Investigating the Effects of a Multicomponent Intervention on the Mathematical Word Problem-Solving Skills of Third Graders Identified as LD, At-Risk. and/or ESOL

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INVESTIGATING THE EFFECTS OF A MULTICOMPONENT INTERVENTION ON THE MATHEMATICAL WORD PROBLEM-SOLVING SKILLS OF THIRD GRADERS IDENTIFIED AS LD, AT-RISK, AND/OR ESOL

By
Sheri Kingsdorf

A DISSERTATION

Submitted to the Faculty of the University of Miami in partial fulfillment of the requirements for the degree of Doctor of Philosophy

Coral Gables, Florida
August 2014
UNIVERSITY OF MIAMI

A dissertation submitted in partial fulfillment of
the requirements for the degree of
Doctor of Philosophy

INVESTIGATING THE EFFECTS OF A
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In third grade, with the introduction of high-stakes testing, the focus on math word-problems becomes prominent. However, intervention research on solving word problems has concentrated on the higher grades. While some of these strategies are valuable, developmental and curricular modifications are needed for third graders. In research where this has been recognized, teacher-mediated explicit instruction with multiple exemplars, teaching students to use visual representations, and the incorporation of self-strategies, have proven effective. However, for these practices to reach their full potential, their content must be relevant and provide for growth to more mature mathematical concepts. Based on these conclusions, additional research was needed to investigate intervention packages which adhere to these practices. Therefore, the focus of this study was to evaluate the effectiveness of a multicomponent word problem-solving intervention that used explicit instruction strategies with multiple exemplars, taught the use of student-generated visual representations, incorporated a self-monitoring checklist, and targeted Common Core State Standards’ appropriate curriculum (i.e., all four operations, measurement, estimation of time, masses of objects, and geometric measurement). Using a multiple baseline across behaviors design, the study evaluated the paraphrasing, visualizing, and computing word problem-solving responses of 10
third-graders identified as LD, at-risk, and/or ESOL. The study revealed that all students made gains in some behaviors related to problem solving (paraphrasing, visualizing, and computation accuracy). Results are discussed in relation to a cognitive-behavioral framework and individual student characteristics, including discussions of limitations and educational significance.
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Chapter 1

Introduction

Mathematics has always been a prominent area of the curriculum. Sets of standards drive the curricular content focus on numbers and operations, algebra, geometry, measurement, data analysis and probability, as well as the process focus on problem solving, connections, communication, reasoning and proof, and representation (NCTM, 2000). In addition, the introduction of Common Core State Standards (CCSS) has strengthened this focus (Common Core State Standards Initiative, 2012). Expectations have risen to include the application of problem-solving skills to real life scenarios. These take the form of word problems, and are present as early as kindergarten (Common Core State Standards Initiative, 2012). Although word problems are introduced early, their weight in the curriculum increases in third grade, when high-stakes testing often begins. This is mismatched however, as many third grade textbooks do not adequately address problem solving (Jitendra et al., 2005). Additionally, the majority of problem-solving research is focused on the upper grades (e.g., Montague, Enders, & Dietz, 2011; Schaefer Whitby, 2009; Xin, Jitendra, & Deatline-Buchman, 2005). With student proficiency in problem solving expected at the third-grade level, finding ways to promote student success in this area is imperative.

The body of research that exists on math problem solving in the upper grades has provided valuable insight into the difficulties students experience when attempting to solve word problems, as well as the intervention strategies that address them. Teachers have identified word problems as the most prominent area of student difficulty; this is
especially the case for students identified with learning disabilities (LD) (Bryant & Bryant, 2008). Montague and Applegate (1993) conducted a study to investigate the problem-solving characteristics of students with LD. They found that problem-solving errors were more related to struggles with problem representation and solution planning, as opposed to operation errors. Additional research has found that students with LD struggle with word problems as they increase in complexity, making more errors and demonstrating less productive solving practices (Kingsdorf & Krawec, under review; Rosenzweig, Krawec, & Montague, 2011). Problem complexity increases with the addition of steps, operations, and irrelevant information in the problems, translating into issues of problem type and missing information (Powell, Fuchs, Fuchs, Cirino, & Fletcher, 2008). Unsurprisingly, middle school students who are also English Language Learners (ELL) struggle with the linguistic complexity of word problems (Barbu & Beal, 2010). This cross-curricular nature of word problems is a challenge for ELL students who may be struggling with reading comprehension. Overall, word problems are mathematically and linguistically complicated, increase in complexity throughout grade levels, and pose a challenge to many students.

As a result, numerous interventions have worked to remediate these areas of student struggle. Assistive technology, including the use of computers, audio-video devices, and calculators, has effectively increased the arithmetic and algebra word problem-solving skills of middle-school students with varying abilities (e.g., Bottge, 1999; Bottge & Hasselbring, 1993; Bottge, Heinrichs, Chan, Mehta, & Watson, 2003; Bottge, Rueda, Serlin, Ya-Hui, & Kwon, 2007). Strategy-training instruction, based on explicit teaching, using metacognitive strategies, and/or mnemonic devices, is another
intervention that has successfully increased the word problem-solving skills of diverse
groups of adolescents (e.g., Coughlin & Montague, 2011; Dietz, Enders, & Montague,
2011; Krawec, Huang, Montague, Kressler, & de Alba, 2013; Maccini & Hughes, 2000;
Maccini & Ruhl, 2000; Montague et al., 2011). Teaching the use of self-strategies has
also proved a beneficial intervention component for increasing the correct problem-
solving behavior of middle-school students (e.g., Case, Harris, & Graham, 1992;
Montague, 2008). Problem structure or visual representation teaching procedures,
targeting explicitly teaching students to represent the problem with a diagram or
mathematical model, is yet another established intervention practice for bettering the
word problem-solving skills of middle school students across ability groups (e.g.,
Jitendra, DiPipi, & Perron-Jones, 2002; Jitendra, Hoff, & Beck, 1999; Jitendra et al.,
2009; Xin et al., 2005). Additionally, when looking at word problem-solving strategies
including middle-school students, recent meta-analyses support the use of visual
representation teaching procedures (Xin & Jitendra, 1999; Zhang & Xin, 2012).

While some of the intervention strategies applied in the upper grades can be
applied in the lower grades, exact replication is not always possible. Developmentally,
third graders are different from middle-school students, where the majority of research
has been targeted. From the perspective of cognitive development, as related to
Piagetian theory (e.g., Piaget, 1970) third graders are beginning to develop concrete
operations related to seriation and classification, but require concrete mathematical
activities with various representations to make connections and move closer to abstract
thought. In contrast, middle-school students, moving into early adolescence, are
beginning to develop abstract reasoning, honing their ability to clarify important
information needed in the problem, making hypotheses and inferences in problem solving, and evaluating their mathematical work (Ojose, 2008). These differences are apparent when considering an area like visual representation instruction in solving word problems. As such, third graders may benefit more from interventions focusing on using concrete objects to make visual representations (e.g., drawing a picture where each piece of important information is explicitly represented). Alternatively, middle school students may be comfortable with the use of more abstract problem representations (e.g., drawing a diagram that uses a number sentence).

In addition to the developmental differences, curricular goals differ from grade to grade. At the third grade level, the Common Core State Standards calls for students to solve problems using all four operations (addition, subtraction, multiplication, and division), fractions, measurement, estimation of time, liquid volume, masses of objects, and geometric measurement (Common Core State Standards Initiative, 2012). These skills are vastly different from the Common Core State Standards’ targets at the middle school level, where students are expected to be learning proportional relationships, expressions and linear equations, solving problems using area and volume, equations, using functions to describe quantitative relationships, and applying advanced geometric theories (Common Core State Standards Initiative, 2012).

Specific research teams that are targeting third graders (e.g., Fuchs and colleagues and Jitendra and colleagues) have addressed some of these limitations in the problem-solving research. The work of these teams, and a few others, has supported the use of word problem-solving interventions that incorporate explicit strategy instruction, teaching students to identify problem-type information before making a plan to solve,
using multiple exemplars, encouraging self-strategies, and using visual representations
(Cassel & Reid, 1996; Fuchs, Fuchs, et al., 2008; Fuchs, Fuchs, Prentice, Burch, Hamlett,
Owen, Hosp, et al., 2003; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, & Schroeter,
2003; Fuchs, Seethaler, Powell, Hamlett, & Fletcher, 2008; Griffin & Jitendra, 2009;
Jitendra et al., 2007; Jitendra et al., 1998; Jitendra & Hoff, 1996; Leh & Jitendra, 2013;
Owen & Fuchs, 2002; Seo & Bryant, 2012; Wilson & Sindelar, 1991). All of the third
grade studies focused on using explicit instruction at a developmental level not above the
third grade level. The studies using the problem-type strategy (Cassel & Reid, 1996;
Fuchs, Fuchs, et al., 2008; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, Hosp, et al.,
2003; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, & Schroeter, 2003; Fuchs,
Seethaler, et al., 2008; Griffin & Jitendra, 2009; Jitendra et al., 2007; Jitendra et al., 1998;
Jitendra & Hoff, 1996; Leh & Jitendra, 2013; Owen & Fuchs, 2002; Wilson & Sindelar,
1991) and the visual representation strategies (Griffin & Jitendra, 2009; Jitendra et al.,
2007; Jitendra et al., 1998; Jitendra & Hoff, 1996; Leh & Jitendra, 2013; Seo & Bryant,
2012) worked to provide the third graders with more concrete procedures for solving the
problems. This adherence to a developmentally appropriate feature was also the case for
the studies that used multiple exemplars, which functioned as multiple representations
(Fuchs, Fuchs, et al., 2008; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, Hosp, et al.,
2003; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, & Schroeter, 2003; Fuchs,
Seethaler, et al., 2008; Owen & Fuchs, 2002).
Studies using self-strategies (Cassel & Reid, 1996; Fuchs, Fuchs, et al., 2008; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, & Schroeter, 2003; Fuchs, Seethaler, et al., 2008) recognized the need to make these strategies age appropriate as well, working to teach self-evaluation, rather than build on that already present skill.

Although this third-grade research recognized some of the developmental limitations of the larger body of math word problem-solving studies, the researchers still struggled to address appropriate curricular goals. Specifically, the current curricular targets in the studies (e.g., word problems using only addition and subtraction operations) may have matched with the district curriculum at that time, but do not comply with the Common Core State Standards’ expectations of today (e.g., word problems using all four operations). The problem-type strategies employed in all cases were also a mismatch for the Common Core State Standards’ expectations by targeting categories such as buying-bag, pictographs, halves, and difference. The visual representation strategy also raises concerns, as in all cases, the visual representations used were pre-made templates provided by the teachers. Using pre-made templates, depending on the nature of the template, may not allow students to create visual representations that are concrete, aligning with the specific problem information and portraying individualized understanding of the problem. Visual representations certainly permit both concrete and abstract representations; however, third grade students need to move in a developmentally appropriate trajectory from creating individualized and concrete problem representations to the abstract. It is as important for interventions to be developmentally appropriate as it is for them to target the necessary curricular benchmarks that build toward more complex mathematical skills.
Both in mathematics as well as other academic areas, it is empirically supported that early intervention is associated with increased academic success (e.g., Reynolds, Temple, Robertson, & Mann, 2001). There is a paucity of research looking at the value of early intervention related to mathematical problem solving; however, it is recommended (Gersten, Jordan, & Flojo, 2005). It seems plausible, then, that successful mathematics word problem-solving interventions, or rather successful mathematics problem-solving teaching procedures, will have greater long-term benefit when applied in third grade, as opposed to middle school. This is likely to increase student success on standardized tests earlier in their academic career, possibly reduce the probability of student identification of LD, and even affect the need for intervention in the later grades.

**Purpose of the Study**

It is clear that using explicit instruction with multiple exemplars, while teaching students to identify important problem information for use in visual representation construction, and engaging students in the use of self-strategies, is effective in improving math problem-solving skills. However, applying these intervention components in combination, while using developmentally appropriate curriculum adhering to Common Core State Standards has not yet been investigated. Because of the need for research in this area, the purpose of this study was to evaluate a math word-problem intervention for third-graders, which used explicit instruction strategies with multiple exemplars, taught the use of student-generated visual representations, incorporated a self-monitoring checklist, and targeted Common Core State Standards’ appropriate curricular targets (i.e., all four operations, measurement, estimation of time, masses of objects, and geometric measurement). The specific research questions focused on the individual performance
of third-graders identified as LD, at-risk, and/or ESOL to determine: What was the effect of explicit instruction using multiple exemplars, and a self-monitoring checklist, on increasing correct paraphrasing responses on math word problems? What was the effect of explicit instruction using multiple exemplars, and a self-monitoring checklist, on increasing correct visual representation responses in math word problems? What was the cumulative effect of this intervention in the target areas of paraphrasing and visualizing on solution accuracy in math word problems? Were intervention effects maintained over time? How long did intervention implementation and mastery take when presented in a general education inclusive setting?
Chapter 2

Review of the Literature

Theoretical Framework

Solving word problems is a complicated and often misunderstood process (Lai, Griffin, Mak, Wu, & Dulhunty, 2001). Over the years, prominent cognitive psychologists (e.g., Mayer, 1983; Pólya, 1957) have proposed organizational structures with embedded cognitive processes to aid in defining this ambiguous area. Synthesizing these structures and frameworks, the Organization for Economic Co-operation and Development (OCED) has outlined the following problem-solving processes: (1) understanding the problem, (2) characterizing the problem, (3) representing the problem, (4) solving the problem, (5) reflecting on the solution, and (6) communicating the problem solution (OCED, 2003). Figure 1 depicts the components of the OCED problem-solving model, including the processes, their variables, and their hypothesized relationships. Students must learn to navigate these processes in order to be successful in math problem solving, and thus teachers must find means of assessing students’ proficiency in each component. To do so, the components of the problem-solving process must be translated into observable terms. The behavior analytic perspective on problem solving helps to create this translation.
In the seminal work of Gagné (1959), problem solving is described as occurring in five phases: (1) reception of the stimulus situation, (2) concept formation of which rules to adopt to apply to parts of the stimulus situation, (3) planning a course of action, (4) decision making within the course of action, and (5) verification of process, by receiving feedback that the solution was correct or incorrect. There is clear overlap between these cognitive and behavioral models of problem solving. When merged, as depicted in Figure 2, a more comprehensive and measurable view of problem solving emerges. The process in the cognitive-behavioral model, as in the cognitive model, is depicted in a linear fashion. For novice problem-solvers, according to the cognitive-behavioral model, a student attempting to solve a word problem would move through the process in the following manner:

- Reading the word problem (reception);
- Identifying the important information and constructing a problem representation by generalizing previously learned rules for solving...
problems, and discriminating differences in the target problem from previously targeted problems (concept formation);

- Making a plan to solve by choosing an operation/operations and identifying the number of steps needed to solve the problem (planning); identifying operations and steps is also rule-governed and closely related to the concept formation process;

- Checking the plan with the problem information to make sure that the plan matches the problem information and the representation (reflection). This step cohesively brings the concept formation and planning phases together;

- Showing the work on the paper, writing down the answer (communication); and

- Checking the work and the solution by using a calculator, reviewing the steps, or using inverse operations (verification).

*Figure 2.* Cognitive-behavioral model of the problem-solving process, created based on OCED 2003 guidelines and Gagné’s (1959) theory.
However, a more experienced problem-solver may move through the process in a non-linear fashion. For example, he or she may be able to skip the phase of drawing a representation of the problem, moving directly from reception to planning.

Within this cognitive-behavioral problem-solving framework, a number of behaviors need to be observed for educators to assess the problem-solving skills of students. Determining if students understand how to solve the problem is made observable by evaluating their concept formation and planning behaviors (i.e., the information they identify as relevant, the representation that they construct, operation(s) they select, and steps identified as needed). This complex combination of skills makes problem solving a difficult skill to learn and an even more difficult skill to teach.

**Traditional Word Problem-Solving Instruction**

Traditional word problem-solving instruction follows textbook procedures where the same target skill or procedure (e.g., two-step multiplication) is used to solve all of the problems presented in that section (Jitendra, Sczesniak, Griffin, & Deatline-Buchman, 2007). As a result, specific instruction is not typically devoted to the concept formation, planning, and reflection phases within the problem-solving process. The organization of problem solving as presented in textbooks assumes that if students are able to complete a current procedure (e.g., one-step addition) then they are able to solve any problem which uses that procedure, regardless of context. Thus, problem solving is not typically targeted as a discrete skill or procedure. When solving word problems is more specifically addressed, usually as a result of student struggles, mathematical strategies related to procedures and syntactic cues are the typical areas of instruction (English, 2009). This instructional focus results in word problems being reduced to relevant numerical
information and key words. Students are taught to memorize strategies and apply discrete steps. In an effort to promote their success in solving word problems, problem solving is replaced with an exercise in numbers and operations, where students are instructed to pull out the important numbers in the problem and select an operation for computation based on a key word. This approach ignores the importance of deep conceptual understanding and instead promotes superficial problem analysis, despite the evidence of its ineffectiveness, as indicated by both the research on good problem solvers and students’ continual struggle to solve word problems (Hegarty, Mayer, & Monk, 1995)

Third Grade Interventions

Traditional word problem-solving instruction has proven ineffective for many students, especially those identified with, or at risk for, learning disabilities (LD), a group that struggles most with solving word problems (Bryant & Bryant, 2008). As a result, intervention research has surfaced that targets this population. This research has spanned grade levels, focusing predominantly on upper-elementary and secondary students (e.g., Montague, Enders, & Dietz, 2011; Schaefer Whitby, 2009; Xin, Jitendra, & Deatline-Buchman, 2005). However, word problems are introduced early in the curriculum, with their weight increasing in third grade, where high-stakes testing often initiates. With curricular expectations of problem-solving proficiency at the third-grade level, finding ways to promote student success in this area is vital; research, particularly over the past 10 years, has begun to reflect this need.

A comprehensive search of the empirical literature using search terms *math, intervention, instruction, word,* and *problem,* followed by a manual review of the results
for third (3rd), revealed 13 relevant studies conducted in the United States over the past two decades. Over 1,000 diverse third-graders, identified across the categories of average-achieving, at risk, low-achieving, and special education (LD being the majority), participated in these studies. The intervention spanned settings (i.e., small-group resource rooms and inclusive classrooms) as well as implementers, including researchers, teachers, and paraprofessionals. Outcome measures typically assessed word problem-solving accuracy using researcher-created measures. All of the studies used treatment packages for intervention, incorporating a number of instructional components, with significant overlap in many of the intervention procedures.

**Instructional components.** Although each intervention identified a primary strategy, a number of instructional components enhanced these strategies. Additionally, intervention strategies were often given different names, but shared the same instructional components. In carefully reviewing the studies, five instructional components were identified: (1) Direct Instruction (DI)/explicit instruction, (2) problem type, (3) multiple exemplars, (4) self-strategies, and (5) visual representation models. Table 1 identifies the instructional components within each study.

**Direct Instruction/explicit instruction.** Direct Instruction (DI) is a comprehensive curricular approach which is largely scripted in nature, and follows a specifically designed sequence (Marchand-Martella, Slocum, & Martella, 2004). Additionally, it involves logically sequencing skills, breaking down skills into smaller units, providing step-by-step demonstrations, using clear and concise language, providing
guiding and supported practice, providing frequent opportunities for student responding, and providing immediate feedback. Explicit instruction and DI share these characteristics.

### Table 1

<table>
<thead>
<tr>
<th>Study Instructional Components</th>
<th>DI or explicit instruction</th>
<th>Problem type</th>
<th>Multiple exemplars</th>
<th>Self-strategies</th>
<th>Visual representation models</th>
</tr>
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<tbody>
<tr>
<td>Wilson &amp; Sindelar (1991)</td>
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<tr>
<td>Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, Hosp, et al. (2003)</td>
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<td>Owen &amp; Fuchs (2002)</td>
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<td>Fuchs, Seethaler, Powell, Hamlett, &amp; Fletcher (2008)</td>
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<tr>
<td>Fuchs, Fuchs, Craddock, Hollenbeck, Hamlett, &amp; Schatschneider (2008)</td>
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<td>(Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, &amp; Schroeter (2003)</td>
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<td>Cassel &amp; Reid (1996)</td>
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<td>Jitendra &amp; Hoff (1996)</td>
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<td>Griffin &amp; Jitendra (2009)</td>
<td>x</td>
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<td>Seo &amp; Bryant (2012)</td>
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<td>Leh &amp; Jitendra (2013)</td>
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</tbody>
</table>

However, in contrast to DI, explicit instruction is more naturalistic and less scripted. Rather than requiring instructors to read from a script, explicit instruction follows a very specific procedure or set of guidelines. As originally presented by Engelmann and Carnine (1982), explicit instruction involves step-by-step teacher models and feedback to students during instruction.
DI has a well-researched history of being an effective teaching strategy, especially for students with LD (Hicks, Bethune, Wood, Cooke, & Mims, 2011). This has also been the case for explicit instruction (e.g., Jitendra, Carnine, & Silbert, 1996). As a result, all 13 of the studies included either a DI or explicit instruction component; 12 studies used explicit instruction and one used DI.

Though dated, Wilson and Sindelar (1991) conducted the only study investigating a DI-based intervention for solving math word problems. Sixty-two students with LD across grades 2-5 participated in the study. The DI portion of the intervention provided students with 14 scripted lessons on solving one-step addition and subtraction word problems. The sessions lasted 30 minutes and were run in a small-group setting. Results showed that the students receiving DI performed better than those students receiving other instruction. Unfortunately, very little information was provided on the specific skills being taught during DI intervention, making replication, and the ability to draw inferences about the most valuable areas of instruction for young students struggling with solving word problems, difficult. In later third grade studies using explicit instruction, more information on instructional procedures was provided.

Fuchs and colleagues have conducted numerous studies involving an explicit instruction approach to increasing the word problem-solving accuracy of third grade students (Fuchs, Fuchs, et al., 2008; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, Hosp, et al., 2003; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, & Schroeter, 2003; Fuchs, Seethaler, Powell, Hamlett, & Fletcher, 2008; Owen & Fuchs, 2002). Throughout these interventions, students were explicitly taught rules for solving word problems, were provided with examples, and worked individually and in peer-mediated conditions to
practice applying the strategies taught. In all studies, a control group was used, which incorporated standard district-based curriculum and teaching procedures. The early Fuchs and colleagues studies (Fuchs, Fuchs, et al., 2008; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, Hosp, et al., 2003; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, & Schroeter, 2003; Fuchs, Seethaler, et al., 2008; Owen & Fuchs, 2002), presented this explicit instruction in a general-education, class wide format. In the later studies, (Fuchs, Fuchs, et al., 2008; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, Hosp, et al., 2003; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, & Schroeter, 2003; Fuchs, Seethaler, et al., 2008; Owen & Fuchs, 2002), intervention was provided in a tutoring context, with the intervention being provided in a small-group setting as supplemental instruction. Intervention length varied across studies, ranging from three weeks to 16 weeks. In all studies, the treatment groups receiving an intervention with an explicit instruction component outperformed control group peers. However, in the study by Owen and Fuchs (2002) the accuracy posttest scores for students with disabilities only reached 45%-raising questions about the distinction of success at the research versus the practical level.

There is another limitation to this research. Although this large body of research by Fuchs and colleagues involves a sizable and diverse sample of third-graders, with all of the research being generated by one research team, targeting the same geographical region of students, generalizability is in question. The classrooms that participated in this research are not likely to be typical to the majority of third-grade classrooms that are not supported by University-based research projects. These classrooms and teachers have had considerable support from these researchers over the years, making them comparatively different to usual third-grade classrooms.
This similar issue was found in the studies conducted by Jitendra and colleagues (Griffin & Jitendra, 2009; Jitendra, Griffin, et al., 2007; Jitendra et al., 1998; Jitendra & Hoff, 1996; Leh & Jitendra, 2013). In these studies, explicit instruction was again used to teach third-graders strategies for solving word problems. Jitendra and Hoff (1996) used a single-subject design with intervention delivered in a small group setting, which proved effective in increasing the problem-solving skills of students with LD. The other studies (Griffin & Jitendra, 2009; Jitendra, Griffin, et al., 2007; Jitendra et al., 1998; Leh & Jitendra, 2013), which used large group designs, and targeted a diverse population of students, ran the intervention in an inclusive class-wide format. The majority of the studies (Jitendra, Griffin, et al., 2007; Jitendra et al., 1998; Leh & Jitendra, 2013) found that students in the condition using explicit instruction outperformed their control group peers. Although a similar research team conducted all these studies, their participant locations differed.

Stand-alone studies using explicit instruction were conducted by Cassel and Reid (1996) and Seo and Bryant (2012). These studies used single-subject designs to evaluate the efficacy of explicitly teaching word problem-solving procedures to third graders identified with math difficulties or LD. In the Seo and Bryant (2012) study, students were taught to use a four-strategy solving approach of reading, finding, drawing, and computing. In both studies, the explicit strategy intervention proved effective in increasing word problem-solving accuracy.

In conclusion, explicit instruction is a prominent component in the third grade intervention research targeting word problem-solving instruction. It is clear that explicit instruction is a valuable method for teaching students a set of skills, strategies, or a
solving process. As evident in these studies, the use of explicit instruction provides
students with a clear model of the concept formation, planning, and reflection processes.
None of these studies solely used explicit instruction, though. Therefore, to make
determinations on the specific contributions of the skills, strategies, or processes targeted
in each intervention through explicit instruction, their additional instructional components
need to be investigated.

**Problem type.** Teaching using problem type refers to teaching students to
recognize patterns in problems and assign that problem to a previously taught category.
This is also referred to as problem schemata identification (Jitendra, 2002). Categorizing
problems based on a set of identified characteristics aligns with the concept formation
phase of the cognitive-behavioral problem-solving framework. As discussed and
supported by Jitendra and colleagues (2007), research on teaching students to identify
specific characteristics of a problem has proven more valuable than teaching students to
identify syntactic cues (e.g., key words). Different problem type categories have been
identified in the literature (e.g., change, group, compare). However, there is a lack of
consensus on the presence and applicability of these categories across grade levels.
Regardless of the problem types targeted, when used as an instructional component,
students are taught how to identify and match problem characteristics to previously
provided plans for solving. This common intervention component was found in 12 of
the 13 third grade studies that were reviewed.

In the Wilson and Sindelar (1991) study, a problem-type instructional component
was added to the DI lessons by teaching problems in a sequence based on problem type,
though the specific problem type categories were not identified in this study. However,
they found that teaching with this problem-type sequence added to the DI lessons was more effective than teaching using only the problem-sequence strategy or only the DI lessons in isolation.

All of the Fuchs and colleagues studies (Fuchs, Fuchs, et al., 2008; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, Hosp, et al., 2003; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, & Schroeter, 2003; Fuchs, Seethaler, et al., 2008; Owen & Fuchs, 2002) also found that explicit instruction was an effective means for teaching a problem-type strategy. In three of the Fuchs studies (Fuchs, Fuchs, et al., 2008; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, Hosp, et al., 2003; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, & Schroeter, 2003), students were taught how to identify and apply solving rules for the four problem categories of (1) shopping-list problems, (2) half problems, (3) buying-bag problems, and (4) pictograph problems. In the Owens and Fuchs (2002) study, only half problems were targeted (e.g., Every day John works an 8 hour shift at the toy store. On Tuesday, he got sick and had to leave after ½ of his shift. How many hours did he work on Tuesday?). In the Fuchs, Seethaler, Powell, Hamlett, and Fletcher (2008) study, problem types included total, change, and difference problems. All of these interventions used the procedure of teaching students to identify problem structures that corresponded to the problem types. For example, the students were taught to read the problem, underline the question, and then name the problem type by identifying the problem’s underlying mathematical structure. Structure identification and problem naming were taught through practice with concrete examples and role-playing through explicit instruction. After identifying the problem type, students were taught to follow the directions to solve the problem by following specific steps presented on posters for each
problem type. It was reported that teachers used scripts in these studies to teach the problem-type identification and solution strategies; however, these scripts were not provided in the studies. This omission makes replication of these procedures difficult. Additionally, the structures that were taught to correspond with each problem type were not apparent in any of the studies; that is, the authors did not specifically outline what problem features students were taught to recognize to correspond with each problem category. The other prominent third-grade research team also conducted problem-type research, but similar issues affecting replication were found.

All of the Jitendra and colleagues studies (Griffin & Jitendra, 2009; Jitendra, Griffin, et al., 2007; Jitendra et al., 1998; Jitendra & Hoff, 1996; Leh & Jitendra, 2013) used problem-type categories similar to those used in the Fuchs, Seethaler, Powell, Hamlett, and Fletcher (2008) study (i.e., change, group, and compare problems) and students were taught a procedure similar to that used in the Fuchs and colleagues studies to identify the problem type. The general procedure involved recognizing semantic features in the problem, matching the problem to the problem type, and designing a solution strategy and picking an operation. Cassel and Reid (1996) used similar problem categories, targeting equalize, combine, change, and compare problems. However, rather than teaching students to identify the problem type before solving, they taught students how to solve these problem types in a sequence (i.e., all of the combine problems were taught, then all of the change problems, etc.). This was also the case in the Wilson and Sindelar (1991) study.

Explicitly teaching students to identify problem type before moving forward with the solving process has proven effective in some studies. This problem-type
identification process aligns with the concept formation and planning problem-solving phases, where students are identifying important problem components to make a plan to solve. When students are taught using discrete problem types though, generalizability will become an issue. Some studies worked to address this problem by incorporating multiple exemplars in practice.

**Multiple exemplars.** Using multiple exemplars refers to using a range and sequence of examples in teaching procedures. Mathematics research has established the value of using multiple exemplars when teaching concepts to students (e.g., Witzel, Mercer, & Miller, 2003) in order to better establish their generalization and discrimination abilities. The studies reviewed here were identified as using multiple exemplars if a specific sequence of examples or systematic variation of examples were used. This followed the definition outlined in the meta-analysis on mathematical instructional components described by Gersten and colleagues (2009).

Five of the studies explicitly stated that they taught using multiple exemplars. All of these studies were conducted by Fuchs and colleagues (Fuchs, Fuchs, et al., 2008; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, Hosp, et al., 2003; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, & Schroeter, 2003; Fuchs, Seethaler, et al., 2008; Owen & Fuchs, 2002). In these studies, they termed their procedure “teaching for transfer,” and investigated the effect of the procedure and whether it varied based on the number of novel problems included. The transfer procedure taught students to broadly group word problems requiring similar solutions based on sets of problem features, as well as how to apply this strategy to solving novel word problems. In all of their studies, the students taught with increasingly novel problems excelled in posttest conditions over their peers
receiving the explicit intervention without this strategy. It makes sense that teaching using novel examples would have a positive effect on the generalization of an intervention; however, the limited scope of this practice (i.e., being applied by one research team in one intervention context) would make additional research in this area valuable. Additionally, the novel examples used in their practice were still related to their narrow problem categories of shopping-list problems, half problems, buying-bag problems, pictograph problems, or total, change, and difference problems; thus, the degree to which these problems were truly “novel” is debatable. Teaching students to work from such discrete examples makes them reliant on teachers to generate novel models for instruction, to move the use of their solving strategies forward. One of the goals of intervention should be to teach strategies which have longevity and are initiated by students rather than teachers.

**Self-strategies.** Teaching using self-strategies is one way to work towards this student-mediation of the problem-solving process. In intervention research, there are many variations of self-strategies, including self-regulation/self-regulating, self-monitoring, self-management, self-recording, self-observation, self-assessment, and self-evaluation. All of these strategies typically include a student systematically monitoring his or her covert or overt behavior. This is especially relevant when considering the problem-solving process within the cognitive-behavioral framework, where reflection involves self-assessment or evaluation of the rules applied and the plan made, as well as the modification of behavior to align with the desired outcome. These self-strategies have proven effective as instructional components of intervention packages for students with LD (Montague, 2008). The inclusion of these strategies is common in mathematics
intervention research. A meta-analysis conducted by Kroesbergen and Van Luit (2003) found that self-instruction was the second most common intervention method used in mathematics interventions for students with special needs, after DI/explicit instruction. Use of such strategies has been afforded some consideration in research on word problem-solving instruction for third-graders.

Five of the 13 studies included some component of self-strategies in their intervention (Cassel & Reid, 1996; Fuchs, Fuchs, et al., 2008; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, & Schroeter, 2003; Fuchs, Seethaler, et al., 2008; Seo & Bryant, 2012); however, the specifics of those strategies differed in each study. In Cassel and Reid (1996), the self-strategy components included individual student graphs (monitored by the students), a learning contract, and a self-monitoring strategy checklist with self-generated statements. All students in the study benefited from the use of these strategies, with a particularly interesting finding being that the students abandoned use of teacher-created scripts or prompt cards and began relying exclusively on their self-monitoring checklist, thus assuming control of their movement though the problem-solving phases.

The older study by Fuchs and colleagues (Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, & Schroeter, 2003) made the use of self-strategies a systematic part of their intervention. They had students check their own work with an answer key, graph their individual scores, set goals for their next day’s scores, self-evaluate, and make self-report presentations to the class on how they generalized the problem procedure. The results of the study showed that the addition of the self-regulation strategies positively affected the posttest problem-solving scores, with the students in that group outperforming both other groups on even the most novel posttest word problems. The two newer Fuchs and
colleagues studies (Fuchs, Fuchs, et al., 2008; Fuchs, Seethaler, et al., 2008) did not cite the use of self-strategies as a primary part of their intervention; however, they incorporated self-monitoring and goal setting to aid in the intervention’s efficacy. This was similar to the Seo and Bryant (2012) study, where the self-regulation strategy steps of do activity, ask activity, and check activity statements (e.g., I read the problem for understanding. Does the picture fit the problem? I check that the number sentence and the answer are correct.) were embedded in their four-strategy solving approach, which proved effective.

It is valuable that the use of self-strategies proved effective in these few studies. This research is still limited though, and needs application in different types of intervention packages and with more diverse research teams and context. It would seem likely that self-strategies would be more prominent in the problem-solving research, since they appear necessary in the problem-solving process. Explicitly teaching students to use self-strategies aligns seamlessly with the cognitive-behavioral problem-solving model. For students to effectively move through the model, they must be able to evaluate their completion of phases and continually reflect on the decisions they have made throughout the process. One area where this self-reflection is particularly useful is when concept formation is supported by problem representation.

**Visual representation models.** It has been established that one of the main problem-solving components in mathematics is representing the problem (Goldman, 1989; Stylianou & Silver, 2004). As a result, word-problem instructional procedures that teach the use of visual representations have been researched and proven effective (e.g., Edens & Potter, 2008). A research synthesis by Jitendra and Xin (1997) found that visual
representations were present in a number of word problem-solving interventions for students identified with, or at risk for, disabilities, as creating this graphic representation allows students to organize problem information and move towards the translation and solution processes (Jitendra, 2002). Effectively using graphic representations in solving math word problems involves more than just the use of diagrams. As supported by the studies below, visualizations used in solving mathematical word problems need to represent connections between the problem parts to effectively link the concept formation phase to the planning phase of problem solving.

All of the studies by Jitendra and colleagues (Griffin & Jitendra, 2009; Jitendra, Griffin, et al., 2007; Jitendra et al., 1998; Jitendra & Hoff, 1996; Leh & Jitendra, 2013), as well as the Seo and Bryant (2012) study, taught the use of visual representations as an instructional component. In the Seo and Bryant (2012) study, teaching using visual representations was embedded within the larger computer-mediated intervention to solve word problems, though having students draw pictures was limited by the computer-program’s ability to represent the word problems. In contrast, in the studies by Jitendra and colleagues (Griffin & Jitendra, 2009; Jitendra, Griffin, et al., 2007; Jitendra et al., 1998; Jitendra & Hoff, 1996; Leh & Jitendra, 2013), teaching using visual representations was noted as the key intervention component. The intervention involved providing students with teacher-created visual representation templates. The templates corresponded to the targeted problem types. Students were taught how to use the visual representation that corresponded with each problem type to recognize semantic features in the problem and match the problem to the problem type. Next, students were taught how to extend use of the visual representations to design a solution strategy and pick an
operation for computation. In one study (Jitendra, Griffin, et al., 2007), the pre-made diagram templates were faded out, with students being given the freedom to create their own. In the majority of the studies (Jitendra, Griffin, et al., 2007; Jitendra et al., 1998; Jitendra & Hoff, 1996; Leh & Jitendra, 2013), all students who received the visual-representation intervention made improvements in comparison to their pretest assessment and/or their control group peers. However, in the Griffin and Jitendra (2009) study, students in the schema-based instructional (SBI) condition did not score higher in mathematical problem solving on standardized posttest scores than the students in the general strategy instruction (GSI) condition. Both conditions proved equally effective in improving word problem-solving performance. This is an interesting finding, but could be related to the similarity between the SBI and GSI conditions. The general strategy instruction (GSI) condition was scripted, and encouraged students to use strategies including manipulatives, drawing a diagram, writing a number sentence, and using data from a graph. Additionally, in one study (Jitendra, Griffin, et al., 2007), an analysis of the student subgroups of LD, English language learners (ELL), and Title I (students receiving free or reduced lunch) within the SBI group showed that students did not improve scores at initial posttest, only maintenance. The somewhat limited results of the Jitendra and colleagues 2007 and 2009 studies makes necessary additional research in the use of teaching visual representation strategies to student identified with, or at-risk for, LD. Additionally, while teaching students to use visual representations when solving word problems is a needed component of the problem-solving process, the use of the pre-made templates does little to support students in their use of generalizable problem-solving strategies. It is also worth noting that none of these studies incorporated self-
strategies instruction, despite the strong evidence for its effectiveness. Teaching students to use visual representations is ineffective if they are not also taught how to monitor and evaluate the use of their representation throughout the solving process.

**Instructional components summary.** A comprehensive review of the literature on third-grade problem-solving interventions for students at risk for or with LD sheds light on some key instructional components that have shown to be effective in improving students’ problem-solving performance. It is established that explicit instruction is a necessary component of an effective problem-solving intervention. This aligns well with making the problem-solving processes observable skills. Teaching visual representations also aligns well with the model, providing an observable basis for assessing concept formation and extending insight into the planning process. Using multiple exemplars in teaching has proven effective in increasing skill generalization, which in turn expands a student’s use of the problem-solving process. However, multiple exemplars alone still make students reliant on teacher support to monitor the intervention and continually create novel problems. Incorporating self-strategies, though, establishes self-sufficiency in the problem-solving process and supports the reflection phase in particular. Teaching students to identify relevant information in the problem in order to make a plan to solve it is a key part of concept formation and planning, and is a skill addressed when teaching the problem-type strategy. However, the instructional content within the problem-type strategy needs further review.

**Instructional content.** Evaluating the instructional components used in third grade word problem-solving interventions is critical in determining intervention efficacy and effectiveness. However, interventions are comprised of not only instructional
components, but also the content targeted through those components: instructional content. Critically evaluating the content targeted through intervention is important in determining intervention generalizability and overall efficacy. There is a degree of ambiguity in problem solving as related to the unobservable covert cognitive processes. However, when assessed in relation to the cognitive-behavioral model, looking specifically at the planning phase, we can discern that instructional content within problem solving must consider operations and steps. Additionally, the concept formation phase points toward using prior knowledge and rules to determine what information is important, and how the information connects to one another. Across grade levels, difficulty related to the operations, number of steps in problems, and targeted concepts varies, and research should reflect the level of difficulty expected of its sample population. According to the Common Core State Standards in mathematics (Common Core State Standards Initiative, 2012), third grade level targets include solving problems using all four operations (addition, subtraction, multiplication, and division), fractions, measurement, estimation of time, liquid volume, masses of objects, and geometric measurement. After a careful review of the studies, it was clear that neither operations nor concepts aligned with these standards.

*Operations and steps.* All of the studies reviewed targeted only addition and subtraction problems (Cassel & Reid, 1996; Fuchs, Fuchs, et al., 2008; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, Hosp, et al., 2003; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, & Schroeter, 2003; Fuchs, Seethaler, et al., 2008; Griffin & Jitendra, 2009; Jitendra, Griffin, et al., 2007; Jitendra et al., 1998; Jitendra & Hoff, 1996; Leh & Jitendra, 2013; Owen & Fuchs, 2002; Seo & Bryant, 2012; Wilson & Sindelar, 1991). It
could be argued that students should first master the complex skill of problem solving with the more basic operations of addition and subtraction before moving onto multiplication and division. If this is the case, however, then follow-up procedures should have been provided in these studies on how the intervention was going to be extended to other operations. Without a plan for generalization, the students taught these discrete solving strategies for addition and subtraction are unlikely to transfer them to multiplication and division; further, some of the strategies cannot be extended beyond their current application. Additionally, when intervention time is spent on a remedial skill, students already at-risk or identified may fall even farther behind in the curriculum. A few studies (Griffin & Jitendra, 2009; Jitendra, Griffin, et al., 2007; Leh & Jitendra, 2013) did try to plan for increased problem complexity by targeting two-step problems, but this was rare. This content limitation was also present in concepts targeted through problem categories.

**Problem categories.** While the use of a problem-type strategy (which teaches students to identify important information from a problem before building a plan for solving) has proven effective, the problem categories used in these studies raise questions about the generalizability of the procedure. In the study by Fuchs, Seethaler, Powell, Hamlett, and Fletcher (2008), the problem types included total, difference, and change problems. Similar problem types (i.e., change, group, and compare problems) were used in studies by Jitendra and colleagues (Griffin & Jitendra, 2009; Jitendra, Griffin, et al., 2007; Jitendra et al., 1998; Jitendra & Hoff, 1996; Leh & Jitendra, 2013). These problem types were described as: (1) total problems combining two or more quantities, (2) difference problems comparing two or more quantities, (3) change problems involving
increasing or decreasing a starting quantity, (4) group problems, related to total
problems, combining groups to form new groups, and (5) compare problems, related to
difference problems, involving the comparison of two sets. The use of these problem
types was rationalized by identifying them as most common in math curricula for grades
1 to 3. While some of these categories do seem to offer some growth potential (e.g, total
problems), the fact that they are noted as prominent in the lower grades makes this
rationale questionable; that is, it implies that these problem types will become obsolete
after third grade, as problem “types” broaden with additional operations and multiple
steps. These particular problem categories are directly related to the operations of
addition and subtraction, making their application to more complex operations and
problems that include multiple steps ineffective.

In the other work by Fuchs and colleagues (Fuchs, Fuchs, et al., 2008; Fuchs,
Fuchs, Prentice, Burch, Hamlett, Owen, Hosp, et al., 2003; Fuchs, Fuchs, Prentice,
Burch, Hamlett, Owen, & Schroeter, 2003; Owen & Fuchs, 2002), the problem categories
used were even more narrow (shopping-list problems, pictograph problems, buying-bag
problems, and/or half problems). These problem structures were not researcher-created,
but taken specifically from the Math Advantage (Burton, 1994) curriculum used in the
target schools, and specific to individual units. Therefore, the questions were not a
composite of the most common problems used in the Math Advantage curriculum, but
questions present in specific units. This is extremely limiting. These problem types are
not likely to be present in any curriculum past the third grade, or even in other third-grade
curriculums. For example, one such buying-bag problem reads as follows: “You want to
buy some lemon drops. Lemon drops come in bags with 10 lemon drops in each bag.
How many bags should you buy to get 32 lemon drops?” (Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, Hosp, et al., 2003, p. 305). The number of such “shopping-bag” problems these students will see again after the study is low if not non-existent; this concern raises serious questions about the usefulness of such an instructional strategy.

Overall, the problem-types strategy as targeted in these interventions lacks growth potential. As is, these problem categories appear juvenile, and do not align with the concepts that should be targeted in accordance with the Common Core State Standards. As the curricular targets increase in complexity in grades four and five, students are expected to be solving problems that involve factors, multiples, decimals, measurement conversion, geometric measurement, multiplication and division of fractions, graphing, and multiple-digit multiplication and division. These skills move far beyond basic addition and subtraction word problems that use lists, halves, or pictograph contexts. Therefore, while an intervention must be focused and specific in order to improve performance on a certain skill, it should also be broad enough to produce measurable, practical gains in the classroom (and not just the research) setting.

Summary

The intervention practices that most clearly support the processes within the cognitive-behavioral model of problem solving, and have proved effective in the literature, include teacher-mediated explicit instruction with multiple exemplars to teach students to demonstrate understanding of the problem and work to solve it. Visual representation has been shown to effectively support students’ concept formation and their ability to plan a viable solution path. Finally, self-strategies such as self-monitoring and self-correcting aid students in the reflection and verification phase. For these
practices to reach their full potential, their content must be relevant to third-grade curriculum and provide the potential for growth to more mature mathematical concepts. Based on these conclusions, additional research is needed to investigate intervention packages which adhere to these practices.
Chapter 3

Methods

Participants and Setting

One third-grade Miami-Dade County Public Schools (M-DCPS) classroom was selected to participate in the study. The classroom was chosen because it was the only classroom at the third grade level that contained students with at-risk and disability status. The school practiced inclusion but used ability grouping for classroom assignment, a common practice in the M-DCPS district. As a result, the selected third grade classroom was the lowest ability classroom, containing between 15 and 18 students throughout the course of the study (students withdrew and were added to the classroom on a rolling basis). All students belonged to one or more of the following categories: LD, at-risk, and English for Speakers of other Languages (ESOL). At the time of identification for these students, the school used the discrepancy model (i.e., a student was identified as having a learning disability if his or her score on an IQ test was at least two standard deviations higher than his or her achievement test score) to identify students with LD. The school was in the process of transitioning to a Response to Intervention (RTI) model for identification. Students were considered at-risk for LD identification through the RTI model based on a “not-proficient” score in a subject area of math or reading at the start of the year assessment. All of the students identified as at-risk in this classroom scored not proficient in the math assessment area. In this school, ESOL students were initially identified with a parent questionnaire at the start of the school year; if on the questionnaire a parent identified that another language was spoken at home, then the student entered the ESOL program. The student’s proficiency in English was then
assessed each year using the Comprehensive English Language Learning Assessment (CELLA). ESOL identification was based on a four level system of preproduction, early production, speech emergence, and immediate fluency. ESOL level 5 was recorded on a student’s record to indicate that the student had exited the ESOL program. Not all students in the study were identified as ESOL. However, all students reported speaking another language at home. The school’s ESOL identification process may have missed classification of some of these students, or these students may be speaking mostly English in their home settings.

Initially, 13 students provided student assent and parent consent forms. However, three students withdrew from the school prior to the start of the intervention, which resulted in 10 students being present for the full duration of the study. Specific student information is provided in Table 2. Demographic information regarding race, nationality, and language spoken at home was based on participant self-report. Information regarding age, gender, ethnicity, ESOL level, free/reduced lunch, probability-of-success score on the Florida Assessments for Instruction in Reading (FAIR), retained status, and disability status was taken from school records. The FAIR score (included in the table if students were tested) was included as a measure of student achievement in reading comprehension, since reading comprehension is a vital part of solving math word problems.

One teacher ran the classroom. She had a bachelor’s degree, was certified in the areas of elementary education and ESOL, spoke English and Spanish, had been teaching for 10 years (3 years in the inclusive special education setting), and was Hispanic. She presented all intervention procedures in the classroom during the mathematics class.
period; additionally, a special education support teacher and pre-service teacher were occasionally present in the classroom. The special education support teacher and pre-service teacher were aware of the study procedures. When present, the pre-service teacher only observed from the back of the classroom and the special education support teacher only involved herself with the students when directed to do so by the classroom teacher (e.g., to hand out materials, support students not participating in the study, make sure that the students were paying attention during a lesson).

Design

A single-subject design was used to analyze individual student data. Ongoing student progress was tracked with three graphs for each student: one for paraphrasing accuracy, one for visualizing accuracy, and one for computation accuracy. The study was conducted using a multiple baseline across behaviors design (Cooper, Heron, & Heward, 2007). The two behaviors targeted within the design were paraphrasing accuracy and visualizing accuracy. Baseline data collection on the behaviors of paraphrasing accuracy and visualizing accuracy began for all students simultaneously. Each assessment yielded a score for each behavior at each time point. After steady state responding was achieved for at least eight of the 10 students (80%) on the paraphrasing behavior, the intervention targeting paraphrasing accuracy began; meanwhile, data continued to be collected on the visualizing behavior, which was still under baseline conditions. After at least eight of the students met criteria on paraphrasing, set at 7/8 across two consecutive sessions, the paraphrasing intervention ended and the visualizing intervention began. The visualizing intervention continued until at least eight of the students met criteria on visualizing, set at 7/8 across two consecutive sessions.
<table>
<thead>
<tr>
<th>Student</th>
<th>Age</th>
<th>Gender</th>
<th>Ethnicity</th>
<th>Race</th>
<th>Nationality</th>
<th>Language Spoken at Home</th>
<th>ESOL level</th>
<th>Identified as:</th>
<th>Free/reduced lunch</th>
<th>FAIR score</th>
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<td>Serbian</td>
<td>N/A</td>
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<tr>
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<td>8.5</td>
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<td>White</td>
<td>Israeli</td>
<td>Hebrew</td>
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<td>Spanish</td>
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<td>White</td>
<td>Guatemalan</td>
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<td>Honduran</td>
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<td>Asian</td>
<td>Spanish</td>
<td>Spanish</td>
<td>2</td>
<td>None*</td>
<td>No</td>
<td>70</td>
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</tr>
</tbody>
</table>

Note. *Student was not present for the start of year assessment.
Throughout baseline and intervention, data on computation accuracy were collected. The intervention did not explicitly target computation accuracy, but rather looked at the effects of the intervention with paraphrasing and visualizing on computation accuracy.

**Definition of Behaviors**

The three dependent variables in the study were paraphrasing, visualizing, and computation accuracy. Paraphrasing accuracy was operationally defined as writing a list of the important information in the problem, including the question (e.g., 36 kids, 1 van = 9 kids, # vans?). Visualizing accuracy was operationally defined as drawing a picture to represent the problem that included all the important information, the question (or the solution to the question), and the operation to be used. Computation accuracy was operationally defined as writing the correct answer to the word problem.

**Assessments**

**Problem-solving worksheets.** Data were collected throughout the study via permanent products. During each opportunity for assessment, students were presented with a researcher-created double-sided worksheet with two math word problems (e.g., “Our school is taking a class trip tomorrow. Thirty-six students are going. If each van can hold 9 students, how many vans will we need?”). All of the word problems required one step, and included one of the four operations (addition, subtraction, multiplication, and division). The skill focus in each problem aligned with the district pacing guide, which aligned with the math Common Core State Standards (Common Core State Standards Initiative, 2012). Therefore, all problems were within one of the third-grade target areas (i.e., measurement, time, and shape) and included all four operations.
(addition, subtraction, multiplication, and division). Additionally, to control for operation difficulty and to ensure that each operation was assessed an equal number of times, every two worksheets contained one problem from each operation, with division and multiplication separated across worksheets. Thus, for each worksheet pair, the first included one multiplication or division problem and one addition or subtraction problem, and the second included the remaining two operations.

**Scoring.** Under each word problem, there were three headings: paraphrase, visualize, and compute. A paraphrasing response on one word problem was scored out of four. One point was awarded for including each piece of relevant information, including numbers and words/phrases/abbreviations to clarify the relevant information; because each problem contained two pieces of relevant information, this totaled two points. Then, one point was awarded for including the question, and one point for rewording the problem (i.e., maintaining the accuracy of the problem without rewriting it verbatim). This equaled four points for paraphrasing one problem and eight points for paraphrasing each worksheet.

Similarly, a visualizing response on one word problem was scored out of four. One point was awarded for including each piece of relevant information in the picture (totaling two points for the two pieces of relevant information in each problem), one point for accurately placing either the question in the picture (using the written question or a question mark) or the solution to the question if solving had occurred, and one point for selecting the correct operation (i.e., writing the operation symbol). This equaled four points for visualizing one problem and eight points for visualizing each worksheet. For the visualization, the presence of only a number sentence, without labels or the
framework of a schematic (e.g., boxes or circles to represent the information components, a number line, or a diagram) did not result in points in the aforementioned categories.

Each word problem was scored out of one for computation accuracy (thus, two points for computation accuracy for each worksheet). Feedback was not provided to the students on their specific problem performance. The researcher scored the dependent variables on the worksheets, with 20% of the measures scored by a research assistant for inter-rater agreement.

Materials

**Student checklist.** During lessons, the teacher modeled the use of a researcher-created self-monitoring checklist. The students were allowed access to the checklists during each related intervention phase. Examples of these supporting materials are provided in Figure 3 (for paraphrasing intervention) and Figure 4 (for visualizing intervention).

---

**PARAPHRASE**

- SAY: Underline the important information.
- ASK: Have I underlined the important information?
- SAY: Put the problem in your own words and write the important information.
- CHECK: That the information goes with the problem.

**PARAPHRASING PROMPT**

I’m trying to figure out _______________. I know that __________ and that ________________.
Again, I’m looking for ________________.

*Figure 3.* Paraphrasing self-monitoring checklist provided to the students during the paraphrasing intervention phase.
Teacher script. The teacher was provided with mock scripts for the initial paraphrasing and visualizing lessons. The scripts provided think-aloud examples, such as the following: “Okay, now that I have read the problem, I am going to paraphrase it, or put it in my own words. Let’s see, I am going to look at my checklist. I am going to underline the important information. I know that ___ is important, and I think that ___ is important too. Okay, I’ve underlined the important information. I am going to check that off on my checklist.” The teacher was instructed not to use the scripts during the lessons though, and to refer to them only as examples.

Lesson problems. During each lesson, the teacher used researcher-created word problems that mirrored the structure of the assessment problems. To incorporate the best
practice of using multiple exemplars, the teacher used novel word problems when presenting the lessons that included all four arithmetic operations.

**Procedure**

**Pre-baseline.** Prior to starting baseline data collection, the teacher administered the AIMSweb Math Computation assessment for progress monitoring, grade 3, probe 4, and the AIMSweb Math Concepts and Applications assessment for progress monitoring, grade 3, probe 4. As per the AIMSweb guidelines, students were given eight minutes to complete each assessment, and were not provided with any assistance. AIMSweb data are provided in Tables 3 and 4. The computation assessment data in Table 3 reflect scores out of 37 questions and 68 possible points. The concept and applications assessment data in Table 4 reflect scores out of 29 questions and 46 possible points.

Students without data were not present during assessment administrations.

<table>
<thead>
<tr>
<th>Table 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>AIMSweb Math Computation Scores</em></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Student G</td>
</tr>
<tr>
<td>Student D</td>
</tr>
<tr>
<td>Student H</td>
</tr>
<tr>
<td>Student Z</td>
</tr>
<tr>
<td>Student J</td>
</tr>
<tr>
<td>Student P</td>
</tr>
<tr>
<td>Student B</td>
</tr>
<tr>
<td>Student M</td>
</tr>
<tr>
<td>Student L</td>
</tr>
<tr>
<td>Class Average</td>
</tr>
</tbody>
</table>
Baseline. During baseline, which included a minimum of six baseline measures (12 math word problems) over the course of two months, the teacher presented students with the researcher-created measures in a whole-class setting during regular class time. The students were given 10 minutes to solve each two-problem measure and were not provided with any assistance or feedback on their performance. Non-participating students were included in all assessment procedures. Their data were not provided to the researcher.

Teacher training. Prior to beginning intervention, the teacher met with the researcher during her preparation period to review the intervention procedure. The teacher was presented with the scripts for review. The researcher modeled each initial lesson for the teacher, role-played presenting the lesson with the teacher, and provided immediate feedback. The teacher was also provided with a video of a similar intervention routine being practiced by other teachers. The researcher was present during the initial lesson presentations and provided support as needed (i.e., walking around the classroom to help keep students on task, answering any teacher questions during the lessons).
**Intervention.** The teacher presented the initial explicit instruction lesson on paraphrasing for one class period. During this initial paraphrasing intervention lesson, a novel word problem aligned to the pacing-guide target for that week was presented on the whiteboard. Students had individual copies of the problem and a copy of the paraphrasing self-monitoring checklist. The teacher read the problem twice and then modeled the use of the paraphrasing checklist to paraphrase the problem, verbalizing all of her actions. Students were encouraged to follow along with the teacher and complete their papers to match. The teacher followed the same procedure with a second novel problem. The students then worked in pairs to practice paraphrasing a third problem, using the paraphrasing intervention materials. After the paired practice, selected pairs presented their paraphrasing solutions to the class. The students then worked individually to practice paraphrasing a new problem, using the paraphrasing intervention materials. After the individual practice, selected students presented their paraphrasing solutions to the class. The classroom teacher and researcher provided support to the students during the paired and individual practice.

During the second paraphrasing intervention lesson, the teacher started the math period by modelling how to paraphrase a novel word problem, as in the initial lesson. The assessment measure was then presented in the same format as in baseline. The only difference was that students were permitted to use the paraphrasing self-monitoring checklist. As in baseline, the students were instructed to complete all three sections of each problem, including paraphrasing, visualizing, and computation.

This lesson and assessment format, as described on the second day, continued an average of three times a week. As the lessons progressed, the teacher tailored instruction
based on assessment data and also modeled more efficient paraphrasing practices (i.e., writing abbreviations of the important information instead of complete sentences) and encouraged the students to do the same. The lessons continued until at least eight of the students met paraphrasing criterion of 7/8 across two consecution sessions. After paraphrasing was mastered, the visualizing intervention began.

The teacher presented the initial explicit instruction lesson on visualizing for one class period. During this initial visualizing intervention lesson, a novel word problem, which aligned with the pacing-guide target for that week, was presented on the whiteboard. Students had individual copies of the problem and a copy of the visualizing self-monitoring checklist. The teacher read the problem twice and then modelled the use of the visualizing checklist, limiting the paraphrasing strategy to underlining for the paraphrasing (i.e., she did not write out the important information). She verbalized all of her actions (e.g., “Okay, now that I have read and paraphrased the problem in my head, I am going to visualize it, or draw a picture that is going to help me make a plan to solve the problem. Let’s see, I am going to look at my checklist. I am going to ask myself, what am I looking for, am I looking for the total? Well, let’s see, from looking at the information that I paraphrased, I can see that I am looking for how many ____ there are altogether, so it looks like I am looking for the total. Okay, I’ve answered that question. I am going to check that off on my checklist.”). Students were encouraged to follow along with the teacher and complete their papers to match. The teacher followed the same procedure with a second novel problem. The students worked in pairs to practice visualizing a third problem, using the visualizing intervention materials, but were encouraged to create their visual representation in any fashion (e.g., circles with lines, a
number line, drawings of objects relevant to the problem). After the paired practice, selected pairs presented their visualizing solutions to the class. The students then worked individually to practice visualizing a new problem, using the visualizing intervention materials; again, they were encouraged to create their visual representation in the format that made the most sense to them. After the individual practice, selected students then presented their visualizing solutions to the class. Feedback to the student and class discussion followed each student presentation, providing opportunity for corrective feedback and error correction. The classroom teacher and researcher provided support to the students during the paired and individual practice.

During the second visualizing intervention lesson, the teacher started the math period by modelling how to visualize a novel word problem, as in the previous visualizing lesson. The assessment measure was presented in the same format as in baseline, except that students were permitted to use the visualizing self-monitoring checklist. As in baseline, the students were instructed to complete all three sections of each problem (i.e., paraphrasing, visualizing, and computation).

This lesson and assessment format, as described on the second day, continued an average of three times a week, until at least eight of the students met visualizing criterion (i.e., 7/8) across two consecution sessions.

**Follow-up.** Approximately seven weeks after the conclusion of intervention, students were presented with up to eight follow-up assessment measures, administered over the course of two weeks. The measure and procedures matched those described in baseline.
Inter-Rater Reliability and Fidelity

Inter-rater reliability checks were conducted for 20% of each student’s measures at baseline, intervention (paraphrasing and visualizing), and follow-up. The checks were conducted by having a second researcher score the student measure independent of the first researcher. The number of agreements on each measure for each dependent variable were divided by the number of agreements and disagreements, and then multiplied by 100 to yield a percentage agreement score. Any disagreements in scoring were discussed. The average inter-rater reliability agreement score was 95%.

In addition, fidelity checks were conducted on the presentation of the lessons. For the initial lesson for each intervention target and at least once a week thereafter, the researcher observed the teacher presenting the lessons and completed a fidelity checklist. Each item on the checklist was scored as present/not present and yielded a fidelity percentage score (see Appendix A for a sample fidelity checklist). Fidelity checks were conducted for 80% of the paraphrasing lessons (8/10 lessons) and 78% of the visualizing lessons (7/9 lessons). The fidelity percentage score was 100% across all observations. This score was expected due to the scripted nature of the intervention, and the continued researcher presence and support during the majority of the lessons.

Social Validity

In addition to evaluating the impact of the intervention on the target behaviors, the social acceptability, complexity, and practicality of the intervention, or its social validity (Wolf, 1978), was evaluated. Two researcher-adapted social validity scales were distributed to the students and the teacher at the conclusion of the intervention. Each scale used statements to assess the value of the intervention and its outcomes, as perceived by the students and the teacher. The teacher form had 16 statements and the
response choices were strongly agree, agree, neutral, disagree, or strongly disagree. The student form had eight statements and the response choices were yes, maybe, or no.

**Graphing and Analysis**

Individual student data were graphed for paraphrasing, visualizing, and computation accuracy. The paraphrasing and visualizing graphs depicted the probe assessment data as part of the multiple baseline design. Visual analysis was used to examine the data for changes in level, trend, and variability in order to determine if the behaviors changed in a meaningful way, as well as to measure the extent to which the changes could be attributed to the cumulative effect of the intervention (Cooper, Heron, & Heward, 2007). The computation graphs depicted the probe assessment data combined within each of the four sections of baseline, paraphrasing intervention, visualizing intervention, and follow-up. Since each assessment was scored out of two for computation accuracy, visual analysis after each probe was not possible. Additionally, presenting the data cumulatively better enabled an assessment of the overall effect of the intervention within each phase.

A decision protocol (Keohane & Greer, 2005) was used to make moment-to-moment decisions about student progress during the use of visual analysis. In accordance with the protocol, the trend of the data was analyzed to determine intervention effectiveness for each individual student after either three steady data paths on an ascending, descending, or stable (flat) trend, or five variable data paths with an overall ascending, descending, or stable (flat) trend. Increasing, or overall increasing, trends resulted in the continuation of the intervention for that student. Descending, stable, overall descending, or overall stable trends resulted in an investigation of the student’s
learning difficulties within the intervention (i.e., analysis of student work samples and close observation during assessment), and the application of a tactic to supplement intervention effectiveness. During intervention, the use of visual analysis with the decision protocol was ongoing for each individual student until the previously specified criterion was met within each phase.

In addition to visual analysis, percentages of non-overlapping data (PND; Cohen, 1988) scores were calculated for each student for each main target (paraphrasing and visualizing). PND is a nonparametric approach, which incorporates statistical tests that do not make parametric or distributional assumptions. It is the most widely used effect size measure in single-subject research (Parker & Hagan-Burke, 2007). The PND scores were calculated by counting the number of data points in the intervention phase that did not overlap with the highest data points in the baseline phase, dividing by the total number of data points in the treatment phase, and then multiplying by 100.
Chapter 4

Results

In the following sections the results are discussed for each individual student. Ordering of results is based on ascending subject code order, which was determined based on the time that students returned parent consent forms. The student letters (e.g., Student Z) were assigned based on first initial. In addition to individual student graphs, discussions of visual analysis of data, mean and range data, and PND scores are also presented. PND scores are in Table 5. PND scores are interpreted in accordance with the guidelines for interpretation outlined by Scruggs, Mastropieri, Cook, and Escobar (1986); PND scores less than 50% reflect an unreliable treatment, PND scores between 50% and 70% reflect a treatment with questionable effectiveness, PND scores between 70% and 90% reflect a fairly effective treatment, and PND scores greater than 90% reflect a highly effective treatment.

<table>
<thead>
<tr>
<th>Table 5</th>
<th>PND Scores for Each Student and Target</th>
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<tbody>
<tr>
<td></td>
<td>Paraphrasing</td>
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<tr>
<td>Student G</td>
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<td>Student D</td>
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<tr>
<td>Student M</td>
<td>100%</td>
</tr>
<tr>
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<td>100%</td>
</tr>
<tr>
<td>Student S</td>
<td>100%</td>
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</tbody>
</table>
**Student Z (At-risk status)**

Student Z’s performance on the target behaviors of paraphrasing and visualizing is presented in Figure 5. For paraphrasing, his baseline scores were stable at 0 across all seven sessions. Substantial improvements in performance occurred after the introduction of the intervention, with two scores at criterion level (8/8 two consecutive times). His visualizing data were more variable in baseline, but still overall stable, with a mean of 0.85 and a range of 0 to 2. Again, substantial improvements in performance occurred after the introduction of the intervention, with two scores at criterion level (8/8 two consecutive times). Overall, visual analysis revealed that the intervention proved efficacious for increasing both his paraphrasing and visualizing responses. Furthermore, the overall stable trend in his visualizing data, which demonstrated a lack of improvement in visualizing despite the introduction of the intervention for the paraphrasing behavior, provided evidence of a functional relationship between the intervention and the changes in the target behaviors. As an additional measure of his paraphrasing and visualizing progress, his PND scores are presented in Table 5. His PND scores for both responses were 100%, which represents a highly effective treatment.

His cumulative computation performance is presented in Figure 6. In baseline, he achieved only 21% of the total computation points across seven assessments; that is, out of the 14 novel problems presented across the seven assessments, he computed three of the problems accurately. During the intervention phase targeting paraphrasing, he achieved 58% of the total computation points across six assessments. During the intervention phase targeting visualizing, he achieved 63% of the total computation points across eight assessments.
At follow-up, he achieved 75% of the total computation points across eight assessments. Overall, his computation accuracy improved throughout the duration of the intervention, and further increased at follow-up.

Figure 5. Student Z’s correct responses to paraphrasing and visualizing rules.
Figure 6. Student Z’s percentage of correct computation points achieved cumulatively on novel assessments within each phase.

**Student B (At-risk status)**

Student B’s performance on the target behaviors of paraphrasing and visualizing is presented in Figure 7. For paraphrasing, her baseline scores were stable at 0 across all seven sessions. Substantial improvements in performance occurred after the introduction of the intervention, with two scores at criterion level (8/8 two consecutive times). Her visualizing data were more variable in baseline, but eventually reached a stable 0 trend, with a mean of 0.64 and a range of 0 to 3. Again, substantial improvements in performance occurred after the introduction of the intervention, reaching criterion level on the second data point with a mean of 7 and a range of 5 to 8. Overall, visual analysis revealed that the intervention proved efficacious for increasing both her paraphrasing and
visualizing responses. Furthermore, the overall stable trend in her visualizing data, which demonstrated a lack of improvement in visualizing despite the introduction of the intervention for the paraphrasing behavior, provided evidence of a functional relationship between the intervention and the changes in the target behaviors. As an additional measure of her paraphrasing and visualizing progress, her PND scores are presented in Table 5. Her PND scores for both responses were 100%, representing a highly effective treatment.

Her cumulative computation performance is presented in Figure 8. In baseline, her cumulative computation score was very high. She achieved 86% of the total computation points across seven assessments. Therefore, prior to intervention, although her paraphrasing and visualizing accuracy responses were very low, her overall computation accuracy responses were high. During the intervention phase that targeted paraphrasing, her computation accuracy score drastically dropped to 14% of the total computation points across seven assessments. It should be noted however, that her computation responses were not incorrect during this phase, but absent. When targeting paraphrasing, she typically did not attempt to solve the problems. During the intervention phase targeting visualizing she began computing the problems again. Her computation score increased to 93% correct across seven assessments. Unfortunately, Student B was absent quite frequently during the end of the school year, during the collection of follow-up data. As a result, she only completed four follow-up assessments, achieving 75% of the total computation points. This follow-up score was lower than her scores during the baseline and visualizing phases.
Figure 7. Student B’s correct responses to paraphrasing and visualizing rules.
Figure 8. Student B’s percentage of correct computation points achieved cumulatively on novel assessments within each phase.

Student D (At-risk status)

Student D’s performance on the target behaviors of paraphrasing and visualizing is presented in Figure 9. For paraphrasing, his baseline scores were stable at mostly 0 across the seven sessions, with one outlying score of 2. This resulted in a mean of 0.29 and a range of 0 to 2. After the introduction of the intervention, Student D’s scores were still quite variable; this variability coincided with the state testing practice. Over the course of nine sessions, his mean score was 4.56, with a range of 0 to 8. His visualizing data were also variable in baseline, but stabilized at an overall 0 trend, with a mean of 0.44 and a range of 0 to 5. In comparison to his established 0 trend in baseline for sessions 6 to 16, substantial improvements in performance occurred after the introduction of the visualizing intervention, with a mean of 6 and a range of 3 to 8. Overall, visual
analysis revealed variable intervention effects. The changes in the behaviors do seem to be attributable to the intervention though, with the overall stable trend in his baseline visualizing data demonstrating a lack of improvement in visualizing despite the introduction of the intervention for the paraphrasing behavior. As an additional measure of his paraphrasing and visualizing progress, his PND scores are presented in Table 5. His PND scores for paraphrasing and visualizing were 56% and 50%, respectively. These scores represent only a questionably effective intervention for Student D.

His cumulative computation performance is presented in Figure 10. In baseline, he achieved only 43% of the total computation points across seven assessments. During the intervention phase targeting paraphrasing, he achieved 44% of the total computation points across nine assessments. During the intervention phase targeting visualizing, he achieved 71% of the total computation points across seven assessments. At follow-up, he achieved 79% of the total computation points across seven assessments. Overall, his computation accuracy improved throughout the duration of the intervention, and further increased at follow-up.
Figure 9. Student D’s correct responses to paraphrasing and visualizing rules.
Figure 10. Student D’s percentage of correct computation points achieved cumulatively on novel assessments within each phase.

**Student L (At-risk and ESOL level 5 statuses)**

Student L’s performance on the target behaviors of paraphrasing and visualizing is presented in Figure 11. For paraphrasing, her baseline scores were variable across seven sessions, with a mean of 1.29 and a range of 0 to 2. Substantial improvements in performance occurred after the introduction of the intervention, with two scores of 4, followed by two scores at criterion level (8/8 two consecutive times). Her visualizing data were also variable in baseline, but eventually reached a stable 0 trend, with a mean of 0.79 and a range of 0 to 2. Again, substantial improvements in performance occurred after the introduction of the intervention, with a mean of 5.89 and a range of 3 to 8. Overall, visual analysis revealed that the intervention proved efficacious for increasing...
both her paraphrasing and visualizing responses. Furthermore, the overall stable trend in her visualizing data, which demonstrated a lack of improvement in visualizing despite the introduction of the intervention for the paraphrasing behavior, provided evidence of a functional relationship between the intervention and the changes in the target behaviors. As an additional measure of her paraphrasing and visualizing progress, her PND scores are presented in Table 5. Her PND scores for both responses were 100%, representing a highly effective treatment.

Her cumulative computation performance is presented in Figure 12. In baseline, her cumulative computation score was very high. She achieved 86% of the total computation points across seven assessments. Therefore, prior to intervention, although her paraphrasing and visualizing accuracy responses were low, her overall computation accuracy responses were high. During the intervention phase that targeted paraphrasing, her computation accuracy score drastically dropped to 7% of the total computation points across seven assessments. It should be noted, however, that her computation responses were not incorrect during this phase, but absent. When targeting paraphrasing, she typically did not attempt to compute the problems. During the intervention phase targeting visualizing, she occasionally computed the problems but often ran out of time prior to completion. Her computation score increased to 38% correct across eight assessments. Her follow-up data reflected a similar pattern. She continued to spend considerable time creating a visualization for the problem, thus running out of time to finish her computation. As a result, she scored 69% accuracy on the eight follow-up assessments.
Figure 11. Student L’s correct responses to paraphrasing and visualizing rules.
Figure 12. Student L’s percentage of correct computation points achieved cumulatively on novel assessments within each phase.

Student M (At-risk status)

Student M’s performance on the target behaviors of paraphrasing and visualizing is presented in Figure 13. For paraphrasing, her baseline scores were stable at mostly 0 across the seven sessions with one outlying score of 2, resulting in a mean of 0.29 and a range of 0 to 2. After the introduction of the intervention, Student M’s scores were variable before reaching criterion level. Over the course of seven sessions, her mean score was 6 with a range of 4 to 8. Her visualizing data were somewhat variable in baseline, but hovered around the 0 level most consistently, with a mean of 0.60 and a range of 0 to 2. Substantial improvements in performance occurred after the introduction of the intervention, with the first two scores reaching criterion level. Overall, visual
analysis revealed that the intervention proved efficacious for increasing both her paraphrasing and visualizing responses. Furthermore, the overall stable trend in her visualizing data, which demonstrated a lack of improvement in visualizing despite the introduction of the intervention for the paraphrasing behavior, provided evidence of a functional relationship between the intervention and the changes in the target behaviors. As an additional measure of her paraphrasing and visualizing progress, her PND scores are presented in Table 5. Her PND scores for both responses were 100%, representing a highly effective treatment.

Her cumulative computation performance is presented in Figure 14. In baseline, she achieved only 43% of the total computation points across seven assessments. During the intervention phase targeting paraphrasing, she achieved only 25% of the total computation points across eight assessments. As with other students, Student M routinely did not solve during the paraphrasing phase due to time constraints (this was evidenced by her continuing attempts to write when the assessments were being collected). During the intervention phase targeting visualizing, she achieved 93% of the total computation points across seven assessments. At follow-up, she achieved 94% of the total computation points across eight assessments. Overall, her computation accuracy improved greatly after the visualizing portion of the intervention and further increased at follow-up.
Figure 13. Student M’s correct responses to paraphrasing and visualizing rules.
Figure 14. Student M’s percentage of correct computation points achieved cumulatively on novel assessments within each phase.

**Student G (LD and ESOL level 5 statuses)**

Student G’s performance on the target behaviors of paraphrasing and visualizing is presented in Figure 15. For paraphrasing, his baseline scores were stable at 0 across all seven sessions. After the introduction of the intervention, Student G did not score at criterion level until his 6th session; his mean score was 3.43 with a range of 0 to 8. His visualizing data were initially variable in baseline, but stabilized at an overall 0 trend, with a mean of 0.36 and a range of 0 to 2. He made substantial improvements after the introduction of the visualizing portion of the intervention, scoring at criterion level immediately. Overall, visual analysis revealed variable intervention effects for the paraphrasing portion of the intervention but strong effects for visualizing. The changes in
the behaviors do seem to be attributable to the intervention though, with the overall stable trend in his baseline visualizing data demonstrating a lack of improvement in visualizing despite the introduction of the intervention for the paraphrasing behavior. As an additional measure of his paraphrasing and visualizing progress, his PND scores are presented in Table 5. His PND scores for paraphrasing and visualizing were 86% and 100%, respectively. These scores represent a fairly effective intervention for paraphrasing and a highly effective intervention for visualizing.

His cumulative computation performance is presented in Figure 16. In baseline, he achieved only 36% of the total computation points across seven assessments. During the intervention phase targeting paraphrasing, he achieved 0% of the total computation points across seven assessments (due to lack of solving attempts). During the intervention phase targeting visualizing, he achieved 67% of the total computation points across six assessments. At follow-up, he achieved 50% of the total computation points across eight assessments. Overall, his computation accuracy improved over baseline level in both the visualizing intervention and follow-up phases.
Figure 15. Student G’s correct responses to paraphrasing and visualizing rules.
Figure 16. Student G’s percentage of correct computation points achieved cumulatively on novel assessments within each phase.

Student H (LD and ESOL level 2 statuses)

Student H’s performance on the target behaviors of paraphrasing and visualizing is presented in Figure 17. For paraphrasing, her baseline scores were stable at 0 across all seven sessions. After the introduction of the intervention, Student H’s scores reached criterion level immediately. Her visualizing data were somewhat variable in baseline, but hovered around the 0 level most consistently, with a mean of 0.57 and a range of 0 to 4. After the introduction of the visualizing portion of the intervention, her data, while variable, represented an overall ascending trend. While she did not reach the mastery criterion of two consecutive scores of 7/8 or higher, at the conclusion of the intervention her score was 8/8. The mean and range of her visualizing data in that phase were 3.63
and 0 to 8, respectively. Overall, visual analysis revealed that the intervention proved efficacious for increasing her paraphrasing responses, with more questionable results for her visualizing responses. Additionally, the variability in her visualizing data do not provide clear evidence of a strong functional relationship between the intervention and the changes in her behaviors. As an additional measure of her paraphrasing and visualizing progress, her PND scores are presented in Table 5. Her PND scores for paraphrasing and visualizing were 100% and 38%, respectively. This low visualizing PND score was mostly due to an outlying data point in baseline. Considering all data, these scores represent an effective intervention for the paraphrasing response and an unreliable intervention for the visualizing response.

Her cumulative computation performance is presented in Figure 18. In baseline, she achieved only 14% of the total computation points across seven assessments. During the intervention phase targeting paraphrasing, she achieved 21% of the total computation points across seven assessments. During the intervention phase targeting visualizing, she achieved 44% of the total computation points across eight assessments. At follow-up, she achieved 38% of the total computation points across eight assessments. Overall, her computation accuracy improved greatly over baseline level across all intervention and follow-up phases.
Figure 17. Student H’s correct responses to paraphrasing and visualizing rules.
Figure 18. Student H’s percentage of correct computation points achieved cumulatively on novel assessments within each phase.

Student P (At-risk and ESOL level 5 statuses)

Student P’s performance on the target behaviors of paraphrasing and visualizing is presented in Figure 19. For paraphrasing, her baseline scores were stable at 0 across all seven sessions. After the introduction of the intervention, Student P’s scores were variable, with an overall ascending trend. She reached criterion level at the 7th session, with an overall mean of 5.38 and a range of 3 to 8. Her visualizing data were variable in baseline, with a mean of 0.93 and a range of 0 to 4. After the introduction of the visualizing portion of the intervention, she scored at criterion level quickly (on the second session). Overall, visual analysis revealed that the intervention proved efficacious for increasing her paraphrasing and visualizing responses. However, a functional
relationship was only weakly demonstrated due to the variability in her visualizing data. As an additional measure of her paraphrasing and visualizing progress, her PND scores are presented in Table 5. Her PND scores for paraphrasing and visualizing were 100% and 67%, respectively. These scores represent an effective intervention for the paraphrasing response and a questionable intervention for the visualizing response.

Her cumulative computation performance is presented in Figure 20. In baseline, she achieved 36% of the total computation points across seven assessments. During the intervention phase targeting paraphrasing, she achieved 19% of the total computation points across eight assessments. During the intervention phase targeting visualizing, she achieved 44% of the total computation points across eight assessments. At follow-up, she achieved 50% of the total computation points across eight assessments. Overall, her computation accuracy improved over baseline level during the visualizing portion of the intervention and further increased during the follow-up phase.
Figure 19. Student P’s correct responses to paraphrasing and visualizing rules.
Figure 20. Student P’s percentage of correct computation points achieved cumulatively on novel assessments within each phase.

Student J (ID and ESOL level 2 statuses)

Student J’s performance on the target behaviors of paraphrasing and visualizing is presented in Figure 21. For paraphrasing, her baseline scores were stable at 2 across the first 5 sessions, before reaching 0 at the last session. After the introduction of the intervention, Student J’s scores were variable, but remained above baseline level for the first 6 sessions. Although after 6 intervention sessions the mean (4.5) and range (3 to 6) were significantly higher than in baseline, in accordance with the decision protocol her data represented an overall no trend. Therefore, a decision was made to supplement the paraphrasing intervention by printing the paraphrasing template (paraphrasing prompt shown in Figure 3) on her assessment papers. This initially resulted in noncompliance;
that is, the student would begin talking like a baby and say that she wanted her paper to look like the other papers. Ultimately, this phase of the intervention ended when the majority of the class met the criterion to move forward with the intervention.

Resultantly, Student J never scored at criterion level for paraphrasing.

Her visualizing data were also complicated. They were variable in baseline, with a mean of 1.4, and a range of 0 to 4. Her data remained variable even after the introduction of the visualizing portion of the intervention, with a mean of 4.13 and a range of 2 to 7. While her visualizing mean was higher in intervention than baseline and she did score at criterion level once, she never met the specified criterion for success.

Overall, visual analysis did not support the efficacy of the intervention for substantially improving Student J’s paraphrasing or visualizing responses. Her PND scores presented in Table 5 also reflect this, with a paraphrasing score of 89% and a visualizing score of 50%. Her paraphrasing score was high and represents a fairly effective intervention. Her visualizing score was much lower, representing a questionable intervention.

Her cumulative computation performance is presented in Figure 22. In baseline, she achieved 50% of the total computation points across six assessments. During the intervention phase targeting paraphrasing, she achieved 39% of the total computation points across nine assessments. During the intervention phase targeting visualizing, she achieved 56% of the total computation points across eight assessments. At follow-up, she achieved 69% of the total computation points across eight assessments. Overall, while her paraphrasing and visualizing
responses did not improve to reach criterion, her computation accuracy improved slightly over baseline level during the visualizing portion of the intervention, and further increased during the follow-up phase.

Figure 21. Student J’s correct responses to paraphrasing and visualizing rules.
Figure 22. Student J’s percentage of correct computation points achieved cumulatively on novel assessments within each phase.

Student S (ESOL level 2 status)

Student S’s performance on the target behaviors of paraphrasing and visualizing is presented in Figure 23. For paraphrasing, her baseline scores were stable at 0 across all five sessions. After the introduction of the intervention, Student S’s scores were variable before meeting criterion. Over the course of seven sessions, her mean score was 6.57, with a range of 2 to 8. Her visualizing data were mostly stable in baseline, hovering around the 0 level most consistently, with a mean of 0.46 and a range of 0 to 2. Substantial improvements in performance occurred after the introduction of the intervention, with the second score reaching criterion level. Overall, visual analysis revealed that the intervention proved efficacious for increasing both her paraphrasing and
visualizing responses. Furthermore, the overall stable trend in her visualizing data, which
demonstrated a lack of improvement in visualizing despite the introduction of the
intervention for the paraphrasing behavior, provided evidence of a functional relationship
between the intervention and the changes in the target behaviors. As an additional
measure of her paraphrasing and visualizing progress, her PND scores are presented in
Table 5. Her PND scores for both responses were 100%, representing a highly effective
treatment.

Her cumulative computation performance is presented in Figure 24. In baseline,
she achieved only 40% of the total computation points across five assessments. During
the intervention phase targeting paraphrasing, she achieved 44% of the total computation
points across eight assessments. During the intervention phase targeting visualizing, she
achieved 79% of the total computation points across seven assessments. At follow-up,
she achieved 81% of the total computation points across eight assessments. Overall, her
computation accuracy improved throughout the duration of the intervention, and further
increased at follow-up.
Figure 23. Student S’s correct responses to paraphrasing and visualizing rules.
Figure 24. Student S’s percentage of correct computation points achieved cumulatively on novel assessments within each phase.

Social Validity

Overall student validity scores are presented in Table 6. The students’ responses to the intervention were mostly positive. Question 1 addressed problem solving in general, with the majority of students feeling that problem solving is important (70%). Questions 2 and 6 focused on the skill of paraphrasing, and questions 3 and 7 focused on the skill of visualizing. Overall, the students appeared to value the intervention’s visualizing component more than the paraphrasing component, with a 100% favorable response to both visualizing questions and more variable responses for the paraphrasing questions. Questions 4, 5, and 8 inquired about the overall intervention. The responses were somewhat variable, but overall students felt that the intervention strategies were
now automatic (70%), will continue to be used (80%), and enhanced problem-solving ability (80%). However, these social validity results should be interpreted with caution. Having the teacher interview the students about what is essentially her teaching effectiveness is likely to impact the validity of their responses, as young students in particular are susceptible to social desirability bias; that is, their relationship with the teacher may hinder their ability to truthfully express an opinion about the intervention's value.

The teacher’s responses were also positive. She strongly agreed or agreed with all 16 questions assessing the value of the intervention, 69% and 31% respectively (see Appendix B for a list of the teacher’s social validity scale questions).
<table>
<thead>
<tr>
<th>Questions</th>
<th>Response Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. It is important to me to be able to solve math word problems.</td>
<td>70% 30% 0%</td>
</tr>
<tr>
<td>2. Learning to paraphrase has made me better at math word problems.</td>
<td>30% 40% 30%</td>
</tr>
<tr>
<td>3. Learning to visualize has made me better at math word problems.</td>
<td>100% 0% 0%</td>
</tr>
<tr>
<td>4. The strategies I learned are now automatic and I no longer need to use my checklist.</td>
<td>70% 10% 20%</td>
</tr>
<tr>
<td>5. I will continue to use the strategies (of paraphrasing and visualizing) I learned to solve math word problems in the future.</td>
<td>80% 20% 0%</td>
</tr>
<tr>
<td>6. I think it is important to paraphrase before solving math word problems.</td>
<td>90% 0% 10%</td>
</tr>
<tr>
<td>7. I think that it is important to visualize a picture or a diagram before solving math word problems.</td>
<td>100% 0% 0%</td>
</tr>
<tr>
<td>8. Learning to paraphrase and visualize has made me feel like I can be a better math problem solver.</td>
<td>80% 10% 10%</td>
</tr>
</tbody>
</table>
Chapter 5

Discussion

The purpose of this study was to evaluate a math word problem-solving intervention for a diverse group of third graders, which used explicit instruction strategies with multiple exemplars, taught the use of student-generated paraphrases and visual representations, incorporated a self-monitoring checklist, and targeted Common Core State Standards’ curriculum (i.e., all four operations in the context of measurement, estimation of time, masses of objects, and geometric measurement). The results of the study, which looked at the individual data of all 10 students, revealed favorable outcomes in the areas of paraphrasing, visualizing, and computation accuracy. In the sections that follow, components of the intervention (explicit instruction, a self-monitoring checklist, and the use of multiple exemplars) are discussed, followed by an examination of the targeted processes of paraphrasing and visualizing as well as the differential intervention effects based on overall student characteristics. Next, limitations and educational significance are discussed in relation to previous research, theoretical foundations, and examples of student work.

Components of the Intervention

Overall, the multicomponent intervention proved effective in increasing the paraphrasing, visualizing, and computation responses for all students. The main intervention components were the use of explicit instruction, a self-monitoring checklist, and multiple exemplars in instruction and assessment practices. However, due to the treatment package nature of the study, determining the most valuable pieces of the intervention is difficult.
The explicit instruction component of the intervention was present in all 19 instructional sessions. It provided the overall structure of the intervention format (i.e., guiding the teacher’s lesson structure, use of modeling, and opportunities for student practice and feedback). In the work of Fuchs and colleagues (e.g., Fuchs, Fuchs, et al., 2008; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, Hosp, et al., 2003; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, & Schroeter, 2003; Fuchs, Seethaler, et al., 2008), an explicit instruction lesson format was found to be superior to a general instruction format when delivering an intervention which increased the correct problem-solving responses of third graders. Jitendra and colleagues (e.g., Jitendra et al., 2007; Jitendra et al., 1998; Jitendra & Hoff, 1996) also found that using an explicit instruction format was most beneficial when implementing a visualization intervention with a similar population. Both researchers utilized interventions that included multiple components but identified explicit instruction as a necessary piece. Therefore, that this intervention was delivered in an explicit instruction format and resulted in favorable student outcomes aligns with the previous research on the critical characteristics of effective math problem-solving interventions for third graders.

Separating the explicit instruction component and the instructional guidance provided with the self-monitoring checklist is impossible, as the teacher consistently modelled use of the self-monitoring checklist during the lessons, intertwining it with the explicit instruction strategy. The teacher used the checklist to drive her explicit instruction, and that was where the checklist played the most critical role - during instruction. During student assessments, the students were rarely observed using the self-monitoring checklists during solving. However, although the students were not observed
reading and checking off the items on the checklist on a regular basis, inspection of student work after assessment revealed that the behaviors outlined on the checklist were being completed (e.g., underlining the important information). An example of this behavior is presented in Figure 25. The work of Marsico (1998) on increasing the independent math performance of students diagnosed with various learning difficulties found that increases in their correct responses were the observable result of students’ self-monitoring (self-editing) behavior when using a checklist. Harris and colleagues (e.g., Harris, Friedlander, Danoff, Saddler, Frizzelle, & Graham, 2005) discussed similar results when investigating the effects of self-monitoring on the academic performance of students with ADHD and finding that the intervention controlled independent on-task spelling behaviors. Like results were found here, with the behaviors on the checklist becoming automatic and happening covertly, but the checklist still playing a role in increasing independent student responding. As in the work by Marsico (1998) and Harris and colleagues (e.g., Harris, et al., 2005), the role of the checklist became one of a discriminative stimulus (SD) for independent problem solving, rather than a tool needed to facilitate each step in a problem-solving algorithm. That is, the response of solving in the presence of the checklist during the instructional sessions resulted in praise (an established reinforcer for the students), so during assessments the students responded to its presence by again solving. The checklist therefore became the cue to solve the problem, regardless of the need to read and follow the individual steps on the checklist. This role of the checklist aligned with the students’ social validity data.
Only 70% of the students reported no longer needing the self-monitoring checklist. The checklist did serve a function for the students, even if they were not observed reading and checking it off.

Figure 25. Example of a student assessment within the paraphrasing intervention phase where the behavior of underlining, which was prompted by the checklist below it, was observable on the permanent product.

Using multiple exemplars is good practice and has proved effective in increasing the generalization responses in problem-solving intervention studies by Fuchs and colleagues (Fuchs, Fuchs, et al., 2008; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, Hosp, et al., 2003; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, & Schroeter, 2003; Fuchs, Seethaler, et al., 2008; Owen & Fuchs, 2002). Problem-solving work by Hughes (1992) also supported this, finding that the use of multiple exemplars in an instructional package resulted in not only response generalization, but also response maintenance behaviors. All assessments in this study were presented in a similar context; explicit
tests for generalization did not occur. However, the teacher did report that the students were using the paraphrasing and visualizing strategies during their other assignments. Examples of these behaviors are presented in Figure 26. This generalization may be due to the use of multiple exemplars in the teaching practices. Additionally, while tests were not conducted for response generalization across settings, in the follow-up procedures, probes were conducted for response generalization across time. As in Hughes’ (1992) data, the follow-up data here support the use of the multiple exemplars in maintaining the computation skills of the students.

**Processes of Paraphrasing and Visualizing**

Based on the cognitive-behavioral problem-solving model (see Figure 2), which incorporates the frameworks of OCED (2003) and Gagné (1959), paraphrasing and visualizing can be observable behaviors of the problem-solving process and thus may serve as a demonstration of understanding. The performance of the majority of the students in this study provided support for the effectiveness of this model. The increases in paraphrasing and visualizing responses functioned to increase overall success in the problem-solving process by improving computation accuracy. Figure 27 presents an overall summary of these class wide data.

**Paraphrasing.** Across students, instruction in paraphrasing produced discrete changes in the paraphrasing response only; that is, while paraphrasing is represented within the model as a key skill in the problem-solving process, reaching mastery on that skill is not sufficient to increase overall problem-solving performance. Similar results were found in unpublished data that looked at a comprehensive problem-solving routine
Figure 26. Examples of students’ use of the paraphrasing and visualizing strategies during their other assignments.

As in the Krawec (2013) data, the students here required explicit instruction in visualizing before demonstrating gains in that area. In addition, it did not appear that instruction and subsequent mastery in paraphrasing led seamlessly to success in producing visualizing responses. Consequently, regardless of ability, students still required explicit instruction in how to use the problem information to create accurate schematic representations. Overall, the trend in the data across students does not provide clear evidence of the role that instruction in paraphrasing alone plays in improving student problem-solving performance. However, based on the theoretical model with which this intervention aligns, paraphrasing is a foundational skill needed to prepare students to be successful in later visualizing instruction. This may not be such a critical
factor at the third grade level where word problems are not very linguistically complex. However, this would become more prominent as word problems increase in comprehension complexity in later grades. To gain a better understanding of the role that paraphrasing plays in preparing students for problem-solving, future research may consider investigating the relationship of paraphrasing not just to performance, but also to the other processes in the problem-solving process.

**Visualizing.** A much more established area of the problem-solving process, visualizing played a prominent role in the overall problem-solving success of most students. Instruction and later success in visualizing not only resulted in the most gains in computation accuracy for most students, but it also resulted in the most solving
attempts. As mentioned in the results section and shown in Figure 27, a number of students decreased their computation accuracy in the paraphrasing phase of the intervention. However, this was overwhelmingly the consequence of decreased attempts at solving. It appeared that students did not see the link between paraphrasing and solving the problem. In contrast, when instruction targeted visualizing only, students began making more computation attempts and with increased accuracy, even without the teacher modeling computation during instruction. During assessments within the visualizing instruction phase, the concept formation and planning portions of the problem-solving process were observable through students’ schematic representations. Examples of these behaviors are presented in Figure 28. Student success at this level of the intervention aligns with the prior research of Jitendra and colleagues (e.g., Jitendra et al., 2007; Jitendra et al., 1998; Jitendra & Hoff, 1996). In their studies, instructing students in how to use visual representations was the key intervention component. This instruction in using visual representations resulted in increases in problem-solving accuracy at posttest. However, in opposition to the prior research, the visualizing strategies taught to students here allowed for more student freedom in visualization development (see different representation formats in Figure 28) and targeted all four operations. Since the necessity of visualizing skills in problem solving is established in the literature, future research may consider investigating how the more flexible visualization procedures used in this study will continue to support students into the older grades and more advanced curriculum.
For a field trip, 88 students were divided into 8 equal groups. How many students were in each group?

PARAPHRASE:

VISUALIZE/PLAN:

COMPUTE:

\[ 88 \div 8 = 11 \]
Figure 28. Examples of student assessments within the visualizing intervention phase, where the students’ work reflected the concept formation and planning portions of the problem-solving process by depicting the important information in a graphic representation (in differing formats) and identifying the necessary operation.

Interestingly, concerning overall problem-solving performance, the social validity feedback from the students reflected the conclusions drawn from the paraphrasing and visualizing data. In comparison to paraphrasing, the majority of students reported finding more value in learning to visualize, with 30% of students responding favorably to paraphrasing instruction, versus a 100% favorable response rate for visualizing
instruction. Students were not asked to elaborate on their responses to the social validity questionnaire. However, the fact that students increased computation attempts in the visualizing phase could be evidence of the relationship that they see between visualizing and problem solving. Overall, students reported that both visualizing and paraphrasing are an important part of the problem-solving process, 100% and 90% respectively. This contrast between viewpoints of importance and value is interesting. It could be that students perceived the word “importance” as meaning something that needed to be done to correctly solve and perceived “value” as more of a judgment about whether or not they liked doing something. Alternatively, this contrast could provide further support for the point that students do know that paraphrasing should happen, but do not feel that paraphrasing alone leads to computation, as evidenced in their data.

**Differential Effects Based on Student Groups**

Although all students demonstrated increases across the intervention, the specific areas (paraphrasing, visualizing, computation) of these increases, and the degree, were somewhat differentiated by student attributes. Student grouping data are presented in Table 7.

Only four students, Students Z, B, D, and M, did not belong to an ESOL or identified disability status group. This group, though considered at-risk, is the highest level group in this sample. On average, they gained 6.50 points in paraphrasing and 6.49 points in visualizing from baseline to intervention phases. Additionally, from baseline to follow-up their average percentage increase on computation accuracy was 33%. Overall, their gains in all areas reflected their “highest” status.
<table>
<thead>
<tr>
<th>Category</th>
<th>At-risk only</th>
<th>LD</th>
<th>ID</th>
<th>ESOL Level 2</th>
<th>ESOL Level 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Paraphrasing Mean at Baseline</td>
<td>0.15</td>
<td>0</td>
<td>1.67</td>
<td>0.56</td>
<td>0.43</td>
</tr>
<tr>
<td>Average Paraphrasing Mean at Intervention</td>
<td>6.64</td>
<td>5.47</td>
<td>4.00</td>
<td>6.02</td>
<td>4.94</td>
</tr>
<tr>
<td>Average Paraphrasing Point Gain</td>
<td>6.50</td>
<td>5.47</td>
<td>2.33</td>
<td>5.47</td>
<td>4.51</td>
</tr>
<tr>
<td>Average Visualizing Mean at Baseline</td>
<td>0.63</td>
<td>0.47</td>
<td>1.40</td>
<td>0.81</td>
<td>0.69</td>
</tr>
<tr>
<td>Average Visualizing Mean at Intervention</td>
<td>7.13</td>
<td>5.57</td>
<td>4.13</td>
<td>4.92</td>
<td>6.45</td>
</tr>
<tr>
<td>Average Visualizing Point Gain</td>
<td>6.49</td>
<td>5.10</td>
<td>2.73</td>
<td>4.11</td>
<td>5.77</td>
</tr>
<tr>
<td>Average Computation Percentage Correct at Baseline</td>
<td>48%</td>
<td>25%</td>
<td>50%</td>
<td>35%</td>
<td>53%</td>
</tr>
<tr>
<td>Average Computation Percentage Correct at Follow-up</td>
<td>81%</td>
<td>44%</td>
<td>65%</td>
<td>63%</td>
<td>56%</td>
</tr>
<tr>
<td>Average Computation Percentage Gain</td>
<td>33%</td>
<td>19%</td>
<td>15%</td>
<td>25%</td>
<td>3%</td>
</tr>
</tbody>
</table>
In comparison, the one student identified with an intellectual disability, Student J, a student who was retained, held ESOL level 2 status, and had the lowest FAIR score, struggled most with the intervention. She did not meet the mastery criterion for either target behavior. Her mean point gain from baseline to intervention for paraphrasing and visualizing was also the lowest of all the student groups, 2.33 and 2.73, respectively. Interestingly though, her baseline scores on paraphrasing (1.67) and visualizing (1.4) were the highest in the class, although still quite below criterion level. Her higher scores at baseline could have been the result of her retained status though, which would have resulted in some prior exposure to similar word problems.

Both students identified with LD, Student G and Student H, made gains through the intervention. They gained a mean of 5.47 points in paraphrasing and 5.10 points in visualizing from baseline to intervention phases. Student G met the mastery criterion (i.e., 7/8 or higher across two consecutive sessions) on both behaviors. Student H, however, never met the mastery criterion on visualizing and her PND score in visualizing (38%) was the lowest in the class. Additionally, from baseline to follow-up their average percentage increase on computation accuracy was 19%. These two students differed in ESOL status though, with Student G being identified as ESOL level 5, and Student H being identified as ESOL level 2. Student H’s combined ESOL level and LD status likely compounded her struggles with visualizing.

While all students spoke a language at home other than English, there were only two distinct ESOL groups, the ESOL level 2 group and the ESOL level 5 group. Students L, G, and P belonged to the ESOL level 5 group. On average, they gained 4.51 points in paraphrasing and 5.77 points in visualizing from baseline to intervention phases.
This group had the lowest overall paraphrasing gains. This is not overly surprising, since paraphrasing requires increased reading and comprehension ability in English, skills impacted by English language fluency ability. This group of students responded very well to visualizing though, which may imply that ESOL students at a certain level benefit more from using word-problem solving strategies that are less linguistically-based and more schematic.

Students H, J, and S belonged to the ESOL level 2 group. They gained a mean of 5.47 points in paraphrasing and 4.11 points in visualizing from baseline to intervention phases. The pattern of these scores contrasts that of the ESOL level 5 group. It would be anticipated that this lower ESOL group would benefit more from using word-problem solving strategies that are less linguistically-based and more schematic. The reason for this contrast is unclear, but could be related to the fact that two of the three students in this group, Students H and J, were not only part of the ESOL 2 group, but also had diagnoses of LD and ID, respectively. Additionally, these two students were the only two students who did not meet criteria on both paraphrasing and visualizing. The co-existence of their learning difficulties along with ESOL level 2 statuses may mean that an effective intervention needs to address areas of difficulty beyond those targeted here. However, with only three students in each ESOL group, and the very different characteristics of each student beyond status labels (e.g., Student S’s motivation level during assessment was much higher than that of Students’ H and J), drawing overall conclusions with aggregated student data is difficult- reinforcing the importance of data analysis at the individual level.
Limitations

While the intervention proved valuable, three main limitations exist. First, because most students belonged to multiple groups, trying to draw conclusions of intervention effectiveness based on student classification status was difficult. This may limit the generalizability of the intervention for specific student groups. However, it provides support for the single-subject design and analysis used in this study that focused on individual student data. Second, although the design and analysis used within this study were the most beneficial for exploring the results in relation to unique student characteristics, certain environmental constraints limited the use of best design practices. While each student did serve as his or her own control within the study, further measures would have been beneficial to increase the validity of the design. For example, putting the students into two groups where the intervention phases were counterbalanced would have provided more information about the role of paraphrasing and visualizing skills within the problem-solving process, and also would have addressed the potential confounds of sequence effects. This was not possible though, since all students were part of the same class, and the intervention was delivered in a group lesson format.

Further, the theoretical model (which places paraphrasing before visualization) guided the sequence of the intervention. Therefore, while counterbalancing processes would have strengthened the methodology of the study, it may have done so at the expense of the intervention. Additionally, two of the students, Student B and Student L, had high computation scores at baseline that decreased after intervention. The decision to include these students in the study could be seen as a limitation. However, a few things are worth noting. First, although decreases in computation scores occurred for both students, their
scores were still relatively high. Student B’s scores increased in the visualization phase to 93% before decreasing in the follow-up phase to 75%. Student L’s score was 69% at follow-up. These decreases were attributable to discrete issues for both students. Student B had limited opportunities for assessment because of excessive absences. Student L routinely ran out of time during assessment before she was able to complete computation. Second, although both students were proficient in computation, their visualization scores were very low at baseline. The intervention improved visualization abilities in both students that may not be needed with the more simple third grade problems presented here, but will likely help them as problems increase in complexity. As related to this, both students were observed using these visualization skills outside of the intervention context with more complex problems. Although the link between their visualization and computation abilities was not represented in the data here, more practice in fluency for Student L and more opportunities for assessment with more complex problems for Student B may reveal otherwise. Third, although the intervention was teacher-delivered, the researcher was present during the majority of the lessons. It is likely that reactivity occurred; that is, the researcher’s presence may have had an impact on the behavior of the teacher and the students. It would be valuable to further assess the ecological validity of the intervention by having it delivered in a more natural context by the teacher without the presence or support of the researcher.

A few other limitations that were out of the control of the researcher are also worth noting. One area of difficulty was that interim testing (i.e., testing used to prepare for the upcoming standardized state assessment) occurred during the first week of the paraphrasing intervention. This resulted in an interruption in the intervention schedule
and a significant disruption to the daily schedule. This disruption may have been reflected in the paraphrasing score drop seen in the data for some students (e.g., Student J, Student S, Student G, Student M, and Student D) after the first paraphrasing assessment within the intervention phase. Second, the transient nature of the school’s population resulted in numerous changes to the classroom during the study. Students withdrawing from the school resulted in attrition of three participants. There were also several students who either became part of the class or were moved to a different classroom during the course of the study. This disrupted the general flow of classroom operations, like the structure of the teacher’s lessons (e.g., having one student translate her instruction into Russian for a new Russian-only speaking student) and the classroom seating arrangement.

**Educational Significance**

Despite these limitations, the results of this study offer valuable contributions to the field. For one, the theoretical framework explored here was somewhat novel. Previous research with this age group (e.g., Fuchs, Fuchs, et al., 2008; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, Hosp, et al., 2003; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, & Schroeter, 2003; Fuchs, Seethaler, Powell, et. al., 2008) has focused on the mainly cognitive aspects of the mathematical problem-solving process. One of the goals of this study was to merge a cognitive and behavioral model of mathematical problem-solving to better understand the observable skills that may demonstrate student understanding in this complicated process. Looking at the discrete skills associated with paraphrasing and visualizing and investigating their impact on computation were areas not previously explored; in doing this, this study generated some conclusions as well as
important questions for future investigation. It also provided teachers with a different way of teaching and assessing problem solving in the general education curriculum. Teachers are likely to feel more comfortable teaching and assessing skills of the problem-solving process which are observable (e.g., underlining important information, schematically representing parts of the problem) to make determinations about student areas of need, their own teaching effectiveness, and student problem-solving ability, as opposed to trying to draw conclusions based on unobservable cognitive processes or student answers alone. Such a process of student learning and teaching evaluation aligns with the current response to intervention (RTI) framework being implemented in many schools across the nation. A basic RTI framework includes ongoing tracking of student progress through stages of prevention and intervention, which includes: (a) student screening, (b) implementing evidence-based intervention, (c) monitoring student progress, and (d) analyzing student progress to determine special education eligibility (Fuchs, Mock, Morgan, & Young, 2003). The intervention applied here began with a baseline assessment of problem-solving skills (stage a), implemented evidence-based practices of using explicit instruction, multiple exemplars, and self-strategies (stage b), monitored student progress through ongoing assessment of problem-solving skills (stage c), and examined student learning through the graphing and analysis of individual student problem-solving data (stage d). Students identified in stage d as struggling with problem solving despite the application of high quality instruction at stage b, may then benefit from more intensive, individualized, one-on-one problem-solving practice using the strategies applied here (e.g., working with a special educator who systematically teaches the student each step of creating a schematic representation to mastery criterion).
model could seamlessly be applied by educators committed to using evidence-based mathematical teaching practices in the classroom to make determinations about student classification and remediate learning difficulties. This practice appeared to resonate with the teacher in this study, based on her very favorable feedback on the social validity scale and request to apply these teaching procedures and assessments with her future classes.

Furthermore, previous research on math problem-solving interventions at the third grade level failed to address critical issues such as incorporating curriculum which aligned with the Common Core State Standards, targeting all four operations, targeting practice and assessment with a broad set of word problems, and teaching visualization strategies which were not problem-type specific. These concerns, addressed through this intervention, make the intervention practices applied here more aligned with the regular education curriculum and resultantly more valuable in the general education inclusive classroom and for the general education teacher. Also, the overall format of the intervention employed a very natural and simple framework. The teacher required very little training to learn the teaching strategies used here and felt flexible to make the intervention her own (i.e., was not required to use a script or a set of contrived practice and assessment materials). These aspects increase the likelihood of intervention use outside of the intervention context; in fact, the teacher in this study reported that she used the intervention strategies in her teaching practices outside of the intervention sessions, and will continue to incorporate the strategies in upcoming years.

Lastly, the majority of previous research that investigated related intervention strategies presented in a group inclusive setting did not sufficiently disaggregate and discuss individual student data. As a result, the effects of the interventions on students
with special education needs were often masked. In cases where student data were broadly categorized by disability status, as in the study by Owen and Fuchs (2002), the accuracy of posttest scores for students with disabilities only reached 45%, a still failing level. In this study, seven of the 10 students reached a computation accuracy level at follow-up of about 70% or higher. Overall, this study was able to show that students with LD, ESOL classification, and at-risk status were all able to benefit from the intervention in a practical way by increasing their problem-solving skill set. This is useful when considering the current service delivery model of special education services and the variety of student needs that a teacher in this context strives to meet.


APPENDIX A

SAMPLE FIDELITY CHECKLIST

3rd Grade SIB Intervention Fidelity Checklist

<table>
<thead>
<tr>
<th>Date:</th>
<th>Observer:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time:</td>
<td>Target:</td>
</tr>
</tbody>
</table>

**Preparation**

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students had copies of the practice problem(s)?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students had appropriate support materials?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students had copies of assessment (if applicable)?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Implementation**

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provided explicit instruction?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>If initial lesson, incorporated or modeled?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modeled only the target behavior?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verbalized throughout solving?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Used the appropriate support materials?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engaged students during the lesson to follow her model by completing their outputs?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Practice (if applicable)**

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitored and supported students during practice?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Referred students to support materials during practice?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provided positive and corrective feedback?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provided opportunities for students to share their work?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reviewed solutions to practice problems?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Assessment**

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provided only 10 minutes for assessment?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Did not provide student assistance (except reading problems)?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Additional Information**

<table>
<thead>
<tr>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of adults present in the room:</td>
</tr>
<tr>
<td>Number of problems modeled:</td>
</tr>
<tr>
<td>Number of problems practiced:</td>
</tr>
<tr>
<td>Practice was paired, individual, or both:</td>
</tr>
</tbody>
</table>

Notes:
APPENDIX B

TEACHER’S SOCIAL VALIDITY SCALE QUESTIONS

3rd Grade Social Validity Scale (Teacher Form)

Teacher: ___________________________ Date: ____________

This questionnaire consists of 16 items. For each item, you need to indicate the extent to which you agree or disagree with each statement by circling one of the five responses to the right.

<table>
<thead>
<tr>
<th>Questions</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.  The target problem-solving skills emphasized in the intervention are important.</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>2.  It is important to me to make math problem solving easier for my students.</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>3.  The intervention was easy to implement in my classroom.</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>4.  The intervention fits into my existing mathematics curriculum/schedule smoothly.</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>5.  The intervention is a complement to the existing curriculum.</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>6.  My ability to teach mathematics problem solving has increased as a result of the intervention.</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>7.  I am better able to understand how my students think about word problems as a result of the intervention.</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>8.  My students reacted well to the instruction given for paraphrasing.</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>9.  My students reacted well to the instruction given for visualizing.</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>10. My students reacted well to the instruction given for using the operations decision tree.</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>11. I will continue to use this intervention in my classroom after the study is completed.</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>12. The intervention was effective for increasing the problem solving abilities of my students.</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>13. The intervention was effective for increasing the problem representation abilities (such as paraphrasing and visualizing) of my students.</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>14. My students showed increases in problem solving abilities outside of the research sessions.</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>15. My students appeared motivated and interested during the lessons.</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>16. I would recommend this intervention to other math teachers of students at risk for or with learning disabilities.</td>
<td>Strongly Agree</td>
</tr>
</tbody>
</table>

Other comments: