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Effective Interventions on Word-Problem-Solving for Students with Mathematics Difficulties

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Chapter 1 Introduction

I have been a special education teacher for seven years at an elementary school in a rural area in Minnesota. My main responsibility is to provide specialized instructions in reading, mathematics, and writing to students with specific learning disabilities (SLD), emotional/behavioral disorders (E/BD), other health disabilities (OHD), and autism. In the subject area of mathematics, my students struggle the most with word problem solving. Some of them quickly catch up with computational skills to approximate their corresponding grade levels. Unfortunately, this progress in computation usually does not lead to an equivalent success in word problem solving. When given a mathematics word problem, it is relatively commonplace to observe my students randomly pick two numbers in the problem, apply an operation that they practice most at a given moment, and reach a solution without considering whether it makes sense. They do not analyze the word problem nor do they fully understand the relation between the numbers given and what the word problem asks them to find. It appears that they do not think about how to solve the problem. Rather, they just calculate a numerical answer to be done with it. Many of my students loathe solving word problems because they rarely experience success with the given task.

Over the years, I have taught my students to utilize key words, diagrams, and graphic organizers to facilitate word problem solving. I created a template based on a four-step problem-solving procedure from the school's mathematics curriculum – *Understand*, *Plan*, *Solve*, and *Check*. I used the instruction approach of *I do*, *we do*, and *you do*. However, the interventions are very often not effective. Without adult supervision, many of my students choose to abandon the tools and strategies learned. Unfortunately, poor performance in word problem solving is not isolated to students with special education services. Many students without any identified disabilities struggle with word problem solving as well. It is a shared frustration among both general education and special education teachers.

"A problem is not truly solved unless the learner understands what he has done and knows why his actions were appropriate" (Brownell, 1942, p. 439). I intend to examine the existing research on effective interventions that improve mathematics word-problem-solving performance among students with or at risk for learning disabilities (LD) in mathematics and those at risk for mathematics underachievement. My goal is to modify my teaching practice to help my students advance their word-problem-solving skills and, at the same time, be a resource for general education teachers to help their students struggling with mathematics.

The rest of this chapter is organized as follows: First, the historical background about mathematics education standards and expectations for student performance is discussed briefly. Next, a theoretical background related to mathematics word-problem solving is presented. Research questions and the focus and importance of this paper are discussed afterwards. Definitions and a summary conclude the chapter.

Historical Background

The National Council of Teachers of Mathematics' (NCTM, 2000) *Principles and Standards for School Mathematics* redirected the focus of mathematics teaching away from procedural knowledge and began to direct the practice toward a conceptual understanding of mathematics (Griffin & Jitendra, 2009; Xin et al. 2005). Subsequently, the National Governors Association Center for Best Practices & Council of Chief State School Officers (2010) issued the *Common Core State Standards for Mathematics* (CCSSM) that endorsed the shift promoted by the NCTM (2000) (Griffin et al., 2018; Kiuhara & Witzel, 2014). Both the NCTM's standards and CCSSM emphasized teaching problem-solving skills at all grade levels (Kiuhara & Witzel, 2014).

Increasing expectations in mathematics meant helping students to develop mathematics proficiency. The National Research Council (2001) defined mathematical proficiency via five mutually dependent, integrated components: conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition. Mathematics proficiency is essential to succeed at school, enter and stay in the workforce, and function adequately in daily life and in a community (Fuchs & Fuchs, 2003; Fuchs et al., 2009; Xin et al., 2005).

Meanwhile, the No Child Left Behind Act (NCLB, 2002), the Individuals with Disabilities Education Act (IDEA, 1997), and the Individuals with Disabilities Education Improvement Act (IDEIA, 2004) pushed forward the reform that promotes standards-based, inclusive education in the United States. The legislation required educators to provide students with disabilities equal access to the general education curriculum content (Xin et al. 2005). This required that students at all ability levels learn arithmetic concepts, skills, and procedures and apply them to solve problems.

In the United States, at least 20% of the student population has various learning difficulties and attention issues. Unfortunately, only about a quarter of these students in public schools are identified with SLD and receive special education services (Horowitz et al., 2017). In terms of mathematical disabilities (MD) in particular, researchers suggest that 3% to 9% of school-age children have MD (Driver & Powell, 2017; Fuchs & Fuchs, 2003; Fuchs et al., 2009). For those unidentified, struggling students, the lack of targeted interventions and adequate support may lead to a dislike of school, low self-esteem, and early dropout (Horowitz et al., 2017). It is critical that schools are prepared to help these unidentified students succeed as well.

Mandated equal access for students with disabilities did not magically help them thrive in mathematics. Changes in laws are often a step in the right direction, but they rarely result in ideal learning scenarios. Results of the National Assessment of Educational Progress (NAEP) in Mathematics revealed persistently low achievement of students with disabilities over the past twenty years. For example, 50% of students with disabilities in fourth grade performed below the basic level for mathematics on the 2019 NAEP, compared to 14% of students without disabilities (The Nation’s Report Card, 2019). Unfortunately, the performance gap between students with and without disabilities grows wider as students advance through grades (Reed et al., 2014). Among eighth graders, 68% of students with disabilities scored below the basic level for mathematics on the 2019 NAEP, in comparison with 25% of students without disabilities (The Nation’s Report Card, 2019). This means that half of students with disabilities in fourth grade and over two thirds of them in eighth grade do not understand the grade-level mathematics concepts and are unable to solve simple grade-level word problems.

Despite equal access to the general education curriculum and increasing research on teaching practice to help students with disabilities succeed in mathematics, there continues to be a significant gap in mathematics performance between students with and without disabilities, as is evident by their dire results on the NAEP. Therefore, it is critical that scholars continue to develop and experiment with mathematics interventions for improving mathematics performance among students with disabilities so that educators can have a repertoire of evidence-based practice to help students with disabilities to enhance their mathematics performance and close the achievement gap between those with and without disabilities. Furthermore, a significant number of students who struggle with academics but do not meet the criteria for any special education services by legislation (Horowitz et al., 2017) should not be forgotten. Therefore, this paper includes interventions for students at risk for mathematics failure as well.

Theoretical Background

For educators working with students with mathematics difficulties, the challenge is to help students move beyond the basic computational skills and provide quality mathematics problem-solving instruction. Mathematics word problems are commonly used at the elementary level to teach students problem solving skills. Math word-problem solving involves sophisticated cognitive processes that can be categorized in two phases: problem representation and problem execution (Alghambi et al., 2019; Montague et al., 2011).

In mathematics word problems, problem representation consists of "translating and transforming linguistic and numerical information into verbal, graphic, symbolic, and quantitative representations that show the relationships among the problem part prior to generating appropriate mathematical equations or algorithms for problem solution" (Montague et al., 2011, p. 263). Problem execution involves designing and carrying out necessary computation, deciding the reasonableness and accuracy of the solution, and reporting and interpreting the answer (Alghambi et al., 2019; Montague et al., 2011). Students with mathematics difficulties typically struggle at the representation phase. They only focus on the numbers and keywords instead of visualizing the underlying mathematics relationships in the word problems (Montague, 2003).

Students with mathematics difficulties may have deficits in memory, attention, self-regulation, language processing, and generalization/transfer (Kiuhara & Witzel, 2014; Kroesbergen & Van Luit, 2003; Montague, 2003; Powell et al., 2009). These characteristics adversely affect their ability to solve mathematics word problems. Additionally, a lack of motivation and low confidence often leads students with mathematics difficulties to become passive learners (Montague, 2003).

Academic studies have developed and explored interventions for improving mathematics word-problem-solving skills for students with mathematics difficulties. Leading scholars in the field include Montague, Jitendra, Fuchs and Fuchs, and Swanson. Mounting evidence suggests that strategy instruction is an effective method to help students with learning difficulties master problem-solving skills.

Montague (1992) utilized a mix of cognitive processes and metacognitive strategies to teach problem-solving skills. Jitendra and colleagues (1998, 2002, 2007, 2013a) developed schema-based instruction to allow students visualize the underlying mathematics relationships in the word problem and find the solution. Fuchs, Fuchs, and colleagues (2002, 2003, 2004, 2006) extended schema-based instruction to explicitly teaching transfer so that students can more effectively apply the strategy to novel problems. Swanson has done substantial work on the characteristics of students with LD, and in recent years, he and his colleagues (2013b, 2014) have explored the efficacy of paraphrasing strategy training for improving mathematics word-problem-solving skills.

As research grew in the field of special education, the quality of studies improved as well, following various guidelines over the years. Gersten et al. (2005) proposed standards for group-design studies, while Horner et al. (2005) set the quality standards for single-case-design research. The Council for Exceptional Children's (CEC, 2014) standards have established rigorous criteria for special education research. The CEC's standards govern the quality of almost every aspect of the research such as context and setting, participants, implementation fidelity, internal validity, outcome measures/dependent variables, data analysis, and so on. Scholars have welcomed and adopted them in their own studies and identified evidence-based practices among existing research.

Research Questions

The purpose of this study is to investigate the efficacy of mathematics interventions for enhancing word-problem-solving outcomes among students with mathematics difficulties at the elementary level. The following research questions will be addressed:

(1) What are the effective interventions that significantly improve and maintain word-problem-solving skills among students with mathematics difficulties?

(2) What are the major components of the effective mathematics interventions identified in Question 1?

Focus of the Paper

An intensive database search of existing literature on mathematics interventions targeting students with mathematics difficulties was conducted. The initial search began with Academic Search Premier. The descriptors used in the search included *math*, *word problems*, *story problems*, *elementary*, *learning disability*, *instruction*, *strategy*, *strategy instruction*, *math intervention*, *deficits*, *schema*, *schema instruction*, *cognitive*, *metacognitive*, *paraphrasing*, *generative learning*, and various combinations of these key words. A subsequent, smaller-scale search was conducted on JSTOR and SAGE Journals Online. Interlibrary loans were requested to obtain the academic papers that were not available through any St. Cloud State University Library subscription.

Importance

Mathematics word-problem-solving is a challenging, yet essential task for students with learning difficulties. Even though legislation has mandated equal access to students with disabilities, the learning outcomes remain bleak for these students. Now, more than ever, educators need to strengthen their abilities to deliver high-quality and effective instruction. Many special education teachers have relied on commercial mathematics curricula to develop their lesson plans. It is true that some of the mathematics curricula developed based on research-based methods and underwent rigorous efficacy trials. However, special education is an individualized education program that tailors to each student's specific needs. Therefore, commercial curricula promoting one method to fit all students are not going to effectively improve mathematics proficiency for students with mathematics difficulties.

Mathematics teaching standards have been raised by NCTM (2000) and CCSSM. Federal legislation requires educators to apply evidence-based practice to teach mathematics. Academic research provides great resources for educators to deepen their knowledge and expand their repertoire of teaching methodologies. However, teachers may not have the time or means necessary to gather necessary information and implement it effectively. This paper aims at presenting the best practices in use today for improving mathematics word-problem-solving skills for students with learning difficulties to educators so that they can jump start their journey on implementing effective interventions to help their students move closer to mathematics proficiency.

Definitions

Cognitive strategy instruction is an instructional approach that teaches students necessary cognitive processes and metacognitive strategies to become proficient problem solvers (Montague, 1997, 2003, 2007; Wong et al., 2003).

Explicit instruction is an instructional approach that integrates a set of research-based instructional principles and procedures including well-structured and organized lessons, cueing, modeling, rehearsal, distributed practice, immediate corrective feedback, positive reinforcement, overlearning, and mastery (Montague, 2003, 2008).

Learning disability (LD) According to the IDEA (2004), a specific learning disability is "a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, that may manifest itself in the imperfect ability to listen, think, speak, read, write, spell, or to do mathematical calculations, including conditions such as perceptual disabilities, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia." Learning disabilities (LD) and specific learning disabilities (SLD) are both used in this paper to refer to the same special education category. The paper also uses the term, *learning difficulties*, to refer students with or at risk for LD/SLD.

Mathematics difficulties refer to students with or at risk for LD in mathematics and those at risk for mathematics underachievement. In addition to students who are identified with SLD in mathematics, the research and education communities often use cutoff points on norm-referenced mathematics assessments to determine mathematics difficulties. Even though the 25th

percentile is a relatively common cutoff point, a wide range of cutoff points (from the 5th to the 50th percentile) have been used in the studies (Powell et al., 2020; Swanson et al., 2018).

Meta-analysis refers to a statistical procedure of analyzing data from multiple scholarly studies. Distinct from narrative literature review, meta-analysis "has the potential to compare the magnitude of different treatment effects across studies to address more macroscopic research questions or high-order interactions on a specific topic" (Xin & Jitendra, 1999, p. 208).

Schema is a common semantic structure shared by two or more problems that require similar solutions (Fuchs & Fuchs, 2003; Griffin et al., 2018).

Schema instruction trains students to identify the schema (i.e., problem structure), analyze the underlying mathematical relationships in the problem through a schematic diagram or an algebraic equation, and reach the solution (Kiuhara & Witzle, 2014; Powell, 2011).

Schema-based instruction is an instructional approach that teaches students to translate mathematical relationships into schematic diagrams to solve word problems (Powell, 2011).

Schema-broadening instruction extends the schema-based instruction by explicitly teaching students to transfer their knowledge to novel word problems (Powell, 2011)

Transfer refers to a cognitive process that activates prior knowledge to form connections between familiar and novel problems and applies the solutions of familiar problems to solve the novel ones (Fuchs et al., 2002).

Summary

This chapter introduced the historical background related to mathematics education reform and persistently low mathematics performance among students with LD. Difficulties in word-problem-solving experienced by this group of students were discussed followed by a brief review of academic research for improving mathematics word-problem-solving skills. Chapter two will provide an extensive literature review on mathematics interventions for students with mathematics difficulties. Chapter three pulls the research together and will discuss what may be learned from the research and implications for practice.

Chapter 2 Literature Review

The purpose of this chapter is to review the existing scholarly studies related to the efficacy of interventions that improved problem-solving skills among elementary students with mathematics difficulties. In the past three decades, there has been a wealth of research that focused on mathematics word problem solving. First, selected published reviews and meta-analyses are presented to give an overview of intervention research related to mathematics word-problem solving. As more scholars focused on this area of research propelled by the demand of common core state standards, the standards for evidence-based interventions in special education gradually emerged over time. These standards are discussed next. Finally, this chapter reviews studies of four promising interventions that targeted mathematics problem solving, namely, explicit instruction, cognitive strategy instruction, schema instruction, and paraphrasing strategy instruction.

Syntheses and Meta-Analyses

This section summarizes selected syntheses and meta-analyses of research that examined the efficacy of mathematics interventions from 1999 to 2020. Only those focusing on word-problem solving at elementary level are discussed here.

To investigate the efficacy of mathematics word-problem-solving instructions for students with learning problems, Xin and Jitendra (1999) performed a meta-analysis on 15 published research studies from 1986 to 1996 and 10 unpublished doctoral dissertations between 1980 and 1996. The authors divided the studies into two groups based upon their research designs (i.e., group-design studies and single-subject-design studies) and conducted analyses on the two groups separately. The interventions in their sample were categorized into representation techniques (i.e., verbal or visual representation of the information in the word problems), strategy training (i.e., any explicit teaching of problem-solving processes), computer-aided instruction (CAI), and other (i.e., any non-instructional intervention such as key words). Most of the participants in the analysis were identified with or at risk for LD in the elementary level through post-secondary level.

Due to limitations related to analyze effect sizes (ESs) in single-subject studies, Xin and Jitendra (1999) mainly based their discussions on the ESs of the group studies in the sample. Using Cohen's *d* to measure the ESs, they authors found that the effects of word-problem-solving interventions were generally positive for students with learning problems. The ESs of all the instructional interventions ranged from 0.74 to 1.80, which were described as moderate to large effect. By delivering representation techniques or strategy training through tutorial or interactive videodisc programs, the CAI intervention was deemed the most effective. Although representation techniques ranked second in the effectiveness, Xin and Jitendra warned that in order to make a positive impact on students' problem-solving skills, the representation must be based on students' conceptual understanding of the relationships in the word problem. Strategy training including both direct instruction and cognitive strategy instruction produced moderate effect size. Their analysis also indicated that factors such as a longer intervention period, a one-on-one setting, implementation by researchers and teachers combined, and one-step word problems might heighten the effectiveness of the interventions. The authors pointed out that metacognitive strategies might affect the intervention outcomes positively if they were incorporated with cognitive strategy instruction through longer intervention. Furthermore, the results showed positive maintenance and generalization effects despite the fact that not all interventions assessed these skills.

Kroesbergen and Van Luit's (2003) meta-analysis focused on interventions for elementary students with various degrees of mathematics learning difficulties across three mathematics domains: preparatory arithmetic skills, basic computational skills, and mathematical problem-solving skills. Their synthesis selected 58 studies published in well-known journals between 1985 and 2000 comprising 21 single-subject designs and 40 group designs. Only the findings related to problem solving are discussed due to the purpose of the current paper. There were 17 interventions on problem solving in this meta-analysis. The authors used Cohen's *d* to measure the ESs. The results suggested that self-instruction yielded the largest ES (the mean ES = 1.77), and thus was the most effective for improving mathematics problem-solving skills. Even though direct instruction produced the second largest ES (the mean ES = 1.13) among the interventions included in the sample, Kroesbergen and Van Luit indicated that this method was the most effective for teaching basic computational skills. CAI were less effective compared to interventions involving teacher instruction. This finding was inconsistent with that of Xin and Jitendra (1999). The authors reasoned that most studies selected by Xin and Jitendra incorporated some degree of direct instruction, which might boost the effectiveness of CAI. The results showed that peer tutoring did not produce any effect.

Following the guidelines of the What Works Clearinghouse, Gersten et al. (2009a) closely examined existing research on mathematics interventions with high-quality experimental and quasi-experimental designs and outlined eight recommendations for improving mathematics learning for students struggling with mathematics. Two of the recommendations with strong evidence of effectiveness were using explicit instruction and teaching problem solving through various problem types. The authors specified the components of explicit instruction including explicit and systematic instructional materials, teacher modeling through thinking aloud, guided practice, corrective feedback, and regular cumulative review. They pressed the importance of explicitly teaching students the underlying structure of various mathematics word problems and to make structural connections between familiar and new, unfamiliar word problems. Supported by moderate evidence of effectiveness, Gersten and his coauthors recommended offering students opportunities to work with visual representations to enhance their understanding of mathematics concepts and activities.

Different from the meta-analyses by Xin and Jitendar (1999) and Kroesbergen and Van Luit (2003), Gersten et al. (2009b) directed their investigation on interventions specifically for students with identified LD to improve their mathematics proficiency. After extensive review, the authors selected 41 published studies utilizing randomized control trials or quasi-experimental designs over three decades (from 1971 to 2007). Most of the studies included two, three, or four instructional components. Using Hedges' *g* as the ES measure, the results showed the following instructional components with statistically significant positive ESs (the mean ESs shown in the parentheses): explicit instruction (1.22), use of heuristics (1.56), student verbalization of mathematical reasoning (1.04), using visual representations during problem solving (0.47), sequence and/or range of examples (0.82), and providing formative assessment data and feedback to teachers and students (0.23 and 0.21, respectively).

Contrasting instructional components with each other in a regression analysis, Gersten et al. (2009b) found only the effects of explicit instruction and use of heuristics remained significant. Even though this meta-analysis confirmed that explicit instruction was a key component in the effective mathematics interventions, it should not be used in isolation. Rather, it was an effective instructional approach for teaching mathematics ideas to students with LD. The authors also recommended to incorporate visual representation, examples with carefully planned sequencing, verbalization of mathematics reasoning, and/or providing ongoing feedback in the interventions. Due to only four studies using a heuristic strategy, the authors expressed some reservation on the effectiveness of this approach.

As the NCLB (2002), the IDEA (1997), and the IDEIA (2004) propelled standards-based reform and inclusive education in the U.S., the principles and standards issued by the NCTM (2000) and CCSSM raised the expectations of mathematics education and placed an emphasis on problem solving related to real world situations (Hord & Xin, 2013; Hughes et al., 2016; Zhang & Xin, 2012). As a result of the reform, students with disabilities were expected to learn high-order mathematics skills such as problem solving with their peers.

To examine how these significant changes in mathematics education impacted word-problem-solving interventions for students with learning difficulties from kindergarten to 12th grade, Zhang and Xin (2012) performed a meta-analysis sequel to Xin and Jitendra's (1999). Among 39 selected studies published between 1996 and 2009, 29 of them utilized the group design while the remaining 10 adopted the single-subject design. Using Cohen's *d* as the ES measure, the results identified representation techniques related to problem structure (ES = 2.64) as the most effective intervention, followed by cognitive strategy instruction (ES = 1.86) and technology-aided strategies (ES = 1.22). Consistent with previous meta-analysis and reviews, explicit instruction and conceptual modeling were crucial components in the interventions, especially for those of problem structure representations. Only seven studies in the sample used standardized testing measures. The results showed that the ESs measured by standardized testing were significantly smaller than those measured by research-developed tests. Additionally, the interventions carried out in the inclusive classroom appeared to be more effective than those in the special education settings. Furthermore, these interventions seemed to benefit average-achieving students as well. Even though no significant different effects were found between the interventions on simple-structured problems and those on real-world problems, Zhang and Xin called for more interventions on real-world problem solving in order to align with the NCTM's standards and CCSSM.

Even though CCSSM recommends introducing problem solving skills from kindergarten, problem-solving requirements have entered curricula and standardized assessments at the third-grade level. Recognizing mathematics education in third grade as a crucial turning point, Kingsdorf and Krawec (2016a) conducted a literature review on mathematics word-problem-solving interventions specifically designed for third graders. The authors carefully dissected 13 studies published in the peer-reviewed journals from 1991 to 2013 and summarized their characteristics as effective interventions in terms of instructional components and instructional content. Among the chosen studies, the participants' abilities were diverse, including average- and low-achieving students and those with and at risk for LD. Explicit instruction was a key component in all but one intervention (which adopted direct instruction, a similar instructional approach to explicit instruction). In line with previous meta-analyses and narrative reviews, explicit instruction was always paired with other instructional components in the interventions.

Another prominent instructional component in the selection was teaching word-problem solving through a problem type identification process. Even though 12 studies demonstrated improved word-problem-solving performance by students with mathematics learning difficulties, Kingsdorf and Krawec (2016a) cautioned that close connections between problem solving and specific problem types might hinder students' ability to transfer the skills to novel problems. Five studies led by Fuchs used a range of carefully sequenced examples to teach word-problem-solving process, which was a recommended instructional component in Gersten et al. (2009a). This component was intended to explicitly teach students to transfer problem-solving skills from familiar problems to novel ones, but the authors revealed that the novel examples included in the five studies were not broad enough to facilitate generalization effectively. Kingsdorf and Krawec identified self-regulated strategies as another instructional components applied in the effective word-problem-solving interventions. These self-regulated strategies (i.e., metacognitive strategies in Gersten et al., 2009b and Zhang & Xin, 2012), such as self-monitoring, self-evaluation, and others, helped students set learning goals, monitor their problem-solving process, and check their own progress.

Visual representation promoted largely with Jitendra and colleagues was the last instruction component identified in the review. However, due to its inconsistent effectiveness in selected studies, Kingsdorf and Krawec (2016a) recommended using this component with caution. They argued that premade representation templates might preclude generalization. In terms of instructional content, all selected studies focused only on addition and subtraction word problems with narrow problem categories mainly suitable for primary grades. The authors broached the limitations in the instructional content that it did not aligned with the requirements specified in CCSSM for third grade.

Students with learning difficulties often struggle with both mathematics and reading. Powell et al. (2020) revealed the estimated comorbidity rates for mathematics difficulties MD with reading difficulty (RD) were between 30% and 70% among existing research studies. They presented a brief overview of findings related to the characteristics of students with MD and RD. Difficulties in reading and language among students with MD + RD might contribute to their low performance in mathematics. Even though students with learning difficulties showed weaknesses in working memory, short-term memory, and long-term memory, the patterns of these weaknesses were likely different among students with MD alone and those with MD + RD. Consequently, Powell et al. raised the question of whether students' reading abilities might be a moderator that affect how they respond to mathematics interventions.

Powell and colleagues (2020) reviewed 65 published studies on interventions promoting mathematics proficiency at elementary level from 1990 to 2018. Only 13 of these studies provided information related to intervention responses for students with MD+RD or MD alone. Among them, only three studies directly compared the responses of students with MD+RD and with MD alone to the same intervention. Most studies used percentile to identify students with or without MD, but a wide range of cutoff scores were detected from 10th percentile to 50th percentile. Lack of consensus in MD categorization made the direct comparison of student performance across studies impractical.

Knowing that MD is very often comorbid with RD, Powell et al. (2020) only found that about one third of the studies provided reading profiles for students with MD. Without assessing students' strengths and weaknesses in both reading and mathematics, the interventions might not truly meet the students' needs. Word-problem interventions included in the selected studies were variations of cognitive/metacognitive strategy instruction and schema instruction. Half of the interventions were delivered in a small-group setting, and another 40% were implemented in a one-on-one setting. In terms of the efficacy of the interventions, most studies provided evidence for improved outcomes after the interventions.

For the interventions focusing on word-problem solving in the sample, reported effect sizes from students with MD+RD (all ESs > 1) were larger than those from students with MD alone (maximum ES = 0.67). However, Powell et al. (2020) cautioned that this finding regarding the responsiveness of students with MD+RD versus those with MD alone might not be conclusive because the intervention designs and the outcome measures were different across studies. Only two out of 65 studies directly compared students with MD+RD to students with MD alone in how they responded to mathematics word-problem-solving interventions. Unfortunately, the results of those two studies were contradictory. Due to the limited amount of research available, the authors called for further investigation into the responsiveness to math word-problem-solving interventions from students with MD+RD versus with MD alone.

The most recent meta-analysis on word-problem-solving interventions for students with LD and those with low mathematics performance in K-12 was performed by Lein et al. (2020). The authors included 31 studies published in peer-reviewed journals and three unpublished studies between 1989 and 2019. Twenty-four of them (i.e., approximately 70%) were conducted at the elementary level. The authors used Cohen's *d* to calculate ESs. The weighted mean ES for all the interventions was 0.56. They concluded that mathematics word problem solving interventions produced improved outcomes among students with LD or with low mathematics performance.

Upon in-depth analysis, Lein and coauthors (2020) found that the type of students taught, research design, type of intervention model, and type of implementer moderated the magnitude of the ESs. The interventions carried out at the elementary grades had higher ESs (e.g., mean ES = 0.63) than those at secondary grades (e.g., mean ES = 0.33). Quasi-experimental design yielded larger effect sizes than randomized control trials. Schema-broadening instruction was associated with the highest statistically significant effect (ES = 1.06). Schema-based instruction, strategy instruction, and other interventions (such as computer-aided instruction) all produced statistically significant but much less effect with ESs of 0.40, 0.28, and 0.11, respectively. Lastly, interventions appeared to be much more effective if they were implemented by researchers rather than by school staff.

Standards for Evidence-Based Practice

Mathematics reform since the beginning of the twenty-first century and federal legislation such as the IDEIA (2004) urged educators to implement evidence-based interventions to promote mathematics proficiency (Hughes et al., 2016; Zhang & Xin, 2012). However, there was no consensus regarding the research quality and evidence of effectiveness in the field of education around the turn of the century (Odom et al., 2005). In 2003, the Council for Exceptional Children's (CEC) Division for Research formed a task force to establish the standards for high-quality research and provided guidelines for determining evidence-based practice (Odom et al., 2005). Consequently, Gersten et al. (2005) proposed quality indicators (QIs) for research with experimental designs while Horner et al. (2005) recommended QIs for studies using single-subject designs. The two studies provided the foundational work for the development of *Council for Exceptional Children Standards for Evidence-Based Practices in Special Education* (CEC, 2014).

The CEC's guidelines specified the QIs associated with context and setting, participants, intervention agent, description of practice, implementation fidelity, internal validity, outcome measures/dependent variables, and data analysis. Furthermore, the criteria were established to classify studies into five groups based on their effectiveness: evidence-based practice, potentially evidence-based practice, mixed evidence, insufficient evidence, and negative effects. These standards for identifying evidence-based practice were proposed in a timely manner since the Every Student Succeeds Act (ESSA, 2015) mandated educators to use evidence-based practice to promote mathematics learning (Hughes et al., 2016).

Montague and Dietz (2009) applied the QIs in Gersten et al. (2005) and Horner et al. (2005) to evaluate whether the cognitive strategy instruction was an evidence-based practice for improving mathematics word-problem-solving performance for students with disabilities. They selected five studies with single-subject design and two with group design published from 1986 to 2005. Approximately two-thirds of all participants were identified with LD, and roughly 20% were identified as having mild intellectual disabilities. The five single-subject studies met most of the QIs except for interobserver agreement (IOA) and treatment fidelity. None offered information related to treatment fidelity, and only one of the studies provided the IOA data. Therefore, there was not sufficient information to determine whether the intervention was conducted consistently and whether the dependent variables were measured reliably.

The two group-design studies did not match the QIs as well as did the single-subject studies. Both group-design studies did not provide information related intervention fidelity, nor did they report the ESs. Both studies only used outcome measures developed by researchers, whereas Gersten et al. (2005) demanded multiple outcome measures. Furthermore, one of the studies did not include any information about its participants. Based on their analysis, Montague and Dietz (2009) determined that none of the selected studies was qualified to support cognitive strategy intervention as an evidence-based practice for enhancing mathematics word-problem-solving skills for students with disabilities.

Jitendra and colleagues (2015) indicated that schema instruction, another type of strategy instruction "priming the mathematics problem structure" (Jitendra et al., 2015, p. 53), was excluded in Montague and Dietz's (2009) analysis. Schema instruction's effectiveness has been investigated rather extensively. Even though past studies (Alghamdi et al., 2019; Flores et al., 2016; Fuchs and colleagues, 2002, 2003, 2004, 2006; Griffin & Jitendra, 2009; Jitendra and colleagues, 1998, 2007, 2013a; Peltier et al., 2019; Xin, 2008) showed that schema instruction improved problem-solving outcomes for students with mathematics difficulties, this instructional intervention has not been evaluated with criteria proposed by Gersten et al. (2005) and Horner et al. (2005).

To determine whether schema instruction was evidence-based, Jitendra et al. (2015) selected 18 group design studies and 10 single-case design studies published in peer-reviewed journals between 1993 and 2011. All studies included students with LD or at risk for mathematics difficulties. Among 18 group design studies, 12 of them met all essential QIs and two more met all but one of the essential QIs. Among the 14 studies that met the minimum requirements for essential QIs, seven studies were deemed to be high-quality (i.e., they met at least four desirable QIs), and the other seven studies were considered acceptable quality (i.e., met at least one desirable QI). Furthermore, the weighted effect sizes of the seven high-quality and the seven acceptable-quality studies were significantly greater than zero. The group design studies well-exceeded the evidence-based criteria proposed by Gersten et al. (2005). Therefore, Jitendra et al. concluded that schema instruction was an evidence-based practice supported by group design studies.

Unfortunately, the single-case design did not yield the same conclusion. Only one out of 10 single-case studies met the QIs for acceptable research. Horner et al.'s (2005) standards required a minimum of five single-case studies met the methodological criteria. Consequently, schema instruction's evidence-based status was not supported by single-case studies.

The application of evidence-based practice is mandated by legislation (i.e., IDEIA 2004 and ESSA, 2015) and promoted by the CEC's (2014) standards. It is vital for researchers and educators to be aware of the standards and criteria for identifying evidence-based practice and to guide the future high-quality research. Over time, an increasing number of researchers have been calling for the use of standardized assessments to measure outcomes of the interventions instead of simply relying on the measures designed by the experimenters (Peltier et al., 2018; Powell, 2011). Further, the scholarly studies should get teachers more involved in the treatments. Rather than having researchers or undergraduate/graduate students carry out the interventions, general education and special education teachers should be trained properly, so they can provide the instruction to the participants (Peltier et al., 2018).

Explicit Instruction

Explicit instruction, as a "systematic, direct, engaging, and success oriented" instructional approach (Riccomini et al., 2017, p. 3), has garnered strong evidence supporting its efficacy among intervention research on mathematics word problem solving in both general and special education settings over the past few decades (Gersten et al., 2009a, 2009b; Kingsdorf & Krawec, 2016a; Zhang & Xin, 2012). An essential component of effective instructional interventions, explicit instruction is an instructional approach that integrates a set of research-based instructional principles and procedures, typically including well-structured and organized lessons, cueing, modeling, rehearsal, distributed practice, immediate corrective feedback, positive reinforcement, overlearning, and mastery (Montague, 2003, 2008). Explicit instruction promotes meaningful interactions between teachers and students, provides necessary supports for effective learning, and boosts long-term retention of new concepts and skills (Doabler et al., 2015; Hughes et al., 2017; Montague, 2007).

The research by Darch et al. (1984) analyzed whether the explicit teaching strategy was effective in teaching fourth graders with mathematical skill deficits to solve word problems. The explicit teaching strategy was shown by direct modeling each step of the problem-solving process. The authors selected 73 fourth-grade students who failed a mathematics word-problem screening test and struggled with math word-problem-solving in their classrooms as confirmed by their teachers. The participants were randomly placed in four treatment groups: explicit instruction, basal instruction, explicit instruction with extra practice, and basal instruction with extra practice. The intervention included eleven 30-minute lessons for the two treatment groups without extra practice, and eight additional lessons were taught to the two groups with extra practice. The participants received the instruction in small groups of two to four. The intervention was carried out by four graduate students with prior teaching experience majoring in special education. All participants were administered a pretest, and there were no significant differences among treatment groups in terms of the pretest scores. The participants were also given a posttest one day after the treatment was concluded and a maintenance test ten school days after the posttest. The lessons focused on word problems involving multiplication and division. However, the pretest, the posttest, and the maintenance test required all participants to distinguish among all four operations by including a few addition and subtraction word problems.

Darch et al. (1984) revealed that, regardless of with or without extra practice, the explicit instruction treatment groups performed significantly better than the basal groups on the posttest. On the maintenance test, the participants in the explicit instruction with extra practice group scored significantly higher than did those in both basal groups. The information gathered from the student attitude questionnaires indicated that compared to the basal groups, more participants in the explicit instruction groups liked the instructional approach, more were inclined to use the strategy learned in the regular classroom, and considered the learning experience effective. Darch et al. concluded that the explicit instruction produced better performance than the basal instruction. Additionally, extra practice seemed to enhance the performance of explicit instruction in the long run.

Wilson and Sindelar (1991) extended the research by Darch et al. (1984) and examined the efficacy of direct instruction for problem solving and sequencing problems. The study included 62 participants who were elementary students identified with LD. All participants were divided into three treatment groups: strategy plus sequence, strategy only, and sequence only. The setting of the treatment was small groups of three to five participants. The treatment was implemented by college students majoring in special education and with some classroom experience. All participants were given a pretest, a posttest at the end of the treatment period, and a follow-up test two weeks after the conclusion of the treatment. All three groups of participants received fourteen 30-minute lessons over a period of three weeks. The first two lessons conveyed basic computational facts while the remaining 12 lessons focused on three types of mathematics word problems involving addition and subtraction. The strategy-plus sequence and strategy-only groups received the same strategy instruction on word-problem solving while the sequence-only group received basal instruction.

Wilson and Sindelar (1991) found that participants in the strategy-plus-sequence group scored significantly higher than did those in the sequence-only group on both the posttest and the follow-up test. However, the strategy-plus-sequence group performed significantly better than the strategy-only group on the follow-up test. Furthermore, participants in the strategy-only group scored significantly higher than did those in the sequence-only group on both the posttest and the follow-up test. The authors concluded that the direct instruction was an effective strategy for teaching students with LD to solve mathematical word problems involving addition and subtraction, which was consistent with the findings in Darch et al. (1984). The study demonstrated that the direct instruction approach was superior to the basal approach. Additionally, Wilson and Sindelar suggested that incorporating sequenced problem types might heighten the effectiveness of the direct instruction.

To investigate whether constructivist instruction or explicit instruction was more effective with helping students struggling with mathematics acquire basic multiplication skills, Kroesbergen et al. (2004) selected 265 students who scored below 25th percentile on a national criterion mathematics test. The participants were between 8 and 11 years old, and 129 students in the sample were identified with LD, behavior disorders, or mild mental retardation. All the participants were randomly assigned to two treatment groups, constructivist multiplication instruction and explicit multiplication instruction, and one control group with regular classroom instruction. The students in the two treatment groups received multiplication lessons from qualified and trained research assistants in small groups of four to six students outside the regular classroom for four to five months. In total, there were 30 lessons which were taught for 30 minutes each and were given twice a week. The control group received their multiplication from their teachers in the regular classrooms for around 60 minutes per week.

In the constructivist group, after the interventionists introduced a topic, students searched for a solution through discussions of possible procedures and strategies. The interventionists might ask questions or prompt discussion to facilitate learning, but they did not demonstrate the use of any strategy. In the explicit instruction group, after the interventionists reviewed the previous lesson, they introduced a topic to the students and demonstrated how to solve the problem with a strategy. The interventionists also instructed students how and when to use the strategy. After the lesson, students practiced a few problems within the group and then worked some more independently. In the control group, the classroom teachers delivered multiplication lessons following the school mathematics curriculum and provided additional help for students with mathematics difficulties.

The posttest results showed that both treatment groups outperformed the control group. The two treatment groups performed similarly on multiplication computation tests, but the explicit instruction group did better on problem-solving tests than the constructivist instruction group. Therefore, Kroesbergen et al. (2004) concluded that explicit instruction was a better instructional approach for students with mathematics difficulties.

Unlike Kroesbergen et al.'s (2004) study using explicit instruction as a sole intervention, researchers typically adopted explicit instruction as a key instructional component in strategy instructional intervention programs to explicitly teaching a strategy to students with mathematics learning difficulties for improvement mathematics proficiency (e.g., Gersten et al., 2009b; Jitendra et al. 2015; Lein et al., 2020). In recent years, Doabler and colleagues (2015, 2019a, 2019b) focused their research on investigating the contribution of explicit instruction components to its effectiveness through direct classroom observations.

To examine the effect of the rate of explicit instructional interactions on student mathematics outcomes, Doabler et al. (2015) gathered direct observation data from 129 Tier 1 kindergarten classrooms that were randomly assigned to treatment (a mathematics intervention curriculum) or control conditions in a large curriculum efficacy trial. Roughly 6% of the students in the observed classrooms were identified with disabilities. More than 50% of the participants were below the 25th percentile on a standardized early mathematics ability test at the beginning of the kindergarten year. The results showed that the frequency of individual student response opportunities was associated with student achievement, but no relationship was identified between the frequency of group response and student achievement. The authors recommended that increasing the rate of individual student response opportunities would enhance mathematics learning. Moreover, the quality of instruction, as rated by the observers, was also associated with student achievement. Due to the complexity involved in teacher demonstrations and interactions with students during explicit instruction, this study encouraged researchers to investigate the components of explicit instruction in depth to perfect this instructional approach.

Conducting direct classroom observations in the same randomized control efficacy trial, Doabler et al. (2019b) evaluated whether various components of explicit instruction contributed to the curriculum's effectiveness on student learning. The authors found that high rates of individual student practice with teacher scaffolding improved outcomes for students with mathematics difficulties. The results did not support a relationship between either the rate of teacher demonstration or group practice opportunities and student achievement. As teacher modeling was a crucial component of explicit instruction, the authors recommended further research to examine the duration and complexity of the demonstration instead of simply frequency count.

Doabler et al. (2019a) evaluated the relationship between the quantity and quality of explicit instruction and student achievements in a federally funded, Tier 2 mathematics intervention efficacy project. There were 1,251 kindergarteners who scored in the below average range on two standardized mathematics assessments and thus were qualified for the intervention. Observations were conducted on the intervention treatment groups (two or five students per group). The results showed that the group-level pretest scores were not significantly linked to individual practice rates, group practice rates, teacher demonstration rates, and the overall quality of the explicit instruction. It appeared that initial student academic status did not dictate the delivery of explicit instruction. On the other hand, the group-level pretest scores were significantly related to rates of student error and academic feedback. The authors deemed this finding reasonable since low-achieving students made more mistakes and thus received more support from teacher feedback. Furthermore, the authors found that rates of group practice, frequency of academic feedback, and quality of explicit instructional interactions all led to better student learning outcomes. Even though Doabler and colleagues did not directly measure the efficacy of explicit instruction, they provided connections between various explicit instructional components and student achievement. Their research likely led to improvements in explicit instruction.

Cognitive Strategy Instruction

Cognitive strategies are mental processes that learners use coherently to promote learning. Cognitive strategies may be simple processes such as using a short poem to memorize the steps of subtraction with regrouping and metacognitive processes such as knowing when and how to use the poem and monitoring its application (Wong et al., 2003). When solving mathematics word problems, students with a well-developed repertoire of cognitive and metacognitive processes and strategies are able to comprehend problem information, understand the goal, develop a plan with appropriate strategies and procedures, execute the plan, find the solution, and interpret the answer (Montague, 2003, Riccomini et al., 2016). However, students with mathematics difficulties seldom know enough processes and strategies, and even if they do, they often do not know when and how to apply them to solve word problems. Therefore, it is imperative to teach these students necessary processes and strategies so that they can think and act like a proficient problem solver. The goal of cognitive strategy instruction is to train students to use a pool of essential cognitive and metacognitive strategies to solve simple and multiple-step mathematics word problem (Montague, 1997, 2003, 2007; Wong et al., 2003).

Many researchers have studied the effectiveness of cognitive strategy instruction for mathematic word-problem solving over the past three decades and shown that it yielded positive outcomes, in general (Case et al., 1992; Cassel & Reid, 1996; Cuenca-Carlino et al., 2016; Kingsdorf & Krawec, 2016b; Krawec et al., 2013; Losinski et al., 2019, 2020; Montague et al., 2011; Swanson, 2014; Swanson et al., 2013a; Zhu, 2015). The syntheses and meta-analyses discussed earlier in this chapter also provided evidence that cognitive strategy instruction was an effective intervention for improving mathematics performance among students with mathematics difficulties (Gersten et al., 2009b; Jitendra et al., 2015; Kingsdorf & Krawec, 2016a; Kroesbergen & Van Luit, 2003; Lein et al., 2020; Montague & Dietz, 2009; Xin & Jitendra, 1999; Zhang & Xin, 2012). Since the current paper focuses on mathematical word-problem-solving interventions tailored to the elementary grades, six strategy instruction research studies consistent with this focus are discussed in this section. Three single-case studies are reviewed first followed by three group design studies.

Students with LD often apply incorrect operations when solving mathematic word problems. To address this issue, Case et al. (1992) designed a strategy instructional intervention for solving simple word problems for elementary students. The strategy is aimed at teaching students a problem-solving process “including reading the problem, circling important words, drawing a picture, and writing an equation” (Case et al., 1992, p. 2). The authors used a multiple-baseline-across-participant design. The participants were four students identified with LD from fifth and sixth grades. They all scored 80% or higher on the computation pretest and received between 40% and 70% on the word problem pretest.

Two graduate students with a special education major implemented the intervention in a one-on-one setting outside the regular classroom. Before the strategy intervention began, the participants were taught to identify important words associated with each type of word problem. The intervention occurred two or three times a week, and each lasted about 35 minutes. The problem-solving strategy was taught using explicit instruction via the self-regulated strategy development (SRSD) procedures proposed by Harris and Graham (1992). The participants were required to practice the strategy until they memorized all five steps. The word problems were sequenced from addition to subtraction. The instruction was criterion based, and previously taught skills were reviewed regularly. To facilitate generalization and maintenance of the learned skills throughout the intervention period, the participants were encouraged to use the problem-solving strategy, share their experience of using the strategy with the interventionists, and discuss the appropriate use of the strategy with the interventionist at the end of each lesson.

The results showed that all participants improved on their word problem solving performance with fewer applications of incorrect operations after the intervention. They roughly preserved their ability to solve addition word problems but made significant gains on solving subtraction word problems. Both participants and their special education teacher reported positively concerning the intervention and the strategy. The special education teacher observed the participants using the strategy in her classroom, while the participants reported that they used self-regulated strategy in other situations. Only two out of four participants maintained the learned skills eight weeks after the intervention ended.

Solving mathematical word problems was a challenging task for students with mild disabilities other than LD. Cassel and Reid (1996) adopted the cognitive strategy instruction to improve word-problem-solving skills for students with mild mental retardation (MMR). Their strategy was developed based on previous published studies. To help students memorize the problem-solving process, the authors used a mnemonic FAST DRAW (i.e., Find what to solve. Ask what information needed. Set up the equation. Tie down the sign. Discover the sign. Read the numerical problem [referring to the equation set up to solve the word problem]. Answer the problem. Write the answer.). The authors decided not to use the key word approach so that students could focus on the relationship presented in the problem. The strategy was taught following the SRSD procedures (Harris & Graham, 1992). The participants were two third graders identified with SLD and two fourth graders with MMR. All four scored 80% or higher on the basic computation pretests and scored between 20% and 60% on the word problem pretests. The first author carried out the intervention. The participants received instruction on relationships in addition and subtraction word problems before the strategy instruction began. The intervention sessions were 35 minutes long three times a week in a one-on-one setting. The rest of the instructional procedures were very similar to those of Case et al.'s (1992). The authors used a multiple-baseline-across-subject design. After the intervention, all four participants performed at or above 80% on the posttests, which was consistent with Case et al.'s (1992) findings. Maintenance effects were present at six and eight weeks after the end of the intervention. Cassel and Reid concluded that cognitive strategy instruction was effective for increasing word-problem-solving skills for students with MMR.

Kingsdorf and Krawec (2016b) discerned that the difficulty level of word problems in the intervention research typically was lower than the requirements set by CCSSM (2010). They designed a multi-component intervention including explicit instruction with multiple exemplars, visual representation generated by students, and a self-monitoring checklist. They examined the effectiveness of this multi-component intervention for improving mathematics word-problem-solving performance among third graders using materials aligned with CCSSM. The study adopted a single-case design. The participants were 10 third graders who belonged to at least one of the following categories: LD, at risk, and/or English Language Learners (ELLs). A classroom teacher implemented the intervention. The results demonstrated the effectiveness of the intervention on paraphrasing, visualization, and computation response for all participants. Students and teachers responded to the intervention positively.

Cognitive strategy instruction had many variations focusing on different cognitive processes. Swanson et al. (2013a) assessed the efficacy of two different cognitive strategies to determine whether all cognitive strategies were created equally. The author randomly assigned 120 third graders with mathematics difficulties (i.e., scoring at or below 25th percentile on two norm-referenced mathematical word problem tests) to three treatment conditions and one control condition. One treatment taught participants a general-heuristic strategy focusing on analyzing the text in the problem. Another treatment instructed a visual-schematic strategy to help students use a diagram based on the problem structure to solve the problem. A third treatment trained students to use both general-heuristic and visual-schematic strategies to find the problem solution. The explicit instructional approach was applied to teach the strategies. The intervention was conducted by graduate students and paraprofessionals over 8 weeks. Participants received 30-minute lessons three times a week in small groups of two to four students.

The results showed that only participants from the visual-schematic treatment group outperformed the control group (ES = 0.57) in the posttests. The authors reasoned that the design of general-heuristic strategy (such as underlying or boxing the text in the word problem) might distract students from the actual problem-solving process. Swanson et al. (2013a) raised concerns about different treatments placing various demands on students' cognitive processes. Therefore, a strategy such as general heuristic might not be suitable for students with low executive functions.

Suspecting that cognitive strategies might stress students' cognitive resources, Swanson (2014) examined whether students' working memory capacity (WMC) played a role in cognitive strategy instruction for students with mathematics difficulties. There were 147 third graders participating in the study, and 59 of them were identified as having mathematics difficulties since they scored at or below 25^{th} percentile on the problem-solving subtests on standardized mathematics tests. The participants were randomly assigned to three treatment groups, verbal strategy only, visual strategy only, and verbal+visual strategies, and one control group. The strategies taught in the treatment groups were the same as those in Swanson et al. (2013a). The intervention was implemented by doctoral students and/or master's level research assistants. The lessons were 30 minutes in length each and given three times a week in small groups of four to five participants over eight weeks.

Swanson (2014) found that participants with relatively higher WMC in verbal-strategy only or visual-strategy only treatments outperformed their counterparts in the control group.

However, participants with relatively lower WMC did not show any significant improvements with any of the strategy interventions. The results confirmed Swanson's hypothesis that the effectiveness of the cognitive strategy instruction was moderated by students' WMC. He suggested that only students with relatively higher WMC might benefit from cognitive strategy instruction on improving word-problem-solving skills.

Besides evaluating the efficacy of cognitive strategy instruction on promoting mathematics word-problem solving, Zhu (2015) also investigated whether there was a response difference between students with mathematics disabilities only and those with mathematics and reading disabilities in a suburb of a large Chinese provincial city. Scores on municipality-level mathematics and reading tests were used to determine students' academic ability levels. Students were identified with mathematics disabilities when scoring at or below the 25th percentile on the math test. Students were identified with mathematics and reading disabilities if scoring at or below 25th percentile on both mathematics and reading tests. One hundred fifty fourth-grade students participated in the study, including students with mathematics disabilities only, those with mathematics and reading disabilities, average achievers, and high achievers. Zhu randomly assigned the participants to either the treatment condition or the comparison condition. The study adopted the seven-step cognitive process and three metacognitive strategies proposed by Montague (1992). Four fourth-grade classroom teachers carried out the intervention using explicit instructional approach in the regular classrooms over eight weeks.

The results showed that students in the treatment group performed better than those in the control group after the intervention except for the high-achieving students. Students with mathematics disabilities only were more responsive to the intervention than those with mathematics and reading disabilities. Zhu (2015) did not assess the maintenance and generalization effects in his study.

Schema Instructions

Even though cognitive strategy instruction has proven to effectively improve mathematic word-problem-solving outcomes for students with mathematics difficulties, it only provides students with the problem-solving process and self-regulated strategies. Students with mathematics difficulties may need more support on problem structures, problem translation, and visualization of the information in a word problem. Some of cognitive strategy instruction research incorporated visual presentation, but simply drawing a picture without a schematic understanding of the problem did not provide the support that students with mathematics difficulties needed (Montague, 2003; Xin & Jitendra, 1999).

A schema is a common semantic structure shared by two or more problems that require similar solutions (Fuchs & Fuchs, 2003; Griffin et al., 2018). Schema instruction trains students to identify the schema (i.e., problem structure), analyze the underlying mathematical relationships in the word problem through a schematic diagram or an algebraic equation, and reach the solution (Kiuhara & Witzle, 2014; Powell, 2011). When encountering an unfamiliar word problem, schema instruction provides students with a strategy to form the connection between familiar and unfamiliar problems via problem schemata so that students can transfer the knowledge and solve the unfamiliar problem. There are two categories in schema instruction. The first category is called schema-based instruction which teaches students to translate mathematical relationships into schematic diagrams to solve the word problems. The second category is labelled schema-broadening instruction which is similar to the schema-based instruction, but it goes a step further to explicitly teach students to transfer their knowledge to novel word problems (Fuchs & Fuchs, 2005; Fuchs et al., 2006; Powell, 2011).

Following the quality indicators and criteria of evidence-based practice proposed by Gersten et al. (2005) and Horner et al. (2005), Jitendra et al. (2015) concluded that schema instruction was an evidence-based intervention for improving mathematics word-problem-solving outcomes for students with mathematics difficulties. Besides Jitendra et al.'s systematic review and evaluation, one other literature review (Powell, 2011) and two meta-analyses (Peltier & Vannest, 2017; Peltier et al., 2018) were conducted on schema instruction research.

Powell (2011) provided narrative reviews for 12 schema instruction studies including 11 group design and one single-case design. There were five schema-based instruction studies led by Jitendra and seven schema-broadening instruction studies led by Fuchs. Both lines of research moved toward teaching students to set up mathematical equations to reach the solution. All participants were in second or third grade. One third of the studies (i.e., four) only included students with special education services, and the remaining eight studies had 12% or fewer participants receiving special education services (except for one study with approximately 24% of the participants with special education services).

Ten of the studies (including all four studies with 100% participants receiving special education services) showed that both schema-based instruction and schema-broadening instruction produced a positive effect on students' word-problem-solving skills. Powell (2011) observed that most studies used researcher-developed measures instead of standardized assessments to determine the intervention effects. Therefore, it was impossible to assess the generalization effects of the instruction. Additionally, the schema-broadening research demonstrated effectiveness for students at risk for LD but did not provide evidence on its efficacy for students with LD.

Powell (2011) summarized a few suggestions for researchers and educators on implementing schema instruction to advance students' word-problem-solving skills. First, explicit instructional approach should be adopted to teach each schema. Second, educators should be knowledgeable about organizing word problems via schematic diagrams, mathematical equations, or other ways that tie to problem schemata, so they are able to assist students based on their needs. Third, interventional instruction should be delivered via two or more short sessions per week over multiple weeks or months. Fourth, even though students with or at risk for LD may benefit from whole-class interventional instruction, additional small-group or one-on-one supplemental sessions may be necessary for these students to truly grasp the strategy.

Peltier and Vannest (2017) executed a meta-analysis to investigate the efficacy of schema instruction on word problem solving performance and determine possible moderators to the effectiveness. They selected 21 schema instruction studies for elementary school-age students using group designs from 1996 to 2013. Less than 10% of the sample population was identified with disabilities. Using Hedges' *g* to calculate the ES, the analysis provided support for the effectiveness of schema instruction with an overall ES of 1.57 immediately after the intervention and an overall ES of 1.09 for transfer. These ESs were much higher than those reported in previous meta-analyses on intervention research conducted by Gersten et al. (2009b), Kroesbergen and Van Luit (2003), and Xin and Jitendra (1999). However, the authors pointed out that ESs across individual studies varied widely. The analysis for potential moderators showed that the interventions were more effective with schema-broadening instruction and researchers as implementers.

Peltier et al. (2018) meta-analyzed 16 single-case-design studies on the effect of schema instruction on improving word-problem-solving performance among students with disabilities between 1993 and 2017. There were 25 participants with LD, 14 at-risk, seven with intellectual disabilities (ID), seven with autistic spectrum disorders (ASD) plus ID, six with EBD, and one with other health impairments (OHI). Fifty-nine percent of the participants were in elementary school, 34% in middle school, and 7% in high school. Four studies used a computer-based intervention program while the remaining 12 did not use technology.

Using the *Tau-U* ES to measure the intervention effects, the results showed that schema instruction had a significant positive effect (the overall weighted *Tau-U* ES = 88.3%) on students' word-problem-solving performance. Peltier et al. (2018) also conducted moderator analysis, and the findings confirmed that schema instruction was an evidence-based practice for students with LD supported by single-case-design research. The effectiveness of schema instruction was consistent across grade levels. The moderating effect from technology and problem types was inconclusive. The authors noted that it was insufficient to claim that schema instruction was an evidence-based intervention for students with disabilities other than LD. Therefore, they recommended that more research should be done among students with disabilities other than LD and among older students.

Schema-based Instruction (SBaI)

One type of schema instruction is called the schema-based instruction, which employs schematic diagrams to help students understand the mathematical relationships in the word problems and organize the word problems to reach their solutions. Jitendra and colleagues led the research on this intervention. Nine SBaI articles are discussed in this section. Four single-case studies are presented followed by five group design studies.

Because schemata connected familiar and novel word problems “at a relatively high level of abstraction or generality” (Hiebert & Carpenter, 1992, p. 69; as cited in Xin, 2008), Xin (2008) proposed that SBaI could help students transfer mathematical relationships in a word problem to an algebraic equation. Adopting a single-case design, Xin studied whether SBaI could effectively train students with learning difficulties to solve word problems with algebraic equations. Four fifth graders participated in the experiment. All four participants failed state-wide standardized mathematics assessments while one participant was identified with LD and another identified with mild mental retardation. The instruction was delivered by Xu during an after-school program three times a week with 30 minutes per session. Using a direct instruction approach, SBaI taught participants to identify the problem type, map the mathematical relationships to a schematic diagram, convert the schematic representation to an algebraic equation, and then solve the unknown in the equation.

The results showed that all participants improved word-problem-solving performance after the intervention and maintained their skill levels at four to 10 days after the termination of the intervention. Moreover, they partially transferred the learned skills to solve word problems from the school-wide mathematics textbook. Xin (2008) suggested that SBaI should be reinforced in the regular classroom to facilitate transfer.

Flores et al. (2016) used a single case multiple baseline design to examine the efficacy of evidence-based intervention for word problem solving. The strategies in the study included schema-based instruction, concrete-representational-abstract sequence, and FAST strategy. There were three participants who were all enrolled in third grade and received tertiary intervention. The word problems involved addition and subtraction with the problem types of part-part-whole (PPW), change, and compare. The researchers acted as the interventionists, and participants received a 20-minute instruction, four days a week during an afterschool program.

Baseline probes were administered to all participants. Intervention instruction had four phases: teaching problem types, concrete instruction, representational instruction, and abstract instruction. During the teaching problem types phase, participants were taught how to identify three problems types and draw corresponding diagrams or write equations. In the concrete instruction phase, participants used manipulatives such as pencils and markers to demonstrate the semantic relationship in the problem and then followed FAST strategy, combined with the schematic diagram, to solve the problem. At the representational instruction phase, participants used FAST strategy plus the schematic diagram to solve the problem. During abstract instruction phase, participants solve the problems using FAST strategy without any representational assistance. All three participants improved their word-problem-solving skills as demonstrated by three consecutive probes with 100% accuracy.

Peltier et al. (2019) designed an intervention for word problem solving using schema-based instruction and a four-step problem-solving process (i.e. STAR, "Search the problem, Translate the problem into a schematic diagram, Answer the problem, Review the solution" [Peltier et al., 2019, p. 4]). The study employed a single-subject multiple baseline design. There were 12 participants with MD from fourth and fifth grade. Even though all word problems in the study were solved by addition and subtraction, the fourth-grade students worked with two-digit whole numbers while the fifth graders practiced with fractions. A special education teacher implemented the intervention and provided instruction on solving simple, generalized, and combined schema word problems.

The participants were divided to three groups, and all were given baseline probes. They received total 19 intervention sessions. The posttest was given to all participants after the intervention. Maintenance problems were administered to participants at various lengths after the intervention: 2-3, 5-6, 7-8, 14-15, and 23-24 instructional days. All students involved in the study improved their word-problem-solving performance on the posttest. A majority of participants met an 80% criterion on generalized and combined-schema word problems after receiving explicit instruction how to solve these types of problems. Peltier et al. (2019) used mixed schema problems in the maintenance probes, and only four out of 12 participants reached proficiency 14 days after the end of the intervention.

Alghamdi et al. (2019) examined the effectiveness of the schema-based instruction combined with explicit instruction, a four-step problem solving process using a mnemonic FOPS (Find the schema. Organize the information via a diagram. Plan to solve the problem. Solve the problem.), and a reward system on solving multiplicative word problems. The study adopted the single-subject multiple baseline design to focus on individual differences among participants. Three fifth graders with SLD were selected for the study. They all scored below the 10th percentile on a standardized mathematics achievement test. The word problems used in the research involved multiplication and division and consisted of three types of problems: equal group, unit rate, and array. At least five baseline tests were administered before the intervention began.

The first author of this study provided interventional instruction in a one-on-one setting. There were six intervention lessons. The intervention sessions were about 30 minutes each, four times a week. Each lesson required minimum two sessions. Thus, each participant received 12-14 intervention sessions in all. All participants took pretest and posttest. Two participants were given maintenance tests at two and three weeks after the intervention while one was given a maintenance tests at one and two weeks after. The functional relation between the SBI intervention and participants' abilities to solve word problems was established. Using the percentage of nonoverlapping data (PND) and *Tau-U* to measure the effectiveness of the intervention, all three participants' PNDs between the baseline and the posttest were 100%, and their *Tau-Us* were 1.0. Furthermore, all participants maintained their skills after the intervention.

Most mathematics textbooks instructed students to solve word problems using general strategy instruction (GSI). This approach provided a generalized guideline with a set of recommended strategies for solving word problems. GSI might not be suitable for students with mathematics difficulties due to its lack of systematic, task-specific instruction. Jitendra et al. (2007) used a group design to compare the efficacy of SBaI and general GSI for students with mathematics difficulties. The participants were 88 third-grade students from one of the lowest-achieving schools in a Northeastern United States urban school district, including four students identified with LD and 11 students receiving Title I mathematics services. The participants were randomly assigned to SBaI group and GSI group. In the SBaI condition, participants received modified SBaI suggested by Jitendra et al. (1998) with a self-monitoring strategy to solve one-step and two-step addition and subtraction word problems. Through explicit instructional approach, the participants were taught to use a schematic diagram to map information in the problem during lessons, but the diagrams were gradually faded after the lessons. The problems were presented in forms of text, graphs, tables, and pictographs and included irrelevant information. In GSI condition, participants received instruction on a four-step problem-solving process (read, plan, solve, and check) to solve similar one-step and two-step addition and subtraction word problems. The classroom teachers carried out the intervention, and both groups received word-problem solving instruction for 25 minutes daily. Even though the number and types of word problems were the same between the two groups, the sequences of the problems were different. The word problems for the GSI group were organized based on the traditional textbook format, i.e., addition word problems first, subtraction word problems second, and followed by two-step word problems. However, the word problems for the SBaI group were sequenced based on the problem schemata, that is, change problems, group problems, compare problems, and then two-step word problems. Word problems in each schema may involve addition or subtraction.

The results showed that participants in the SBaI condition outperformed those in the GSI condition on a researcher-created immediate posttest and maintenance test administered six weeks after the end of instruction. The differences in ESs between SBaI and GSI were 0.52 for posttest and 0.69 for maintenance. Furthermore, participants in the SBaI condition outperformed those in the GSI condition on the state-wide standardized mathematics test. Jitendra et al. (2007) concluded that SBaI was a more effective intervention for improving students' word-problem-solving skills compared to GSI. However, the results for students with LD and those who were low-achieving were inconsistent. For these students, the SBaI group did not perform better the

GSI group on the posttest but performed better than the GSI group on the maintenance test. There was no significant performance difference on the state-wide mathematics test.

To explore whether the SBaI's effectiveness over the GSI could be realized in a mixed-ability general education classroom, Griffin and Jitendra (2009) replicated Jitendra et al.'s (2007) research in an elementary school in a college town in Southeastern United States. There were 60 third-grade students (five of them with LD) participating in the study. A major difference from Jitendra et al's study was that the classroom teachers delivered SBaI or GSI one day a week for 100 minutes during mathematics instruction time in the regular classroom.

The results of the study were mixed. Participants from both treatment conditions improved their problem-solving performance after the intervention. Furthermore, all participants maintained their learned skills 12 weeks after the intervention was over. However, unlike Jitendra et al.'s (2007) study, there were no differential effects found between the SBaI condition and the GSI condition. Griffin and Jitendra (2009) reasoned that the prolonged instruction sessions (100 minutes) were not common in the elementary setting so the memory resources and the attention span might impact the outcome of the study adversely. Due to the small sample size, the authors could not provide any insights on the effectiveness of SBaI for students across the achievement levels. They recommended future research to investigate differential effects of SBaI and determine what type of student population would most likely benefit from the intervention.

To provide more intensive intervention for students at risk for mathematics difficulties, Jitendra et al. (2013a) extended the SBaI research to a supplemental, small-group tutoring setting. Participants were 125 third-grade students identified as at risk for mathematics difficulties from nine elementary schools from a large urban school district. The authors randomly assigned participants to either the SBaI condition or a control condition. Eighteen tutors with some prior experience working with school-age children were recruited from the community and subsequently implemented the interventions. All tutors received a one-day introductory training. The control-condition tutors received another one-day training on standards-based instruction (i.e., a student-directed, inquiry-based approach that was used in the school-wide mathematics curriculum), and the SBaI-condition tutors received another two-day SBaI curriculum and material training. All tutors were also provided ongoing support from the researchers.

Participants received a 30-minute supplemental mathematics tutoring daily for 12 weeks. The SBaI lessons were similar to those in Jitendra et al. (2007) and Griffin and Jitendra (2009) except the researcher added a pre-unit session focused on teaching participants computational skills. The results showed that participants in the SBaI condition demonstrated significant improvements on word-problem-solving performance over those in the control group. However, the learned skills were not maintained eight weeks after the termination of the intervention. Participants in the SBaI group did better than those in the control group on a standardized mathematics assessment (effect size = 0.34 for the SBaI group when compared to the control group).

Also exploring the area of small-group tutoring, Jitendra et al. (2013b) compared the effects of small-group tutoring on mathematics word-problem-solving using the SBaI or a school-provided, standards-based curriculum (SBC). The participants included 136 third graders who were identified as at risk for mathematics difficulties by the researchers. Among them, 16 participants were identified with disabilities by the school district. Tutors from the community were trained to carry out the intervention. There were five units in SBaI with four units focusing on one-step addition and subtraction problems and one unit on two-step problems. Participants received either treatment or control instruction 30 minutes daily for 12 weeks. The results showed that students with higher pretest scores in the SBaI group outperformed their counterparts in the SBC group on word problem solving, and this superior effect was maintained six weeks after the intervention. However, students with low pretest scores in the SBC group did better compared to those in the SBaI group. The authors reasoned that low pretest scores indicated a lack of mastery of basic computational skills so that this group of students was unable to benefit from strategy instruction for problem-solving skills.

Griffin et al. (2018) chose a randomized-group design to investigate the effectiveness of the schema-based instruction. Among total 27 participants, 11 of them were in fourth grade, and 16 were in fifth grade. Seven students in the sample had SLD, and one student was diagnosed with autism. Three of the authors provided instructions on how to solve multiplicative word problems. Participants were randomly assigned to treatment and control groups. All participants took pretest before the intervention. The treatment group received 20 lessons of schema-based instruction with approximately 40 minutes each. The control group, on the other hand, received instruction or did independent work in non-mathematics content areas during the intervention period. All participants took posttest after the intervention was over.

The study showed that schema-based instruction was effective for improving students' word-problem-solving performance. However, there was no significant difference between the treatment group and the control group for students with disabilities. Furthermore, there were no significant improvements on the word-problem-solving performance for either group. Based on these less encouraging results for students with disabilities, Griffin et al. (2018) advised educators to fully assess students' mathematics and reading abilities before the intervention. Students with only mathematics disabilities might respond differently to interventions compared to those with both mathematics and reading disabilities. They also recommended to use word problems with lower difficulty levels (such as one-step problems, smaller numbers, etc.) for students with disabilities in order to have them benefit from the strategy instruction. In addition, it might be helpful to add 10-minutes of basic computation practice to build their automaticity in basic facts as well. Furthermore, Griffin et al. suggested using small-group, supplemental instruction to tailor the instruction to students' needs.

Cook et al. (2020) explored whether schema-based instruction could be deemed as evidence-based intervention for students with mathematics difficulties using CEC's (2014) standards. Ten studies, including eight with single-case design and two with group design, published in peer-reviewed journals between 1990 and 2017 were selected. All participants fell into one of the following categories: LD, mathematics difficulties, other disabilities. Among the sample of the studies, five single-case-design studies and one group-design study met methodological rigors measured by CEC's QIs. All six methodologically sound studies demonstrated a positive effect on word-problem-solving performance among students with disabilities. Even though schema-based instruction met the number of research criteria for evidence-based practice (i.e., one methodologically sound group-design study and three methodologically sound single-case-design studies), upon closer examination, the qualified studies did not meet the minimum number of participants (at least 30 participants for the group design and 10 participants for all the single case design studies) required by CEC's standards. Therefore, Cook et al. concluded that schema-based instruction was a potentially evidence-based practice.

Schema-broadening Instruction (SBrI)

Like SBaI, schema-broadening instruction (SBrI) also relies on the underlying semantic structure to solve a mathematics word problem. However, it also differs from SBaI in that SBrI does not typically apply schematic diagrams, but mathematics equations. More importantly, it emphasizes explicitly teaching students to transfer the knowledge of schemata so students can solve novel problems sharing the same schemata as the familiar problems.

To examine the effects of explicit transfer instruction in the SBrI, Fuchs et al. (2003) randomly assigned 375 third graders (roughly 26% of them were below grade level in mathematics) to four groups: the problem solution group, the partial-solution-plus-transfer group, the full-solution-plus-transfer group, and the control group. Approximately 6% of the participants received special education services. The first solution lesson and the first transfer lesson lasted 40 minutes each, and all subsequent lessons lasted 25-30 minutes each. The solution instruction included explicit instruction on the solution methods associated with narrow schemata. The transfer instruction included explicit instruction on the concept of transfer, four superficial features that might mask the underly schemata (i.e., different format, different key words, additional questions, and larger context), and the novel problems with superficial features.

The results showed that all participants in the three treatment groups outperformed those in the control group on the immediate- and near-transfer measures. Fuchs et al. (2003)

determined that the transfer component added value to the overall intervention because the full-solution-plus-transfer group did significantly better than the solution group in the near-transfer measure. On the far-transfer measures, participants in the two transfer instruction groups outperformed those in the control group while participants in the solution group did not do better than those in the control group. Once again, the results supported the addition of the transfer instruction. The results were not altered by students' academic achievement levels.

When examining the performance of students with disabilities, the results were bleak. A significant number of participants with disabilities did not respond effectively to the intervention. In particular, 60% to 80% of participants with disabilities in the partial-solution-plus-transfer group performed worse compared to those in the control group on immediate-, near- and far-transfer measures. Fuchs et al. (2003) advised that students with disabilities should "develop a strong foundation in solutions before instruction designed to promote transfer can contribute to learning" (p. 302).

To advance the SBrI research further, Fuchs et al. (2004) incorporated three additional superficial features in their transfer instruction, namely, irrelevant information, problem type combination, and mixing superficial features. These three new superficial features were deemed to be more challenging compared to those included in Fuchs et al. (2003) and made word problems appear even more unfamiliar. There were 351 third graders with low-, average-, and high-performing levels participating in the study. Around 8% of them were identified with disabilities. Participants were randomly assigned to three groups: SBrI (three superficial features), expanded SBrI (six superficial features), and control. The SBrI included one instructional unit on basic mathematics problem-solving strategies and four units on problem types, corresponding solutions, and explicit transfer instruction. The expanded SBrI was organized similarly to the SBrI except for the addition of extra sessions on the three new superficial features.

To study the transfer effect, Fuchs et al. (2004) designed four levels of transfer measures. Level 1 transfer measures included word problems similar to those used in solution instruction but with a different cover story. Level 2 transfer measures altered the problems in the solution instruction with a different format, different key words, or additional questions. Level 3 transfer measures changed the problems in the solution instruction by adding irrelevant information, combining two problem types, or altering two transfer features. Level 4 transfer measures were considered as far-transfer and included problems that closely assembled real-world problems.

The results showed that both SBrI groups outperformed the control group on level 1 and level 2 transfer measures. On level 3 and level 4 transfer measures, even though both treatment groups showed superior improvement to the control group, the expanded SBrI significantly outperformed the SBrI. The results from students with disabilities showed similar patterns to the overall groups but with a lesser magnitude of improvements. Fuchs et al. (2004) concluded that students benefited from explicit instruction on transfer with a wide range of superficial features. This broadened students' schemata and thus promoted transfer.

Even though the SBrI was deemed effective at improving students' ability to solve word problems that paralleled real-life situations (i.e., far transfer in Fuchs et al. [2003] and level 4 transfer in Fuchs et al. [2004]), Fuchs et al. (2006) believed that this ability could be further enhanced through explicitly teaching students strategies to solve real-life mathematics word problems.

Participants in this study included 445 students in third grade who were randomly assigned to two treatment groups (i.e., SBrI and SBrI with real-life problems) and one control group. Approximately 8% of the participants received special education services. All groups received six lessons on general mathematics problem-solving strategies. The two SBrI groups received additional 30 lessons related to four problem types. The SBrI-plus-real-life group received four more lessons on how to solve real-life problems. The real-life problems were presented through videos. The teacher explicitly taught participants six strategies to solve real-life problems, and they were (1) review the problem, (2) determine whether extra steps were necessary, (3) search important information without numbers, (4) seek helpful information outside the problem, (5) reread, and (6) ignore irrelevant information.

Fuchs et al. (2006) developed three transfer measures: immediate, near, and far. For immediate and near transfer, both SBrI and SBrI-plus-real-life groups outperformed the control group with large ESs ranging between 3.59 and 6.84. For the four far-transfer word problems, the results showed that the SBrI group significantly outperformed the control group on three questions with small ESs whereas the SBrI-plus-real-life group demonstrated significantly superior improvements on all four problems with sizable effects. Additionally, the SBrI-plus-real-life group did significantly better than the SBrI group on one problem with an open-ended question. The authors concluded that the SBrI with explicit instruction on real-life word problems exhibited promising potential on improving students' ability to solve word problems with real-life situations.

Paraphrasing Strategy Instruction

Mathematics word problems are commonly used at the elementary level to teach children problem solving skills. Comprehension is an essential step to finding the solution (van Garderen, 2004). “Good problem solvers understand the semantic elements of problems as well as the mathematical or numerical properties” (Montague, 2003, p. 169). Paraphrasing and visualizing are two ways to facilitate this kind of understanding. As a well-known reading comprehension strategy, to paraphrase is to reword a problem without altering its meaning. Visualization is to form a mental picture of the problem (Montague, 2003).

Students often learn strategies related to visualization to improve word-problem-solving performance (Boonen et al., 2016). Schema instruction provides students a strategy to visualize – mapping the mathematical relationships in the word problem to a schematic diagram. Xin and Jitendra (1999) emphasized that the visual representation must be based on students’ conceptual understanding of the relationships in the word problem to effectively facilitate problem solving. This implies that students need to first understand the information presented in the word problem through reading comprehension.

Research has linked text comprehension and mathematics problem-solving skills. Reading comprehension is a strong predictor for success in mathematics, especially in word-problem solution accuracy. It may play a more significant role than arithmetic skills (Grimm, 2008; Swanson et al., 2013b; Swanson et al., 2014). Literacy skills influence word-problem-solving performance from elementary levels to secondary levels. Furthermore, as students advance in mathematics learning, facing more complex verbal instructional and word problems, the role of basic reading skills diminishes while reading comprehension takes up a more prominent position in word-problem-solving performance (Kyttälä & Björn, 2014).

To investigate whether text-reading comprehension in elementary grades could predict mathematics word-problem-solving skills at secondary level, Björn et al. (2016) gathered data from a group of over 200 participants over the course of five years. In this study, 210 fourth graders were administered a battery of tests to measure their skill levels in text-reading fluency, basic calculation, and text comprehension. When this group of participants reached seventh- and nineth-grades, their mathematics word-problem-solving skills were examined. The results showed that text comprehension and basic computation skills in fourth grade contributed to mathematics word-problem-solving skills in seventh grade while text-reading fluency was not a predictor.

In addition to the established link between text comprehension and mathematics word-problem solving, mathematics difficulties are often comorbid with reading difficulties (Powell et al., 2020). Therefore, it is necessary to explore the efficacy of text comprehension strategies for enhancing word-problem-solving performance for students with LD.

To investigate whether paraphrasing propositions (i.e., sentences) in word problems improved solution accuracy among children with mathematics difficulties, Swanson et al. (2013b) selected 91 third graders at risk for mathematics difficulties using a common cutoff score of the 25th percentile on two standardized mathematics word-problem-solving measures. All participants were randomly assigned to four conditions: restate (i.e., rephrasing the question), relevant (rephrasing the question and relevant propositions), complete (i.e., rephrasing the question and relevant and irrelevant propositions), and control. The authors set up a separate control group including 22 third graders without mathematics difficulties.

Participants in the treatment groups received a 30-minute supplemental instruction session twice a week for 10 weeks. The intervention was implemented by tutors using the explicit instructional approach. Participants in the treatment groups were taught to paraphrase various propositions via oral rehearsal and writing. Swanson et al. (2013b) carefully structured the word problems in the interventions, gradually increasing in the number of irrelevant sentences from zero to four in the 20 lessons.

The results showed that participants in the relevant condition (i.e., paraphrasing the question and the relevant information only) and the complete condition (i.e., paraphrasing the question and the relevant and irrelevant information) significantly improved their solution accuracy compared to those in the control groups (both with and without mathematics difficulties). Swanson and colleagues (2013b) observed that, in the complete condition, only the participants with relatively high WMC outperformed the control groups. They concluded that the results support the effectiveness of paraphrasing on enhancing word-problem-solving performance for students with mathematics difficulties.

Swanson et al. (2014) extended their study to examine whether the effectiveness of paraphrasing was moderated by students' WMC. They randomly assigned 82 third-grade students at risk for mathematics difficulties to four groups: restate, relevant, complete and control. The instructional procedures were the same as those used in Swanson et al. (2013b).

The results showed that participants with relatively high WMC in the complete condition outperformed the control group on solution accuracy. Neither the restate nor the relevant conditions produced any superior performance over the control condition. The findings provided a possible explanation for why strategy interventions like this worked for some students but not others. The authors recommended that educators should explicitly teach paraphrasing strategy to students with relatively high WMC to improve word-problem-solving performance but should choose a different strategy for students with relatively low WMC.

As part of a federally funded research project including both Swanson et al. (2013b) and Swanson et al.'s (2014) studies, Moran et al. (2014) replicated the paraphrasing strategy intervention with a separate group of 72 third graders at risk for mathematics disabilities. They randomly assigned the participants to four conditions: restate, relevant, complete, and control. Swanson et al.'s (2013b) and Swanson et al.'s (2014) instructional procedures were adopted.

The results showed that participants from the relevant and complete groups demonstrated superior performance on word-problem solving compared to those in the restate and control groups. Moran et al.'s (2014) findings supported the effectiveness of paraphrasing strategy.

Summary

Mathematics reform, driven by federal legislation and academic standards proposed by the NCTM (2000) and CCSS, has placed higher expectations on mathematics learning for students with mathematics difficulties. Researchers have explored various ways to help this group of students succeed in mathematics. A wide variety of strategy instructions have demonstrated significantly positive effects toward enhancing word-problem-solving performance. It is important for educators to be aware of and apply these strategy instructions to strengthen their teaching practice so that they can help each student in need to reach their potential.

Chapter 3 Conclusions and Recommendations

This paper aims to explore the evidence-based strategies for improving word-problem-solving performance for students with mathematics difficulties. CCSSM and state-wide high-stakes academic assessments have placed tremendous pressures on both students and educators to enhance academic performance. Proficiency in mathematics requires students to not only master the arithmetic skills but to enhance their problem-solving skills as well. Problem-solving skills often are taught via mathematics word problems at the elementary level. Solving word problems is a challenging academic task for many students including average-achieving students and those with or at risk for disabilities. Not only do students need to work hard to improve their performance, but educators should work even harder to help the children to succeed.

Scholars in educational psychology and special education have experimented with many methods to help students with learning difficulties master mathematics skills. From case studies and small experiments with usually less than 10 participants, some projects made it to the large-scale trials of hundreds of participants through funding from various levels of governments, corporations, and organizations. Unfortunately, these studies with time, money, and effort well-spent, often were published in peer-reviewed journals or cited in nation-wide reports without reaching to a vast majority of the educators who desperately need help with professional development and would definitely benefit from these research studies.

The rest of this chapter is organized as follows: What has been learned from the literature review is shared in the *Conclusions* section. Any limitations are addressed in the *Recommendations for future research* section. Any information helping educators improve their teaching is discussed in the *Implication for practice* section.

Conclusions

Ample research, published in peer-reviewed journals over the past three decades, is cited and/or reviewed in this paper. From the sample sizes of the referred studies, one can sense that mathematics word-problem-solving skills have become more prominent in the field of special education. A few articles were part of various federally- or commercially-funded projects/trials. Scaling up means that the content of the research may be implemented in every-day teaching and learning.

As research in the field of special education expanded, quality control became paramount. Gersten et al.'s (2005) QIs for group designs, Horner et al.'s (2005) QIs for single-case design, and CEC's (2014) standards for evidence-based practice safeguarded the quality of scholarly work. These standards and criteria were rigorous. Some of the studies published in the 1980s, 1990s, and early 2000s were not deemed methodologically sounds based on the evidence-based standards. These included works done by even some well-known scholars such as Harris, Montague, and Fuchs. However, this did not mean that those studies were unworthy. The evidence-based criteria required researchers to share specific, detailed information regarding their studies with the public so that people may replicate their research and expand knowledge in the field. For example, Montague and Dietz (2009) determined two frequently cited papers, Montague and Bos (1986) and Case et al. (1992), to be unacceptable based on the QIs proposed by Horner et al. (2005). The reason was that both papers did not provide information related to interobserver agreements. Researchers have embraced the standards since its release and used them as guidelines to direct their ongoing and future projects.

Explicit instruction appears in Chapter 2 repeatedly, not just in the *Explicit Instruction* section. It has been well-supported by researchers over time. Many, if not all of the components, have been adopted by educators at large. Montague, Swanson, Fuchs and Fuchs, Jitendra, and many more have recommended using the explicit instructional approach to teach problem-solving strategies. Students with learning difficulties often have limited repertoire of strategies and procedures to help them accomplish academic tasks. Even when they do, they often do not know how to apply them. Explicit modeling gives these students an opportunity to “hear” the thinking process of a proficient problem solver while observing how s/he uses a strategy or a set of procedures step by step.

Another important component of explicit instruction is immediate corrective feedback. This is not the same as grading an assignment. Teachers, paraprofessionals, or tutors need to comment directly to students regarding their understanding or performance, prompt them to correct their misunderstanding or error, and provide reteaching, if necessary, all in a timely manner. Without proper feedback, students with mathematics difficulties may not learn the concept or skill effectively.

Positive reinforcement is crucial to student success as well. Students with mathematics difficulties are often reluctant learners. Concepts and skills are often hard to grasp, and failures are not rare occurrences to them, even if they work hard. Therefore, some of them develop avoidant behaviors. Positive reinforcement is a useful tool for educators to celebrate students’ successes, however small, and encourage them to actively participating in learning.

Even though explicit instruction has been adopted in the practice for decades, there is always room for improvements. Recent studies led by Doabler and colleague (2015, 2019a, 2019b) aimed at identifying which component(s) made explicit instruction effective and whether a student's status might affect teachers' behavior related to certain components. For example, increasing the frequency of individual student response opportunities improves mathematics learning. Low-achieving students made more errors, and thus teachers provide more feedback to them.

All interventions for improving mathematics word-problem-solving skills in chapter two included some forms of cognitive processes and metacognitive strategies. A seven-step cognitive process and three metacognitive strategies designed by Montague (1992) give students step-by-step directions to solve mathematics word problems and provided tools to self-regulate their behaviors. The self-regulated strategy development (SRSD) procedures developed by Harris and Graham (1992) are a teaching framework that helps students with learning difficulties to improve their knowledge and application of a particular skill and, at the same time, promote self-efficacy.

Schema instruction uses problem types to assist students in identifying mathematical relationships in text form and map them to schematic diagrams or mathematics equations. Jitendra and Fuchs took the strategy down two different paths. Jitendra developed the strategy because of her daughter's special needs. She and her colleagues focused on translating the underlying schema to a schematic diagram, but improved the strategy by adding metacognitive strategies to help students self-regulate, fading the premade diagram template gradually, and forming an equation through the schematic diagram. Fuchs and colleagues focused on facilitating transfer by explicitly teaching superficial features that do not change the underlying schemata and training students to form the connections between the familiar problems and novel problems. Both groups of scholars demonstrated their success through students' improved performance.

To use any of these strategies effectively, students must understand the semantic meaning in the word problem. Therefore, text comprehension is the first step in the word-problem-solving endeavor. It is not unusual for students with mathematics difficulties to also struggle with reading. Therefore, a strategy that facilitates reading comprehension may be helpful in the word-problem-solving process. Paraphrasing strategy uses a well-known reading comprehension tool to aid mathematics word problem solving. Students reword the problem in a way that makes sense to them and thus helps them conceptualize the mathematical relationships in the problem. Once students understand the goal of solving a problem, they can incorporate other cognitive and/or metacognitive strategies to help them solve the problem.

Even though cognitive strategy instruction has been shown to be effective for improving word-problem-solving performance among students with mathematics difficulties, due to their cognitive deficits and non-cognitive factors such as motivation and anxiety, Swanson and colleagues (2013b, 2014) warned that cognitive strategy instructions may not necessarily be effective for every student with mathematics difficulties. For example, a paraphrasing strategy may help students with relatively high WMC to improve their problem-solving skills, but it may hinder progress for those with relatively low WMC. Also, Powell et al. (2020) reminded researchers and educators that mathematics and reading difficulties are often is comorbid at rates between 30% and 70%. Consequently, understanding students' mathematics and reading profiles is critical for choosing and applying the right interventions to help them improve their problem-solving skills.

Recommendations for Future Research

A wealth of knowledge has been shared with the special education community, and many strategies, procedures, instructions, etc. have been tested over and over and shown to be effective. However, there is still lots of work to be done because the performance gap between students with and without disabilities has not narrowed over time.

First, all the interventions discussed in this paper demonstrated moderate to strong effectiveness for improving word-problem-solving performance among students with mathematics difficulties. However, publication bias should not be ignored. Most of peer-reviewed journals publish research with positive results. Even few doctoral dissertations included in meta-analyses reported effective interventions. Students are encouraged daily not to be afraid of making mistakes but to learn from them. Nevertheless, studies with no effects or showing negative effects are not usually shared with the research and education community. Lessons can be learned from failed experiments, and modifications and improvements can be made so that the experiment may be reattempted successfully. It is not human nature to willingly reveal defeat, but we all know that progress can be made from mistakes. So, the research community and well-known journals should embrace high-quality studies with unsatisfactory results.

Second, future studies should increase the rigor of instruction content and outcome measures. For participants in third through fifth grades, mathematics word problems used in the intervention programs were often one-step addition and subtraction problems. There were few studies that used two-step problems or multiplication and division problems. However, CCSSM (2010) requires third-graders to "solve two-step word problems using the four operations. Represent these problems using equations with a letter standing for the unknown quantity" (p.

23). Even though the target student populations in the studies were students with mathematics difficulties, the standards do not treat them differently.

The federal- and state-level legislation hold students with disabilities accountable for the same rigor of standards in mathematics. Whether it is fair or not, to close the performance gap between students with and without disabilities, the same rigor of standards must be applied. Algebra has been deemed a very challenging concept to teach at the elementary level, even for average-achievers. However, using appropriate instruction students with mathematics difficulties can learn the concept successfully (Xin, 2008). Future research should design mathematics word problems following CCSSM's rigor. It may reduce the magnitude of the effect or completely render an intervention ineffective, but it will provide an opportunity for further strides in improvement for the sake of our students.

Additionally, outcome measures for effectiveness used in the studies were usually designed by the researchers and were not typically aligned with the CCSSM standards as well. While researchers almost certainly did not manipulate their results, the participants were likely to do better in those measures because these measures closely resembled the practice materials used in the intervention. In addition to the researcher-designed measures, future studies should also use standardized assessments or even state-wide mathematics assessments to evaluate the outcomes of the interventions.

Third, current studies lack significant investigation into maintenance and generalization effects of the interventions, which is alarming since students with mathematics difficulties typically struggle with retaining and generalizing learning skills. Studies often include maintenance measures, but these measures might be administered a few days or weeks after the termination of the interventions. None provided information on whether students maintained the learned skills in the long run. Generalization was rarely investigated. Even for studies that focused on transfer (e.g., Fuchs and colleagues, 2003, 2004, 2006), the measures were still developed by the researchers and did not resemble “real-world situations” as demanded by CCSSM. Future studies should put more weight on examining the maintenance and generalization effects of the interventions so students with mathematics difficulties can truly benefit from the interventions in the long run.

Fourth, other than the work by Fuchs and colleagues (2003, 2004, 2006), most studies did not explicitly teach transfer or have a component addressing the issue. Transfer or generalization is a well-known weakness for students with mathematics difficulties. They learn a strategy to complete a task under one condition, and when circumstances change, they do not see the connections between the familiar task and the novel one and thus do not know what to do. Students with learning difficulties need to be explicitly taught and trained to identify the connections between the familiar and the novel so that they can use a repertoire of strategies to complete tasks across a variety of situations in a content area and across different content areas.

Fifth, future research should focus more specifically on students with mathematics difficulties and conduct in-depth investigations of how this group of students responds to an intervention for improving mathematics word-problem-solving skills. The term, *students with mathematics difficulties*, is rather broadly defined including students with LD in mathematics, with other disabilities but struggling with mathematics, and with or at risk for mathematics underachievement. To complicate the matter further, some students with mathematics difficulties also experience reading difficulties (i.e., comorbidity of mathematics difficulties with reading difficulties) and consequently respond to an intervention differently from those without reading difficulties. Moreover, students' cognitive deficits (such as low WMC) and noncognitive factors (e.g., lack of motivation) may alter the outcomes of an intervention. Therefore, simply declaring an intervention as effective for students with mathematics difficulties based on the aggregate results does not necessarily mean that it works equally well for those in the various subcategories of mathematics difficulties. In order to close the performance gap in mathematics between students with and without disabilities and to prevent the gap from enlarging as students progress from elementary level to secondary level, more in-depth explorations on mathematics interventions and their components is imperative so an effective intervention can be assembled for a very specific student population (e.g., students with LD in mathematics only, those with LD in both mathematics and reading, those performing persistently below grade level in mathematics, etc.).

Furthermore, studies should provide detailed information about the instruction content, procedures, and research methodology. The end goal for research is to have other researchers be able to replicate the intervention programs and/or to have educators apply the interventions in their teaching routines. So, information such as setting, length of treatment sessions, overall treatment duration, and implementer's qualifications and training should be discussed in detail. Samples of lesson plans and student assignments should be available in the appendices, and the instructional package should be available in its entirety per request. Specific information related to research design such as treatment integrity, routine in the control condition, etc. should be provided as well.

Implications for Practice

A lot can be learned from research studies about teaching mathematics word-problem-solving skills. For example, teachers should know students' strengths and weakness in both mathematics and reading before they choose an intervention or create lesson plans. Explicit instruction should be used to teach concepts and skills related to mathematics word-problem solving. Word problems need to be organized systematically following a specific sequence such as by problem types, from one-step to two-step, etc. Teacher should be mindful about student learning – providing corrective feedback immediately and utilizing the teachable moments to enhance student learning.

Educators are required to use evidence-based practice to teach students with and without disabilities. To do so, they need to keep themselves familiar with ongoing research. This may not be easily accomplished at the individual level because of time constraints and teachers' ability to comprehend the scholarly research and implement an academic research study with fidelity. Therefore, professional learning communities, school districts, and even educator unions should step up and provide training workshops throughout the school year and during summer breaks to help educators improve their teaching practice.

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