to solve the math word problems?</td>
</tr>
<tr>
<td>Researcher provides further clarification and asks student: What did you do to solve the math problem?</td>
<td>“For question 1, it’s kind of just pulling the numbers and deciding whether it should be subtracting, adding, multiplication or division.”</td>
<td>Research points to each question and asks the student what operation he/she used to solve the math word problem. The researcher also asks the student why they choose that operation.</td>
<td>“Well…I don’t know.”</td>
</tr>
<tr>
<td>Researcher points to student’s answer sheet and asks the student: Did you have a plan for Question 1?</td>
<td>“Well for question 1, I pulled out the numbers and did the math obviously. Same with question 2, I did the same thing as I did for question 1.”</td>
<td>22. How did you decide how many steps are needed to solve the math word problems?</td>
<td>“I just kind of broken it down into chunks and then...there wasn’t really chunks...it was kind of like doing the math problem.”</td>
</tr>
<tr>
<td>Estimate</td>
<td>23. What is estimation?</td>
<td>25. How did you estimate or predict the answer before you solved the math word problems?</td>
<td>26. How did you compare your estimate with the answers?</td>
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<tr>
<td>“Estimate is like where you guess. So like, if I was going to guess how many books there are...I would guess...I don’t know...maybe eight. And there is like 10 or something there.”</td>
<td>Skipped</td>
<td>Skipped</td>
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<td>24. Estimation is making a prediction about the answer using the information in the problem</td>
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<td>Researcher provides clarification and says: This means you are guessing what the answer should be before you solve the word problem.</td>
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<td>Researcher asks: How did estimation help you solve the math word problems?</td>
<td>“No.”</td>
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<td>27. What did you think when you solved the word problems?</td>
<td>28. How did you solve the word problems?</td>
<td>29. How did you know that your computations were correct?</td>
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<tr>
<td>For further clarification, researcher asks: Did anything come to your mind while you were solving the math word problems?</td>
<td>“I just picked out the numbers and chose multiplication with the one that the one that I wanted to use or the one that fit more appropriately. I guess.”</td>
<td>“I didn’t. I just kind of like tried my best to figure it out.”</td>
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<tr>
<td>“Not really. No. I was just thinking of oranges in a grocery store.”</td>
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<tr>
<td>Check</td>
<td>30. What does checking mean?</td>
<td>31. Did you check your solutions? How did you check your solutions?</td>
<td>32. How did you check that you have correctly completed the math word problem?</td>
</tr>
<tr>
<td>“I’m pretty sure it’s means you go over your work. So let’s say you are doing a test and like and you want to make sure you get a good mark, you would do the test and read over what you did to make sure it’s correct.”</td>
<td>“Well. I checked questions 1 and 2. I just looked it over.”</td>
<td>“By looking over it.”</td>
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## Megan: Post-Individual Interview

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<td>4. How did you read the word problems?</td>
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<td>8. What questions did you ask yourself while you were reading the word problems?</td>
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<tr>
<td>“I read the question and then I took the numbers out of the question and then… like for…. I took the numbers, which was six and $1.00… yeah $1.92… So I said six apples are $1.92. How much would it cost to buy one apple? So I said find the cost of one apple. I went and looked at the question and then looked at the step sheet and then I looked at the posters.”</td>
<td>“I read it twice.”</td>
<td>“Well for Read, I asked myself, Have I read and understood the problem?”</td>
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<td>6. As you read the problem, did you do anything to help you understand the problem? (Can you explain more?)</td>
<td>7. If you did not understand something, what did you do?</td>
<td>9. Did you ask yourself any questions after you solved the word problems?</td>
</tr>
<tr>
<td>“Not really. Except highlight and re-read it.” Researcher: So what do you mean by highlight? Student: “I highlighted the numbers and highlighted the question.” Researcher: And why did you highlight the numbers? Student: “Because they are important and it helps you solve the problem.”</td>
<td>“I went back and looked at it again.” Researcher: You looked at what again? Student: “Like the question and what I did not understand… so I kind of read it and did not understand it and I went back and read it.” Researcher: Anything else? Student: “No.”</td>
<td>“No. Not really. I just double-checked and asked myself if it was right.” Researcher: What do you mean by double-check? Student: “I mean to go back and to check that I had the correct work… On the graphic organizer and I used the information sheet and the posters.”</td>
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<td>10. Did you do anything when you were reading the word problems?</td>
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<td>“No. Not really.”</td>
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<td>11. How did you help yourself remember what the problem said? (Side comments: And how many times? For each question?)</td>
<td>12. Did you put the problems in your own words?</td>
<td>14. When you put the problem in your own words, how did you know what you said was correct?</td>
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<td>“I just went back to the question if I forgot something instead of trying to figure it out, it would waste time. So I went back and</td>
<td>“For two-step, I did. For question 1, for Read and Paraphrase, it’s just the same writing. It’s the same</td>
<td>“I just kind of like…. checked everything. Like going from the questions to the graphic organizers to the information</td>
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<tr>
<td><strong>Visualize</strong></td>
<td>17. How did you make the pictures or drawings?</td>
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<td>“I drew 6 circles...yeah 6 circles and I put a box around them because it is 6 items and I drew a little arrow pointing to the box as $1.92.” Researcher: What does the arrow mean? Student: “It means that’s how much all of them cost. And then I went over and wrote I equals question mark cost.”</td>
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<td>15. Did you make drawing or pictures of the problems?</td>
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<td>“In Visualize I did.”</td>
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<td>16. Examiner: Show me one of the pictures you drew.</td>
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<tr>
<td><strong>Hypothesize</strong></td>
<td>19. How did you make a plan to solve the math word problem?</td>
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<td>Researcher provides further clarification and asks student: What did you do to solve the math problem?</td>
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<td>Researcher points to student’s answer sheet and asks the student: Did you have a plan for Question 1?</td>
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<td>“Well how much means division. So I wrote how much means division and then it was a one-step word problem. So I wrote it is a one-step problem. And then I had to figure out the cost of one. So I divided $1.92 divided by six and that finds you the cost of one because one item...so that would find you cost like that.”</td>
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<td>20. How did you use your plan to help you solve the math word problems?</td>
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<td>“Well for question 2, I was on estimate and I was checking my work and I felt something was wrong. So I went back to Hypothesize and made sure all the numbers were correct from Hypothesize to Estimate. And I made sure the number line was right. I did not make a mistake, but I thought I did. And I checked the information sheet and the posters.”</td>
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<td>21. How did you know to use addition, subtraction, multiplication or division to solve the math word problems?</td>
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<td>Researcher points to each question and asks the student what operation he/she used to solve the math word problem. The researcher also asks the student why they choose that operation.</td>
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<td>“I used division because it says how much, which means division. So I had to use division. I did addition for the next step because one item plus the other item finds you the cost of how many items you need to find.”</td>
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<td>22. How did you decide how many steps are needed to solve</td>
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<td>Estimate</td>
<td>23. What is estimation?</td>
<td>25. How did you estimate or predict the answer before you solved the math word problems?</td>
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<td>&quot;Estimation is where you guess the answer.&quot;</td>
<td>&quot;So I did $3.96, so I have 3 and 4. And $3.96 is closer to 4 than 3. So I did $4 divided 4, which is $1. So then I took the two items and added them together, 1 and 1, which is 2 dollars. And the approximate cost of two chocolate bars is 2 dollars.&quot;</td>
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<td>24. Estimation is making a prediction about the answer using the information in the problem</td>
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<td>Researcher provides clarification and says: This means you are guessing what the answer should be before you solve the word problem.</td>
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<td>Research asks: How did estimation help you solve the math word problems?</td>
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<td>&quot;It just kind of helped me find the actual answer, which is obviously what you have to do.&quot;</td>
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<td>Compute</td>
<td>27. What did you think when you solved the word problems?</td>
<td>29. How did you know that your computations were correct?</td>
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<td>For further clarification, researcher asks: Did anything come to your mind while you were solving the math word problems?</td>
<td>&quot;I doubled-checked by going to the information sheet and the posters and the steps ahead of the one-step. Researcher: What does that mean? Student: So like, if I was on Read, I just checked the question sheet, and if I was Paraphrase, I checked Read, the question sheet, information sheet, and posters.&quot;</td>
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<td>&quot;No. Not really. I was just kind of the same I guess.&quot;</td>
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<tr>
<td>Check</td>
<td>30. What does checking mean?</td>
<td>32. How did you check that you have correctly completed the math word problem?</td>
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<td>&quot;Checking means to make sure everything is correct.&quot;</td>
<td>&quot;I used a calculator. So I went&quot;</td>
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</table>
"I did. I used a calculator."

from box to box. I went to Hypothesize. I did 1.92 divided by 6 and then found the cost. And then went to estimate and did all the calculations."