Learning Disabilities: A Contemporary Journal 20(1), 2022

A Synthesis of Computer-Assisted Mathematical Word Problem-Solving Instruction for Students with Learning Disabilities or Difficulties

Soo Jung Kim*
Yan Ping Xin
Purdue University

We conducted a comprehensive synthesis of computer-assisted instruction (CAI) research that aimed to facilitate the learning of mathematical word problem solving involving elementary and secondary school students with learning disabilities or difficulties in mathematics. We examined a total of 13 studies under the four instructional categories: direct instruction/guided practice, cognitive/metacognitive strategy instruction, schema-based instruction, and mathematical model-based problem solving. Findings from this review indicate that CAI showed overall positive effects on enhancing students' word problem-solving performance, with mathematical model-based problem solving being most effective and the direct instruction/guided practice least effective. It seems that CAI programs that promote mathematical model-based problem solving have demonstrated promising effects, not only on students' skill acquisition but also skill generalization as measured by commercially published standardized tests.

Keywords: **Learning Disabilities, Mathematics Difficulties, Computer-Assisted Instruction, CAI, Technology, Mathematical Problem Solving, Word Problem Solving.**

Introduction

The Every Student Succeeds Act (ESSA, 2015) and the Individuals with Disabilities Education Act (IDEA, 2004) emphasize supporting *all* students, including students with disabilities, to improve their educational outcomes. However, according to the latest National Assessment of Educational Progress (NAEP, 2019) in mathematics, while 14% of fourth-graders without disabilities in the U.S. scored below the basic level, 50% of fourth-graders with disabilities scored below the basic level. When we look at the NAEP data for the secondary grades, the gap between students with disabilities and their same-age peers is even wider. While 25% of eighth-graders without disabilities scored below the basic level, 68% of eighth-graders with disabilities scored below the basic level. Clearly, there is a need to address underachievement in mathematics among students with disabilities. Proficiency in mathematics problem solving is vital for performing advanced mathematics as well as successful lives after high school graduation (Batty et al., 2010). The National Council of Teachers of Mathematics (NCTM, 2000) has prioritized the nurturing of problem-solving ability in the curriculum across all grade levels. The Common Core State Standards for Mathematics (CCSSM, 2020) has also demonstrated the importance of achieving word problem solving (WPS) skills by presenting multiple standards targeting

*Please send correspondence to: Soo Jung Kim, MSed, Purdue University, Department of Educational Studies, 100 North University Street, West Lafayette, IN 47907-2098. USA, Email: kim2358@purdue.edu.

WPS across various mathematics domains. Unfortunately, many students manifest severe difficulties in WPS (Montague et al., 2014). Mathematical word problems refer to linguistically presented problems requiring the construction of a problem model before a solution occurs (Fuchs et al., 2006). Solving a mathematical word problem requires various skills including reading and comprehending word problems, understanding mathematics conceptually, generating mathematical equations, and performing computations to solve the problem (Cook et al., 2020; Shin & Bryant, 2017). Particularly, students with learning disabilities or difficulties in mathematics (LDM), who are defined as individuals identified as learning disabilities and at-risk for learning disabilities in mathematics (Powell et al., 2013), exhibit considerable difficulties in those WPS skills (Fuchs et al., 2021). The difficulties students with LDM experience may be associated with their cognitive deficits in working memory, processing speed of numerical information, conceptualizing mathematical operations, information retrieval from long-term memory, attention regulation, and language (Fuchs et al., 2010). In order to address the difficulties that students are experiencing in WPS, identifying effective interventions for students with LDM is necessary.

Computer-assisted instruction (CAI), which is defined as the use of a computer to provide educational instruction (Seo & Bryant, 2009), has been considered as one of the effective approaches that fill the needs of the students with LDM by providing individualized and additional supports for WPS. CAI uses not only traditional computers (e.g., laptops) but also mobile devices (e.g., tablets) to provide instructional content to promote learners' skills, knowledge, or academic achievement (Ok et al., 2019). According to the NCTM (2000), the use of technology to support and promote mathematics learning is essential. NCTM (2015) noted previous studies have shown that the use of instructional technology can support the learning of mathematics procedures as well as advanced mathematical proficiencies, including problem solving and reasoning (e.g., Gadanidis & Geiger, 2010; Roschelle et al., 2010). CAI has been successfully used to promote mathematics learning and skills for students with LDM; it provides opportunities for additional practice and immediate feedback, and it helps students develop a positive attitude toward mathematics learning (Ok et al., 2019). CAI also helps teachers to provide individualized instruction (Ok et al., 2019). Given the difficulties experienced by many students in WPS and, on the other hand, the possibility of using CAI to address these challenges, it is timely to take a closer look at intervention studies that have used CAI to facilitate WPS of students with LDM.

Previous Reviews and Rationale of Present Study

A growing body of literature demonstrates some evidence of mathematics CAI on WPS for learners with LDM. Researchers have conducted several syntheses of mathematics interventions for students with LDM related to the topic of WPS as well as CAI. However, existing reviews either address mathematics interventions on WPS for students with LDM without isolating the effect of CAI or address CAI across all mathematics topics. As a result, there is a lack of systematic reviews that target the effect of CAIs on WPS.

Prior syntheses analyzed CAIs together with other technologies, such as the use of media, videodisc, or technical accommodations which the mathematics instruction was not delivered via computer or mobile devices. For instance, Xin and Jitendra (1999) conducted a meta-analysis of 25 WPS intervention studies published between 1986 and 1996 involving elementary and secondary students with LDM. They classified CAI including videodisc programs as one of the intervention approaches, along with representation techniques and strategy training. Their findings indicated that the CAI (including two CAIs and two videodisc programs) was the most effective intervention for group design studies with the largest effect size (ES) for skill acquisition (Cohen's d = 1.80) and skill maintenance (Cohen's d = 1.53). Zhang and Xin (2012) conducted a follow-up meta-analysis including studies published between 1996 and 2009. This study addressed the relative effects of three categories of WPS instructions: problem structure representation techniques, cognitive strategy training, and assistive technology (e.g., CAI, videodisc programs, or technical accommodations). Among 39 studies on WPS, 11 studies used technology; and only one study employed CAI. Although the finding indicates that all three intervention strategies yielded large ESs, technology was the least effective strategy (Cohen's d = 1.22). Zheng et al. (2013) analyzed 15 WPS intervention studies, published between 1986 and 2009, for students with LDM. Ten studies were classified in the technology category (i.e., CAI, pictorial representations, and media), yet only one employed CAI (Hedges' g = -0.15). Lein et al. (2020) conducted a meta-analysis of 31 group design studies that used WPS interventions for K-12 students with LDM, published up to 2019. This synthesis included two CAI studies and classified it along with other three studies that used diagramming and inquiry-oriented practices. The category of the CAI, diagramming, and inquiry-oriented practices together yielded a small ES (Hedges' g = 0.11). Kong et al. (2021) synthesized WPS interventions for K-6 students with LDM from 18 group design studies published between 1990 to 2019. Although two out of 18 studies coded as technology, only one study used CAI and the other used PowerPoint. Technology categories yielded a moderate effect (Cohen's d = 0.54).

The prior syntheses on mathematics CAI/technology-based instruction for students with LDM also provide some more information on the effect of CAI to promote WPS skills. Seo and Bryant (2009) conducted a meta-analysis, published between 1980 and 2008, examining the effects of 11 CAI studies on mathematics for elementary and secondary students with learning disabilities. Only one study targeted WPS and yielded a small effect (Cohen's d = 0.30). Kiru et al. (2018) conducted a synthesis of technology-mediated mathematics interventions published between 2000 and 2016 for K-12 students with LDM. Among 19 studies, four studies incorporated CAIs to promote WPS. Two SCD and two group design studies showed small to large effects (percentage of non-overlapping data; PND = 56 to 100%; Hedges' g = 0.36 to 0.88). Ok et al. (2019) conducted a synthesis of mathematics CAIs, published between 1980 and 2017, involving students with learning disabilities. Among 20 studies included in this review, only three studies targeted WPS and showed a small effect for the group design study (Cohen's d = 0.42) and large effects for the two SCD studies (nonoverlap of all pairs; NAP = 0.88 & 1).

To summarize, first, there has been no synthesis specifically targeting CAI on WPS for students with LDM. Second, previous meta-analyses of WPS interventions classified CAIs along with other instructions (i.e., video-based intervention, pictorial representations, technical accommodations, media, diagramming and inquiry-oriented practices, or PowerPoint), which prevented drawing a conclusion specifically about the effects of CAI on WPS. Third, existing meta-analyses on mathematics CAI/technology-based instruction did not evaluate and report an overall effect of CAI for WPS. Fourth, various restrictions for literature search in terms of study design, grade level, or disabilities status in some recent syntheses (Kong et al., 2021; Lein et al., 2020; Ok et al., 2019) have resulted in the limited database, which prevented comprehensive understanding on this topic. Fifth, the effects of CAIs on WPS from previous syntheses ranged from negative effect to large positive effect and therefore inconclusive. To better understand CAI on WPS involving students with LDM, the present synthesis will focus on the research that incorporated CAIs to enhance the WPS performance of students with LDM. Below we present our two research questions:

1. What instructional strategies are incorporated in CAIs for supporting students with LDM in WPS?
2. What are the overall effects of CAIs to teach students with LDM mathematical WPS?

Method

Literature Search Procedures

We first conducted an electronic search in five online databases, including Academic Search Complete, Education Full Text, Education Source, ERIC, and PsychInfo ending in April 2021. We used a combination of the following search terms: *learning difficult*, learning disab*, learning problems, at-risk, low performing, underachieving, struggling, underperforming, dyscalculia, tech*, computer, tablet, app*, iPad, iPod, smart*, instructional software, educational software, math*, word problem, story problem,* and *problem solving.* Next, we conducted an ancestral search of the reference lists of existing reviews and meta-analyses pertinent to the topic of WPS intervention and technology for students with LDM (articles mentioned in the Previous Reviews section). In addition, we conducted an ancestral search of the reference lists of the included studies for this review.

The specific inclusion criteria encompassed the following: studies (a) included students with LDM in an elementary or secondary school, (b) examined the effect of mathematics CAI on WPS, (c) utilized experimental and quasi-experimental group design or SCD, and (d) were published in English. We excluded the studies that used video-based interventions (e.g., videodisc programs) as the intervention was not delivered via computers or mobile devices.

As presented in Figure 1, the online database literature search yielded 1404 articles using the combination of the keywords. Through reading titles, keywords, and abstracts, we conducted an initial screening, which resulted in 37 articles for further full-text reading. From the ancestral search of the reference lists of the prior syntheses and the studies we identified from initial screening, we found 18 more articles for full-text reading. We read the full texts of 55 articles to determine whether they met the inclusion criteria. Thirteen out of 55 articles met the selection criteria and were therefore included in this review.

Interrater agreement was established for the variables of the included studies. The first author coded all 13 studies, and the second author independently coded five studies (38%) of all the studies. Interrater agreement was calculated as the number of agreements divided by the number of agreements and disagreements between the two raters multiplied by 100. The initial interrater agreement was 95%. Any disagreements between the two raters were discussed and resolved during face-to-face meetings. The two raters shared rationales for the coding and revisited the coding protocol until a consensus was reached on all variables.

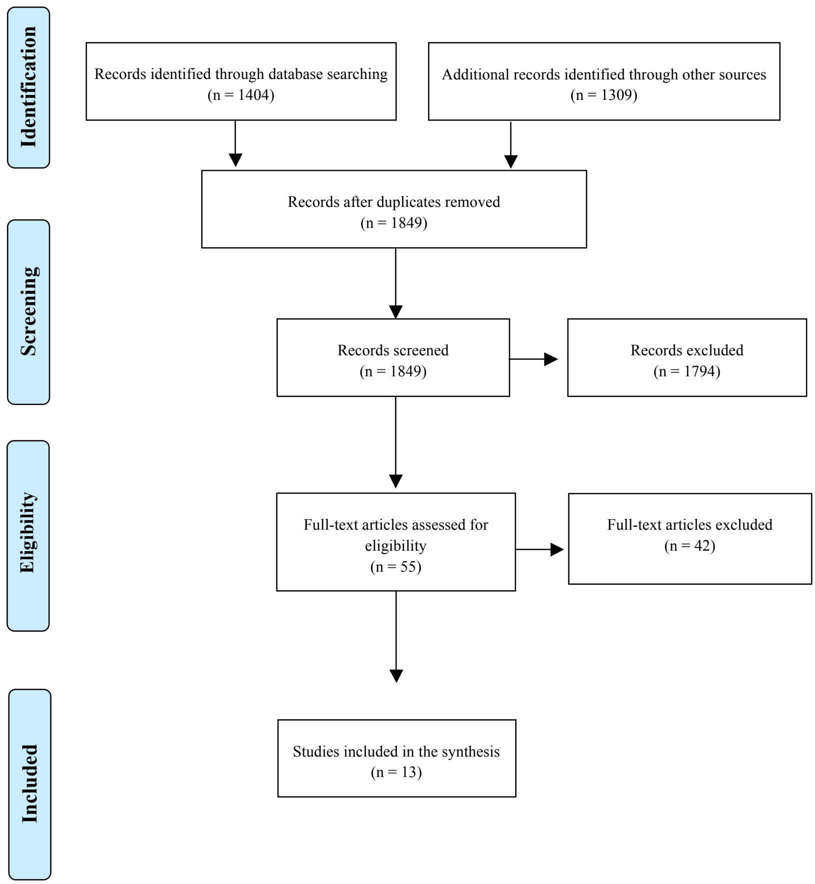

Figure 1. **Literature search procedures**

Treatment Effect Computation

For the group comparison studies, we used Hedges' *g* as the ES measure as recommended by What Works Clearinghouse (2017). We used comprehensive meta-analysis software (Borenstein et al., 2013) for all the ES calculations. When a study reported more than one outcome, we computed an aggregated ES for each study to avoid assigning more weight to studies with multiple outcomes. We used the following interpretations for Hedges' *g*: (a) large effect ($g \geq 0.80$), (b) moderate effect ($g \geq 0.50$), and (c) small effect ($g \geq 0.20$) (Cohen, 1988). For the SCD studies, we used Tau-U to estimate the treatment effect (Parker et al., 2011). We first extracted data from figures in each article using software named Plot Digitizer (Silk Scientific Inc.).Then, we calculated Tau-U using a web-based Tau-U calculator (Vannest et al., 2016). We calculated the individual phase-contrast for the participants and then aggregated the results into an omnibus Tau-U for each study (Vannest et al., 2016). We used the following interpretations for the Tau-U: (a) large effect (Tau-U = 0.93 to 1.00), (b) moderate effect (Tau-U = 0.63 to 0.92), and (c) small effect (Tau-U = 0 to 0.62) (Parker et al., 2011).

Results

Table 1 presents a summary of the 13 studies across the following variables: study design, participants, intervention duration, interventions, tasks and measures, as well as findings.

Overall Study Characteristics

The 13 studies consist of ten group design and three SCD studies. Among the group design studies, eight studies used randomized controlled trials, and two group studies used quasi-group experimental designs. All three SCD studies incorporated multiple-probe-across-subjects designs. Fives studies included participants who were identified as having specific learning disabilities, whereas the remaining eight studies included students with LDM. Eleven studies (85%) targeted elementary school students as their participants. Only two studies (15%) involved middle school students. CAIs in the 13 studies were implemented an average of 24 sessions (range: 2-100 sessions), with each session lasting for an average of 38 minutes (range: 20-90 min). Only one study (Hassler-Hallstedt et al., 2018) used a tablet PC as the device to deliver their intervention; all other studies used computers. Eleven studies (85%) implemented researcher-developed CAIs, while two studies (Fede et al., 2013; Leh & Jitendra, 2013) used commercialized CAIs. The CAIs across the 13 studies targeted WPS skills of addition, subtraction, multiplication, division involving whole numbers and fractions. Eight studies (62%) administered researcher-developed tests only, whereas five studies (38%) administered both researcher-developed and standardized tests.

Question 1: Instructional Strategies Incorporated in CAIs

Based on the nature of the interventions described in each of the CAI studies, we report our findings under the following four categories: (a) direct instruction/guided practice, (b) cognitive/metacognitive strategy instruction, (c) schema-based instruction, and (d) mathematical model-based problem solving.

Table 1. ***Summary of the Included Studies***

Study	Design	Participants	Duration	Intervention	Tasks/ Measures	Findings
Direct Instruction/Guided Practice						
Fuchs et al. (2002)	RCT	Grade: 4 38 LDs (8 CAI; 10 Tutoring+CAI; 10 Tutoring; 10 Ctrl)	24 sessions, 25-30 min	*Computer-Assisted Practice*	A, S, M, D Dcriterion, transfer, real-world WPS	• CAIs outperformed Ctrl on all measures (g = 0.77); Tutoring + CAI showed stronger growth on criterion and transfertests (g = 1.68); Aggregated g (CAI, Tutoring + CAI) = 1.20.
Gleason et al. (1990)	RCT	Grade: 6, 7, 8 19 riskLDs (9 CAI; 10 TDI)	18 sessions, 30 min	*Computer-Assisted Story Problems*	M, D WPS + MAT	• CAI and TDI improved on the researcher-developed test but not on MAT; There was no significant difference between the two groups on the researcher-developed test (g = 0.00) and MAT (g = 0.22).
Hassler-Hallstedt et al. (2018)	RCT	Grade: 2 281 riskLDs (75 CAI, 76 CAI+WM; 25 Ctrl; 78 Reading)	100 sessions, 20 min	*Chasing Planets*	A, S arithmetic, WPS (Tablet-based)	• CAI outperformed Ctrl on A & S arithmetic, but not on WPS: g (CAI) = 0.11; g (CAI+WM) = 0.06; aggregated g (CAI, CAI+WM) = 0.08.
Cognitive/Metacognitive strategy instruction						
Chadli et al. (2018)	RCT	Grade: 2 52 riskLDs (26 CAI; 26 BAU)	10 session, 90 min	*Computer-Assisted System*	A, S WPS	• CAI outperformed BAU on the researcher-developed measure (g = 1.38).

Table 1. ***Summary of the Included Studies (continued)***

Huang et al. (2012)	QED	Grade: 2, 3 28 riskLDs (17 CAI; 11 Ctrl)	12 session, 65 min	*Math Problem-Solving System*	A, S WPS	• CAI outperformed Ctrl on the researcher-developed measure (g = 1.16).
Seo & Bryant (2012)	SCD	Grade: 2, 3 4 riskLDs	25-35 sessions, 20-30 min	*Math Explorer*	A, S WPS	• All participants improved on the researcher-developed computer-based (Tau-U = 1) and paper/pencil measures (Tau-U = 0.98).
Shiah et al. (1994)	RCT	Grade: 1-6 30 LDs (10 CAI-A; 10 CAI-P; 10 CAI-C)	2 sessions, 30 min	*Computer-Assisted Instructional Tutorial Program*	A, S WPS	• All CAIs outperformed Ctrl on the measures: g (CAI-A) = 0.54, g (CAI-P) = 0.75, and g (CAI-C) = 0.66; aggregated g = 0.65.
Shin & Bryant (2016)	SCD	Grade: 6, 7, 8 3 LDs	9-10 sessions 20 min	*Fun Fraction*	F WPS	• Although mixed, all participants showed improvements on the measure (Tau-U = 0.75).
Schema-based Instruction						
Fede et al. (2013)	RCT	Grade: 5 32 riskLDs (16 CAI; 16 BAU)	24 sessions, 45 min	*GO Solve Word Problems* (Commercial)	A, S, M, D WPS+MCAS, GMADE	• CAI outperformed BAU on researcher-developed measure (g = 1.09) and MCAS (g = 0.89), not on GMADE (g = 0.55).
Leh & Jitendra (2013)	RCT	Grade: 3 25 riskLDs (13 CAI; 12 TDI)	15 sessions, 50 min	*GO Solve Word Problems* (Commercial)	A, S WPS + PSSA	• Both CAI and TDI showed significant improvement on the researcher-developed measure (g = 0.90), but not PSSA (g = 0.34).

Table 1. ***Summary of the Included Studies (continued)***

Mathematical Model-based Problem Solving						
Stellingw & Van Lieshout (1999)	QED	Grade: 1 122 riskLDs (25 CAI-N; 25 CAI-M; 25 CAI-COM; 25 CAI-ATC; 22 Ctrl)	12 sessions, 30 min	Computer-Aided Instruction Program	A, S WPS	• CAI involving number sentences (model-based) outperformed Ctrl: *g* (CAI-N) = 0.85 and *g* (CAI-COM) = 0.59; aggregated *g* (CAI-N, CAI-COM) = 0.69; Aggregated *g* (CAI-N, CAI-M; CAI-COM; CAI-ATC) = 0.37.
Xin et al. (2012)	SCD	Grade: 4, 5 5 LDs; 3 riskLDs	20 sessions, 30-35 min	*Conceptual Model-based Problem Solving* (COMPS)	M, D WPS + ISTEP+	• All participants showed improvements on both researcher-developed measure (Tau-U = 0.99) and ISTEP+.
Xin et al. (2017)	RCT	Grade: 3, 4 4 LDs; 13 riskLDs (9 CAI; 8 BAU)	36 session, 25 min	*Please Go Bring Me-COMPS*	M, D WPS + SAT	• CAI outperformed BAU on researcher-developed test (*g* = 2.35) and SAT (*g* = 1.30).

Note: RCT = randomized controlled trial; LD = learning disability; riskLD = at-risk for LD; Ctrl = control condition; A = addition; S = subtraction; M = multiplication; D = division; TDI = teacher-delivered instruction with similar strategy used in CAI; MAT = Metropolitan Achievement Test; WM = working memory training; BAU = business-as-usual condition; MCAS = Massachusetts Comprehensive Assessment System; GMADE = Group Mathematics Assessment and Diagnostic Evaluation; QED = quasi experimental design; PSSA = Pennsylvania System of School Assessment; CAI-A = CAI with animation; CAI-P = CAI with pictures; CAI-C = CAI without cognitive strategy; CAI-N = CAI with number sentences; CAI-M = CAI with manipulatives; CAI-COM = CAI with number sentences and manipulative; CAI-ATC = CAI attention control treatment without manipulatives and number sentences; F = fraction; ISTEP+ = Indiana Statewide Testing for education Progress-Plus Mathematics Test; SAT = Stanford Achievement Test

Direct instruction/guided practice

With direct instruction/guided practice, the learners were required to follow the demonstrated steps or procedures, exercise drill and practice to which the tutor might provide instructional feedback and reinforcement. Three studies (23%) employed direct instruction/guided practice in their CAIs. Fuchs et al. (2002) designed their CAI by providing *Computer-Assisted guided practice* to promote additive and multiplicative WPS of fourth-graders with LDM. The CAI provides intensive instructional feedback and reinforcement according to students' responses to solving real-world problems. This study compared the effects across four conditions: CAI, (human) tutoring+CAI, tutoring, and control. Students were credited for all aspects of the problem-solving processes, including using labels and finding relevant information to solve the problem. Following the principle of direct instruction, Gleason et al. (1990) developed *Computer Assisted Story Problems* for teaching multiplicative WPS. The CAI demonstrated each step of the strategy (e.g., respond to corrections), guided learners to perform the steps, gradually faded prompts, and provided immediate corrections to the errors. Applying direct instruction, Hassler-Hallstedt et al. (2018) created a tablet application named *Chasing Planets*. The CAI primarily taught fluency in additive arithmetic and secondarily WPS skills. The CAI contained recurring phases of modeling of new skills (e.g., translating words to a number sentence), examples, guided/independent practices, and reinforcements. WPS skills taught in the CAI entailed a "keyword strategy" including understanding vocabulary and paraphrasing of words to number sentences (e.g., "take away" would be translated to the "minus" sign), categories (e.g., a dog is subordinate to animal), and labeling problem parts.

Cognitive/metacognitive strategy instruction

Cognitive/metacognitive strategy instruction provided learners with general heuristic guidance for the problem-solving process. Five studies (38%) evaluated the effect of CAI that incorporated cognitive and metacognitive strategies. Chadli et al. (2018) and Huang et al. (2012) developed their CAIs by applying Polya's four-step problem-solving strategy (Polya, 1945): (a) *Understand the problem*, (b) *Devise a plan*, (c) *Carry out the plan*, and (d) *Look back*. In the study by Chadli et al. (2018), students were taught to use a graphic organizer to develop a plan. The graphic organizer was comprised of three boxes for numbers and one circle for an operator. Learners were asked to select an appropriate label for each box to represent its meaning, select an operator, and type numerical values into the boxes. Huang et al. (2012) also applied Polya's problem-solving strategy. Graphical representation strategies developed by Fuson and Willis (1989) were used to help students organize the information based on four problem types: *Put-change* (i.e., combine), *Change-get-more*, *Change-get-less*, and *Compare*.

Shiah et al. (1994) compared different types of CAIs: (a) CAI with cognitive strategy plus animated pictures (CAI-A), (b) CAI with cognitive strategy plus static pictures (CAI-P), and (c) CAI without cognitive strategy (CAI-C). Cognitive strategy in their CAIs consisted of seven steps: (a) *Read the problem*, (b) *Think about the problem*, (c) *Decide the operation sign*, (d) *Write the math sentence*, (e) *Do the problem*, (f)

Label the answer, and (g) *Check every step*. The tutorial program for the CAI-C did not teach any explicit strategies. After the CAI's modeling of solving three problems, students were required to solve the problems independently; they were not required to write a math sentence before entering the answer in the system. Seo and Bryant (2012) developed *Math Explorer* incorporating a four-step cognitive strategy (i.e., *Reading*, *Finding (important information)*, *Drawing pictures*, and *Computing*) and a three-step metacognitive strategy (i.e., *Do Activity*, *Ask Activity*, and *Check Activity*) for each of the four cognitive steps. Shin and Bryant (2016) developed *Fun Fraction*, which integrated cognitive and metacognitive strategies for fraction WPS. The four-step cognitive strategy in their CAI is as follows: "(a) Read (Read the problem carefully), (b) Restate (Click and highlight all important information), (c) Represent (Represent the problem using the area model), and (d) Answer (Write the equation and answer it)" (p. 80). Within each cognitive step, CAI guided students to employ the metacognitive strategy, including self-monitoring ("*I will read the problem. I will reread the problem if I don't understand it*" p. 80) and self-checking (*Have I understood the problem and can now move forward?*" p. 80).

Schema-based instruction

Schema-based instruction focused on semantic analysis of word problems and students' representing information in schema diagrams that were corresponding to word problem types (e.g., combine, changes, compare). Then, students were taught rules (e.g., if the total is given, subtract) for them to select an operation for solving the problem. Two studies (15%; Fede et al., 2013; Leh & Jitendra, 2013) incorporated schema-based instruction by using a commercialized CAI named *GO Solve Word Problems* (Snyder, 2005). The CAI in both studies explicitly taught how to (a) understand word problems by explaining the problem types with several examples, (b) organize information in the corresponding schematic diagram, and (c) solve the problems by computing the answer using the information in the schematic diagram. The CAI provided guided and independent practices with schematic diagrams, a self-regulating checklist for following the steps, and immediate corrective feedback.

Mathematical Model-based Problem Solving

Mathematical model-based problem solving engaged students in the problem solving that was driven by mathematical models. Three studies (23%) applied mathematical model-based problem solving in their CAI programs. Stellingwerf and Van Lieshout (1999) developed *Computer-Aided Instruction Program* for students with mathematics difficulties to construct the additive mathematical model. This study compared the effect across four conditions: (a) CAI with number sentences (CAI-N), (b) CAI with manipulatives (CAI-M), (c) CAI with number sentences and manipulatives (CAI-COM), and (d) CAI attention control treatment (CAI-ATC). CAI-N, CAI-M, and CAI-COM consisted of three successive stages. With the number sentence condition, the child was asked to create open or closed number sentences by representing the unknown quantity using a ● sign (e.g., $8 - ● = 3$) and then solve for the unknown for the solution. With the manipulatives, the child was asked to build a concrete representation using the pictures of objects and then solve the problem using the concrete model. With the CAI-COM condition, the child had to use both manipulatives and number sentences. In contrast, the child in the CAI-ATC condition was asked to solve the problem without the aid of manipulatives and/or number sentences.

Two studies (Xin et al., 2012; Xin et al., 2017) created their CAIs on the basis of the *Conceptual Model-Based Problem Solving* [COMPS] strategy (Xin, 2012). COMPS involved making connections across diverse problem types through learners' constructing of a cohesive mathematical model to drive the problem-solving process. Xin et al. (2012) developed *COMPS* CAI to promote multiplicative WPS for students with LDM. Using examples and non-examples, the CAI first taught fundamental mathematical concepts pertinent to multiplicative reasoning (e.g., the concept of equal groups). Building upon that, the program focused on promoting student construction of multiplicative mathematical models through the student's representing variously situated word problem stories in one cohesive model equation: *unit rate* × *number of units* = *product* (Xin, 2012). Later in the program, when presented with a real-world word problem with an unknown quantity, students' development of the solution plan was directly driven by the mathematical model equation. In order to facilitate students' concept development, the CAI program moved students from concrete object representation to symbolic model equation representation. Xin et al. (2017) compared the effect of an enhanced CAI, *PGBM-COMPS* on multiplicative WPS of students with LDM. Participants in the *PGBM-COMPS* condition first engaged in various activities, titled "Please Go and Bring Me (PGBM, Tzur et al., 2013)", manipulating virtual Unifix Cubes to create same-sized towers for constructing fundamental mathematical ideas (e.g., the concept of the composite unit and multiplicative double-counting). Then, the *COMPS* part of the program advanced students from concrete model representation to the symbolic representation of word problems in mathematical model equations. Students were no longer relying on virtual manipulatives; they instead engaged in representing and solving the word problems only with mathematical model equations.

Question 2: The Overall Effects of CAIs on WPS

Overall effects. Table 1 presents the Hedges' g and Tau-U for each study. The studies included in this review demonstrated a wide range of treatment effects from no effect to large effects (g = 0.00 to 2.35; Tau-U = 0.75 to 1). The aggregated Hedges' g (weighted by sample sizes of the studies) across group design studies was 0.77 (CAI with tutoring and working memory training conditions were excluded for the computation), which is interpreted as a moderate effect. The median Tau-U across SCD studies was 0.99, which is interpreted as a large effect. Specifically, two studies (Gleason et al., 1990; Hassler-Hallstetd et al., 2018) reported no effect, one study (Stellingw & Van Lieshout, 1999) reported a small effect, two studies (Shiah et al., 1994; Shin & Bryant, 2016) reported moderate effects, and eight studies (Fuchs et al., 2002; Chadli et al., 2018; Huang et al., 2012; Seo & Bryant, 2012; Fede et al., 2013; Leh & Jitendra, 2013; Xin et al., 2012; Xin et al., 2017) reported large effects. Furthermore, the generalization effects of the CAIs in the included studies ranged from small to large effects (g = 0.22 to 1.30), with an aggregated ES of 0.58, which was interpreted as a moderate effect. Two studies (Gleason et al., 1990; Leh & Jitendra, 2013) reported small generalization effects, one study (Fede et al., 2013) reported moderate to large generalization effects, and one study (Xin et al., 2017) reported a large generalization effect.

Effects regarding instructional strategies. The three studies (Fuchs et al., 2002; Gleason et al., 1990; Hassler-Hallstedt et al., 2018) that applied direct instruction/guided practice approach showed an aggregated ES of 0.17 (CAI with tutoring and working memory training conditions were excluded from the computation; range: $g = 0.00$ to 0.77). Only one study (Fuchs et al., 2002) demonstrated a significant improvement of CAIs over the control group on WPS. One study (Hassler-Hallstedt et al., 2018) showed no effect of CAI from pre- to post-test. In addition, one study (Gleason et al., 1990) that assessed the generalization of WPS to a standardized test reported no effect.

All of five CAIs designed based on cognitive/metacognitive strategy instruction (Chadli et al., 2018; Huang et al., 2012; Seo & Bryant, 2012; Shiah et al., 1994; Shin & Bryant, 2016) demonstrated significant improvements on immediate acquisition measures with moderate to large effects ($g = 0.65$ to 1.38) for group design studies with an aggregated ES of 0.99. The effects of SCD studies were moderate to large (Tau-U = 0.75 to 1.00) with the median Tau-U of 0.99. Both average/median effects were interpreted as a large effect.

Two studies (Fede et al., 2013; Leh & Jitendra, 2013) that were designed based on schema-based instruction demonstrated large effects ($g = 0.90$ to 1.09), with an average of 1.00. However, the results on generalization effects showed mixed results. One study (Fede et al., 2013) that assessed generalization effect on a commercial standardized test showed no significant effect over the control group.

All three model-based intervention studies (Stellingw & Van Lieshout, 1999; Xin et al., 2012; Xin et al., 2017) demonstrated that CAIs yielded significant improvements of WPS on immediate acquisition tests with moderate to large effects ($g = 0.69$ to 2.35; Tau-U = 0.99). Aggregated Hedges' g for group design studies was 1.42, which is considered a large effect. Two out the three CAIs (e.g., Xin et al., 2017) demonstrated consistent generalization effects on standardized tests.

Discussion

The purpose of this study is to conduct a synthesis of CAI studies to facilitate the WPS performance of students with LDM by investigating the instructional strategies used in CAIs and their effectiveness. CAI programs used in the 13 included studies embedded instructional strategies of direct instruction/guided practice, cognitive/metacognitive strategy, schema-based instruction, and mathematical model-based problem solving. Overall, CAIs showed mostly positive effects in improving the WPS performance on immediate acquisition assessment for students with LDM across the reviewed studies.

The effect of CAI in teaching WPS to students with LDM

Although the effects of CAIs were varied from no effect to large effects, the overall effects of included studies were moderate to large (average $g = 0.77$; median Tau-U = 0.99). Specifically, all studies, except for one, reported that CAIs promoted improvement of WPS performances ($g = 0.00$ to 2.35; Tau-U = 0.75 to 1.00). This result converges with previous reviews in that CAIs demonstrated varied effects across the studies; nevertheless, CAI was effective to improve overall mathematics performance (Ok et al., 2019; Seo & Bryant, 2009) and WPS skills in particular (Xin & Jitendra, 1999; Zhang & Xin, 2012) for students with LDM. These findings suggest that CAI is a promising intervention for enhancing the WPS performance of students with LDM.

The five studies that assessed generalization showed mixed effects with an average Hedges' *g* of 0.58. In particular, the two studies (Fede et al., 2013; Leh & Jitendra, 2013) guided by the schema-based instruction showed mixed effects on items from statewide tests and no transfer effect on norm-referenced standardized assessment. Fede et al. (2013) explained that the positive effect on statewide test items reflected the fact that similar word problems were targeted by the CAI program, whereas the norm-referenced standards-based test, on which the CAI program showed no effect, included a wide range of problem-solving tasks.

Although the overall mixed generalization effect of the CAIs, it is encouraging that two studies (Xin et al., 2012; 2017) in which the CAIs were guided by COMPS (Xin, 2012), showed consistent far transfer effects with a large effect ($g = 1.30$ for the group design study). As described by these studies, both the *COMPS* CAI (Xin et al., 2012) and the *PGBM-COMPS* CAI (Xin et al., 2017) were purposefully designed to promote students' generalized problem-solving skills. Mathematical model-based instruction emphasizes students' conceptualization of mathematical relations in one cohesive model equation, with which students make connections between various problem types and grasp big ideas in multiplication reasoning and problem solving. As a drastic contrast to the traditional way of problem solving that emphasizes students' selection of an operation for the solution, the cohesive mathematical model equation in the COMPS program serves to *drive* the solution plan. That is, after students' representation of information in a mathematical model equation (e.g., unit rate × # of units = product, Xin, 2012), the equation reveals what operation to use for solving the unknown quantity. As such, students no longer needed to "gamble" on the operation for solving the problem.

Instructional Strategies in CAIs

Our findings demonstrate the CAIs that incorporated model-based problem solving, cognitive/metacognitive strategy instruction, and schema-based instruction were promising to promote WPS for students with LDM. In contrast, the CAIs used direct instruction/guided practice showed mixed effects. Based on the treatment effects regarding the instructional strategies, the CAIs built upon model-based problem solving yielded the largest effect (average $g = 1.42$; Tau-U = 0.99). Specific instructional design features of mathematical model-based CAIs included the use of virtual manipulatives, the linkage of concrete to symbolic representations of the word problems, and the representation of word problems in mathematical model equations. Mathematical model-based problem solving is an evidence-based intervention strategy to promote generalized WPS of students with LDM when they are delivered by teachers (e.g., Xin et al., 2011) as well as by a computer tutor (Xin et al., 2017). Our findings provide evidence that CAI can be effective in enhancing the WPS performance of students with LDM when it is well designed with evidence-based instructional strategies. These findings are in agreement with previous findings that the quality of instruction is more important than the media/modality of instructional delivery (e.g., whether it is delivered by computer tutors or human teachers, Chang et al., 2006).

The CAIs guided by the cognitive/metacognitive strategy instruction are the most frequently used instructional strategy among included CAIs and yielded a large effect (average $g = 0.99$; median Tau-U = 0.98). Specific instructional design features of the CAIs that employed this strategy included requests learners to follow several steps of the general problem-solving process as well as steps of self-monitoring. According to existing literature, students with LDM are characterized as having poor working memory and organization skills (Zentall, 2012). These students often lack the knowledge of the problem-solving process or fail to use the process. As such, explicit teaching of self-regulating problem-solving processes is suggested for students with LDM (Montague et al., 2014). As existing literature supports the use of cognitive and metacognitive strategies as a research-based strategy (e.g., Montague et al., 2014), our results show that these strategies enhanced the WPS performance of students with LDM when delivered via computers by guiding them through the problem-solving process. The only commercially developed CAI program (Snyder, 2005) reviewed in this synthesis also yielded a large effect ($g = 1.00$). Specific instructional design features of the CAIs included the use of schema-based instruction to facilitate problem representation and to solve word problems.

Three CAIs guided by the direct instruction/guided practice produced a mixed result with a small ES ($g = 0.17$). Despite the small aggregated effect, the studies by Fuchs et al. (2002) that provided feedbacks to students' practice and Gleason et al. (1990) that involved direct teaching of steps/students' following procedural steps demonstrated promotion of WPS skills of students with LDM after the interventions. One exception was the study by Hassler-Hallstedt et al. (2018), which did not result in a positive effect. According to the description in the article, their CAI involved direct instruction of the "keyword" or "words to number problems (p. 10)." To teach WPS, their CAI focused on the translation of isolated "cue word" to operation such as "equaling 'take away' to 'minus' (p 10)". As existing research (e.g., Hegarty et al., 1995; Jonassen, 2003; Xin, 2019) has pointed out, the "keyword" or "cue word" strategy does not teach conceptual understanding of *mathematical relations* in WPS. In addition, existing research (e.g., Xin, 2019) has noted that the use of keyword strategy could misguide students to make errors when encountering inconsistent language problems (e.g., "*Tara solved 21 problems. She solved three times as many problems as Pat. How many problems did Pat solve?*" p. 140). As a result, it is not surprising that the study by Hassler-Hallstedt et al. (2018) did not show a positive effect as the intervention did not have an emphasis on teaching conceptual understanding in WPS. This finding supports the notion that employing effective instructional strategies for CAI is critical for achieving desired instructional goals (Chang et al., 2006; Hu et al., 2020).

Limitation and Future Research

Our synthesis has at least two limitations. First, our review only included 13 studies, so there should be caution in generalizing our findings. Second, we did not include grey literature (e.g., dissertation and thesis); therefore, the overall effect of CAI might be different after adding them. For almost three decades, only 13 articles were conducted related to CAI for WPS. Contrary to current trends in educational settings that are recommended incorporating technology in learning and teaching, it is evident that there is still a scarcity of research on CAI to promote the WPS performance of students with LDM. Therefore, more research on this topic is required. Moreover, it was interesting that only one study out of 13 utilized a tablet PC. As mobile technology is becoming prevalent in educational settings as an instructional tool, it is expected that there will be more future research on mobile technology to teach WPS. Most of the reviewed studies targeted elementary-level WPS. As a result, the mathematics contents of CAIs were mostly limited to WPS with four basic operations. WPS skill is not limited to the primary level of mathematics; rather, it is needed across all grade levels and a variety of the mathematics contents such as high school algebra. Therefore, more research is needed to address secondary mathematical WPS involving CAIs to help students with LDM.

Implications for Practice

The findings of this synthesis demonstrate that students with LDM benefit from CAI that integrates effective instructional strategies (i.e., guided practice, cognitive/metacognitive strategy instruction, schema-based instruction, and model-based problem solving). Thus, our findings indicate that teachers should pay particular attention to the instructional strategies employed by the CAI and consider whether the instructional strategy used in the CAI is empirically supported as effective for students with LDM. Specifically, our finding suggests that teachers should avoid the CAI that employs ineffective instructional practices such as the "keyword" strategy. The keyword strategy is defined as interpreting keywords as cues to select operations to solve word problems (Xin & Jitendra, 1999). Unfortunately, the keyword strategy is still seen in mathematics teaching practice and/or CAIs. Van de Walle et al. (2019) explain the reasons why the keyword strategy should be avoided: it would (a) prevent students from reading the problem and understanding mathematical situations, (b) hinder the learners from making sense of the actual problem presented and using prior knowledge, (c) take out of the context of problems, and (d) prevent learners from performing when the problem involves multistep and/or does not include keywords (Karp et al., 2019).

As the ultimate goal of all instruction is the generalization of learned skills (Dennis et al., 2016), it will be important to employ CAI programs that promote skill transfer. Based on the findings of this review, it seems that a CAI program (i.e., *PGBM-COMPS,* Xin et al., 2017) that employed model-based problem solving has demonstrated a promising effect on students' transfer of learning. Model-based problem solving has taken center stage in K-12 STEM education (Seel, 2017). In fact, model-based problem solving is one of the essential emphases in the Common Core mathematical practice standards (Common Core State Standards Initiative, 2012). These recommendations for teachers will be similarly applied to the software developers. Our findings indicate that considerations of applying empirically supported instructional strategies should be prioritized when CAI is developed and/or adopted.

References

*References marked with an asterisk indicate studies included in the synthesis.

Batty, G. D., Kivimäki, M., & Deary, I. J. (2010). Intelligence, education, and mortality. *British Medical Journal (Clinical Research Ed.)*, *340*, c563. https://doi.org/10.1136/bmj.c563

Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2013). *Comprehensive Meta-Analysis* (Version 3) [Computer software]. Englewood, NJ: Biostat.

*Chadli, A., Tranvouez, E., Dahmani, Y., Bendella, F., & Belmabrouk, K. (2018). An empirical investigation into student's mathematical word-based problem-solving process: A computerized approach. *Journal of Computer Assisted Learning*, *34*(6), 928–938.

Chang, K. E., Sung, Y. T., & Lin, S. F. (2006). Computer-assisted learning for mathematical problem solving. *Computers & Education*, *46*(2), 120–151.

Common Core State Standards Initiative (2012). *Common core state standards for mathematics practice*. http://www.corestandards.org. Accessed 15 June 2019

Cook, S. C., Collins, L. W., Morin, L. L., & Riccomini, P. J. (2020). Schema-based instruction for mathematical word problem solving: An evidence-based review for students with learning disabilities. *Learning Disability Quarterly*, *43*(2), 75–87.

Dennis, M. S., Sorrells, A. M., & Falcomata, T. S. (2016). Effects of two interventions on solving basic fact problems by second graders with mathematics learning disabilities. *Learning Disability Quarterly*, *39*(2), 95–112. https://doi.org/10.1177/0731948715595943

Every Student Succeeds Act of 2015, Pub. L. No. 112-95, § 1177. Stat. (2015).

*Fede, J. L., Pierce, M. E., Matthews, W. J., & Wells, C. S. (2013). The effects of a computer-assisted, schema-based instruction intervention on word problem-solving skills of low-performing fifth grade students. *Journal of Special Education Technology*, *28*(1), 9–21.

Fuchs, L. S., Fuchs, D., Compton, D. L., Powell, S. R., Seethaler, P. M., Capizzi, A. M., ... & Fletcher, J. M. (2006). The cognitive correlates of third-grade skill in arithmetic, algorithmic computation, and arithmetic word problems. *Journal of Educational Psychology*, *98*(1), 29–43. https://doi.org/10.1037/0022-0663.98.1.29

*Fuchs, L. S., Fuchs, D., Hamlett, C. L., & Appleton, A. C. (2002). Explicitly teaching for transfer: Effects on the mathematical problem-solving performance of students with mathematics disabilities. *Learning Disabilities Research & Practice*, *17*(2), 90–106.

Fuchs, L. S., Seethaler, P. M., Sterba, S. K., Craddock, C., Fuchs, D., Compton, D. L., Geary, D. C., & Changas, P. (2021). Closing the word-problem achievement gap in first grade: Schema-based word-problem intervention with embedded language comprehension instruction. *Journal of Educational Psychology*, *113*(1), 86–103.

Fuson , K.C., & Willis , G. B.(1989). Second graders' use of schematic drawings in solving addition and subtraction word problems. *Journal of Educational Psychology*, *81*(4),514–520.

Gadanidis, G., & Geiger, V. (2010). A social perspective on technology enhanced mathematical learning: from collaboration to performance. *ZDM*, *42*(1), 91–104.

*Gleason, M., Carnine, D., & Boriero, D. (1990). Improving CAI effectiveness with attention to instructional design in teaching story problems to mildly handicapped students. *Journal of Special Education Technology*, *10*(3), 129–136.

*Hassler-Hallstedt, M., Klingberg, T., & Ghaderi, A. (2018). Short and long-term effects of a mathematics tablet intervention for low performing second graders. *Journal of Educational Psychology*, *110*(8), 1127–1128. https://doi.org/10.1037/edu0000264

Hedges, L. V. (1981). Distribution theory for Glass's estimator of effect size and related estimators. *Journal of Educational and Behavioral Statistics*, *6*(2), 107–128.

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

Hu, X., Lee, G. T., Tsai, Y., Yang, Y., & Cai, S. (2020). Comparing computer-assisted and teacher-implemented visual matching instruction for children with ASD and/or other DD. *Journal of Autism and Developmental Disorders, 50*(7), 2540–2555. http://doi.org/ggrwbc

*Huang, T. H., Liu, Y. C., & Chang, H. C. (2012). Learning achievement in solving word-based mathematical questions through a computer-assisted learning system. *Educational Technology & Society, 15*(1), 248–259.

Individuals with Disabilities Education Improvement Act of 2004 [IDEA], Pub. L. No. 108-446.

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

Karp, K. S., Bush, S. B., & Dougherty, B. J. (2019). Avoiding the ineffective keyword strategy. *Teaching Children Mathematics, 25*(7), 428–435.

Kiru, E. W., Doabler, C. T., Sorrells, A. M., & Cooc, N. A. (2018). A synthesis of technology-mediated mathematics interventions for students with or at risk for mathematics learning disabilities. *Journal of Special Education Technology, 33*(2), 111–123.

*Leh, J. M., & Jitendra, A. K. (2013). Effects of computer-mediated versus teacher-mediated instruction on the mathematical word problem-solving performance of third-grade students with mathematical difficulties. *Learning Disability Quarterly, 36*(2), 68–79.

Lein, A. E., Jitendra, A. K., & Harwell, M. R. (2020). Effectiveness of mathematical word problem solving interventions for students with learning disabilities and/or mathematics difficulties: A meta-analysis. *Journal of Educational Psychology, 112*(7), 1388–1408.

Montague, M., Krawec, J., Enders, C., & Dietz, S. (2014). The effects of cognitive strategy instruction on math problem solving of middle-school students of varying ability. *Journal of Educational Psychology, 106*(2), 469–481. https://doi.org/10.1037/ a0035176

National Assessment of Educational Progress. (2019). *National student group scores and score gaps.* Retrieved https://www.nationsreportcard.gov/mathematics/nation/achievement/

National Council of Teachers of Mathematics. (2015). *Strategic use of technology in teaching and learning mathematics. A position of the National Council of Teachers of Mathematics.* Retrieved from https://www.nctm.org/Standards-and-Positions/Position-Statements/Strategic-Use-of-Technology-in-Teaching-and-Learning-Mathematics/

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics.* National Council of Teachers of Mathematics.

Ok, M. W., Bryant, D. P., & Bryant, B. R. (2019). Effects of computer-assisted instruction on the mathematics performance of students with learning disabilities: A synthesis of the research. *Exceptionality, 28*(1), 30–44. https://doi.org/10.1080/09362835.2019.1579723

Parker, R. I., Vannest, K. J., Davis, J. L., & Sauber, S. B. (2011). Combining nonoverlap and trend for single-case research: Tau-U. *Behavior Therapy, 42*(2), 284–299.

Polya, G. (1945). *How to solve it.* Princeton University Press.

Powell, S. R., Fuchs, L. S., & Fuchs, D. (2013). Reaching the mountaintop: Addressing the common core standards in mathematics for students with mathematics difficulties. *Learning Disabilities Research & Practice, 28*(1), 38–48.

Roschelle, J., Shechtman, N., Tatar, D., Hegedus, S., Hopkins, B., Empson, S., Knudsen, J., & Gallagher, L. (2010). Integration of technology, curriculum, and professional development for advancing middle school mathematics: Three large-scale studies. *American Educational Research Journal, 47*(4), 833–878.

Seel, N. M. (2017). Model-based learning: a synthesis of theory and research. *Education Technology Research and Development, 65*(4), 931–966.

Seo, Y. J., & Bryant, D. P. (2009). Analysis of studies of the effects of computer-assisted instruction on the mathematics performance of students with learning disabilities. *Computers & Education*, *53*(3), 913–928.

*Seo, Y. J., & Bryant, D. P. (2012). Multimedia CAI program for students with mathematics difficulties. *Remedial and Special Education, 33*(4), 217–225.

*Shiah, R. L., Mastropieri, M. A., Scruggs, T. E., & Mushinski Fulk, B. J. (1994). The effects of computer-assisted instruction on the mathematical problem solving of students with learning disabilities. *Exceptionality*, *5*(3), 131–161.

*Shin, M., & Bryant, D. P. (2017). Improving the fraction word problem solving of students with mathematics learning disabilities: Interactive computer application. *Remedial and Special Education*, *38*(2), 76–86. https://doi.org/10.1177/0741932516669052

Snyder, T. (2005). *GO Solve Word Problems: Using graphic organizers to understand and solve word problems.* Position statement. Tom Snyder Productions.

*Stellingwerf, B. P., & Van Lieshout, E. C. (1999). Manipulatives and number sentences in computer aided arithmetic word problem solving. *Instructional Science*, *27*(6), 459–476.

Stultz, S. L. (2017). Computer-assisted mathematics instruction for students with specific learning disability. *Journal of Special Education Technology, 32*(4), 210–219.

Tzur, R., Johnson, H. L., McClintock, E., Kenney, R. H., Xin, Y. P., Si, L., Woodward, J., Hord, C. T., & Jin, X. (2013). Distinguishing schemes and tasks in children's development of multiplicative reasoning. *PNA, 7*(3), 85–101.

Vannest, K.J., Parker, R.I., Gonen, O., & Adiguzel, T. (2016). Single case research: Web based calculators for SCR analysis. (Version 2.0). Texas A&M University.

What Works Clearinghouse. (2017). *Procedures and standards Handbook (Version 4.0).* Institute of Education Sciences, U.S. Department of Education.

Xin, Y. P. (2012). *Conceptual model-based problem solving: Teach students with learning difficulties to solve math problems.* Sense Publishers.

Xin, Y. P. (2019). The effect of a conceptual model-based approach on "additive" word problem solving of elementary students who are struggling in mathematics. *ZDM, 51*(1), 139–150.

Xin, Y. P., & Jitendra, A. K. (1999). The effects of instruction in solving mathematical word problems for students with learning problems: A meta-analysis. *The Journal of Special Education*, *32*(4), 207–225. https://doi.org/10.1177/002246699903200402

*Xin, Y. P., Si, L., Hord, C., Zhang, D., Cetinas, S., & Park, J. Y. (2012). Conceptual model-based problem solving that facilitates algebra readiness: An exploratory study with computer-assisted instruction. *Learning Disabilities: A Multidisciplinary Journal*, *18*(2), 71–85.

*Xin, Y. P., Tzur, R., Hord, C., Liu, J., Park, J. Y., & Si, L. (2017). An intelligent tutor-assisted mathematics intervention program for students with learning difficulties. *Learning Disability Quarterly*, *40*(1), 4–16. https://doi.org/10.1177/0731948716648740

Zhang, D., & Xin, Y. P. (2012). A follow-up meta-analysis for word-problem-solving interventions for students with mathematics difficulties. *The Journal of Educational Research*, *105*(5), 303–318. https://doi.org/10.1080/00220671.2011.627397

Zentall, S. (2012). *Students with mild exceptionalities: Characteristics and applications.* SAGE.

Zheng, X., Flynn, L. J., & Swanson, H. L. (2013). Experimental intervention studies on word problem solving and math disabilities: A selective analysis of the literature. *Learning Disability Quarterly, 36*(2), 97–111. https://doi.org/10.1177/0731948712444277