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Computer-assisted Mathematical Interventions on Word Problems for Elementary Students with Underachievement in Mathematics

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Computer-assisted Mathematical Interventions on Word Problems for Elementary Students with Underachievement in Mathematics

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Chapter 1: Introduction

Mathematical knowledge is important for children to develop their inquisitiveness, imagination, flexibility, creativity, and tenacity, which affect their future success (Clements Sarama, & DiBiase, 2004). While children of early elementary ages enjoy mathematics classes at school, many students tend to perceive mathematics as a challenging subject requiring hard work after fourth grade as pre-algebra skills are introduced (Cai et al., 2004). Low-achieving students in mathematics show deficits in the acquiring, applying, and transferring of math knowledge (Goldman, 1989; Mercer, 1997; Rivera, 1997). When it comes to students with math difficulties (MD), research-based and effective mathematical interventions are critical to ensure academic success in elementary school.

One of the biggest concerns for children with mathematical difficulties is word problems (National Mathematics Advisory Panel, 2008). Students with MD are more likely to consider word problems to be challenging due to their reading abilities, and they tend to use inferior strategies when in problem-solving situations compared to their peers (Montague & Applegate, 2000). Reviewed studies demonstrated that mathematical interventions with word problems are significantly beneficial for low-achieving students (Hord & Xin, 2013). Additionally, research findings show computer-based mathematical interventions are effective in improving the academic performance of students who are struggling with mathematics problem solving (Seo & Bryant, 2009).

Computer-assisted instruction provides immediate corrective feedback and enables systematically sequenced curriculum based on individual's academic performance (Nam & Smith-Jackson, 2007; Seo & Woo, 2010; Weng, Maeda, & Bouck, 2014). Computer-assisted instruction helps students to improve their mathematical performance because the instruction and feedback can be tailored to individual student's needs. (Aleven & Koedinger, 2000; Li & MA, 2010). While using the word problem-solving process, students are provided virtual manipulatives which allow them to access visual representations on a computer screen (Sayeski, 2008; Trespalacios, 2010).

The purpose of this starred paper is to review the literature that examines computer-assisted interventions for mathematical word problems for elementary students with MD. In Chapter I, the findings of previous studies on math interventions focusing on word problems are summarized. In Chapter II, recent literature which examined the effectiveness of computer-assisted mathematical interventions for solving word problems for elementary students with MD are reviewed. Lastly, in Chapter III, research findings, future recommendations, and implications are discussed.

Mathematical Interventions for Word Problems

Most mathematics textbooks have been published based on Polya's general strategy. Polya (1945) mentioned four basic principles for solving math problems: (a) understand the problem, (b) devise a plan, (c) carry out the plan, and (d) look back and reflect. The first principle includes questions related to those who the students complete understanding of the problems. The second step suggests choosing the most appropriate strategy among many problem-solving skills. The third step is about executing chosen strategies with persistence and patience. Lastly, students are required to reflect and verify their solution.

Students with MD are in need of direct and explicit instruction, as well as different steps for apparent solutions (Carnine, 1997). Babbitt and Miller (1996) stated that effective problem-solving instructions mostly include: (a) reading problems carefully; (b) thinking problems and analyzing via self-questioning, drawing, or visualizing; (c) marking important information on problems; (d) selecting the appropriate strategy; (e) computing correctly; and (f) reviewing the answers. Some researchers have examined the effectiveness of cognitive and metacognitive strategies. For example, Kameenui and Griffin (1989) identified cognitive instructions as a learning strategy focuses on teaching problem-solving steps to improve academic performance and to facilitate the learning process. Metacognitive instructions incorporate teaching problem-solving skills with self-instruction, self-questioning, and self-regulation. For word-problem solutions, Montague (2003) suggested seven cognitive processes such as read, paraphrase, visualize, hypothesize, estimate, compute, and check. Each process incorporated metacognitive processes such as self-instruction, self-questioning, and self-monitoring.

Cognitive interventions focus on learning steps, and schema-based interventions address representation of the relationships among quantities. Hord and Xin (2013) categorized Schema-based instruction into three parts depending on the focus of the problem: (a) emphasizing semantic analyses of the problem, (b) focusing on transfer, and (c) emphasizing algebra readiness. Griffin and Jitendra (2008) studied the semantic structure and problem representation. Using this learning strategy, students are provided opportunities to practice identifying the problem structure. Fuchs et al. (2004) focused on transferring knowledge to improve students' application ability in mathematical problems.

Use of a Computer in Mathematics Education

Educational researchers have classified various computer uses into five categories: (a) tutorial, (b) communication media, (c) exploratory environment, (d) tools, and (e) programming language (Means, 1994; Lou et al., 2001; Li & Ma, 2010). First, *tutorial* refers to teaching mathematics by offering information, demonstration, and drill/practice opportunities through using a computer (Lou et al., 2001). *Tutorial* includes computer-assisted instruction (CAI) and software for practice or drill. Seo and Bryant (2009) defined CAI as "the use of a computer as a medium for providing instructional content" (p.218). Second, *communication media* means using a communication tool such as email or video-conferencing, which enable students to share information and communicate effectively (Lou et al. 2001). Third, *exploratory environments* refers to learning mathematics through discovering and exploring, which enables students to enhance their problem-solving and critical-thinking skills (Lou et al. 2001). Fourth, *tools* means to use a computer as a technological tool such as doing a writing class through word processors (Lou et al. 2001). Fifth, *programming language* pertains to the teaching of specific computer programming languages.

Meta-analyses

Some researchers have conducted meta-analyses studies in mathematics interventions for students with MD. Kroesbergen and Van Luit (2003) analyzed 58 studies that examined mathematical interventions and evaluated the interventions in three areas including preparatory arithmetic, basic skills, and problem-solving. Maccini, Mulcahy, and Wilson (2007) conducted a meta-analysis of mathematical interventions for secondary students with learning disabilities and described effective intervention strategies such as mnemonic, cognitive, and contextualized videodisc instruction. Gersten et al. (2009) analyzed 42 mathematics intervention studies for students with learning disabilities while focusing on instructional components.

Zhang and Xin (2012) focused on word problem-solving interventions for students who were struggled with mathematics. In this review study, a total of 39 articles published from 1996 to 2009 were selected, including 29 group-design studies and ten single-subject design studies. Mathematical intervention strategies were categorized into assistive technology, problem structure representation, and cognitive strategy. The analysis suggested that mathematical intervention for word problem-solving was effective for students with learning difficulties, identifying significant effect sizes across the group-design studies (d = 1.848) and single-subject studies (PND = 95%)

Hord and Xin (2013) reviewed intervention research on word problems for 1st through 5th-grade students with MD. In this study, 26 articles, published from 1996 to 2010 were analyzed. Also, based on the interventions, mathematical interventions for word problems were categorized into four parts: (a) metacognition, (b) schema-based, (c) conceptual model-based instruction, and (d) mixed approaches including metacognition, diagramming, and transfer-focused instruction. In this review study, each intervention discussed the effectiveness related to the nature of word problems. Students with MD were mostly struggling with working memory, representing, and transferring information when solving word problems. Meta-cognitive instruction was shown to help students organize the problem-solving process and lose less information. Schema-based intervention facilitated students' skills for organizing, representing, and processing information. Conceptual model-based instruction helped the transition from the semantic representation of algebraic model expression, which resulted in more accurate problem-solving.

Research Questions

Two research questions guide the development of this starred paper:

1. To what extent does computer-assisted mathematical intervention contribute to the performance of students with MD in their word-problem solving?
2. What are the prognosis of attitude change for students with MD on the use of technology for solving word problems?

Focus of Paper

The quantitative research studies reviewed in Chapter II were published in the United States between 2012 and 2017. Study participants included students in kindergarten through sixth grade having MD. Academic Search Premier, EBSCO, and PsychINFO were used as the primary database to find appropriate journal articles.

I critically reviewed research papers that could be located under the following keywords: *computer-assisted instruction, computer-mediated instruction, computer-based learning, computer-based story, virtual manipulatives, web-based learning, virtual learning environment, mathematics word problems, word problem solving, technology-based instruction, elementary students, learning strategies, instructional effectiveness, teaching mathematics methods, mathematics learning problems, mathematics learning disabilities, mathematics difficulties,* and *meta-analysis.* Chapter I includes the background on math interventions, previous research, theoretical factors, and definitions germane to this topic. Chapter II reviews current research literature focused on examining computer-assisted interventions for word problems for students with math difficulties.

Importance of the Topic

Students with learning difficulties face more challenges in mathematical learning while their peers make significant progress in mathematics achievement (National Mathematics Advisory Panel, 2008). The discrepancy between students' knowledge and required core knowledge increases as they grow older because the core knowledge expands continuously with each grade level while students with learning difficulties achieve more slowly. Given the difficulties experienced by many students with learning problems, researchers need to look at effective mathematical interventions for students with MD.

Cawley, Parmar, Foley, Salmon, and Roy (2001) identified students' serious difficulties in word-problem solving. Montague and Applegate (2000) stated that children with learning problems are at a higher risk for failure in solving word-problems than their peers. Also, students with academic difficulties tend to use inferior strategies when solving word problems compared to their normal-achieving peers. As many students are struggling with solving word problems, researchers and educators need to determine the most effective mathematical intervention strategies for solving word problems (Hord and Xin, 2013).

Definitions of terms

Meta-analysis. Zhang and Xin (2012) stated that "meta-analysis is a statistical technique that provides a quantitative summary of findings and characteristics of many empirical studies" (p.303).

Chapter 2: Review of the Literature

This literature review intends to examine the computer-assisted mathematical interventions of word problems for elementary students with mathematical disabilities (MD). In Chapter I, the background information and recent meta-analyses studies on mathematical interventions for solving word problems were introduced and discussed. This chapter is organized into four major sections: (a) effectiveness of computer-assisted instruction (CAI), (b) comparison of computer- and human-mediated instruction, (c) comparison of computer- and paper-based learning, and (d) students' attitude toward the technology. Seven studies are reviewed in chronological order, beginning with the oldest study.

Effectiveness of Computer-assisted Instruction

Research has revealed that CAI is useful in supporting students with MD. In word-based mathematical problems, CAI is beneficial in several ways. First, the instruction and feedback can be tailored to individual student needs (Aleven & Koedinger, 2000; Li & MA, 2010). Second, it enables systematically sequenced curriculum based on individual's academic performance, and students can have the opportunity to solve problems step-by-step with visual representations (Nam & Smith-Jackson, 2007; Seo & Woo, 2010; Weng, Maeda, & Bouck, 2014). Third, it decreases students' emotional pressure, and students are more likely willing to work with computer-based learning (Fede, Pierce & Matthews, 2013). Considering the diversity of students and the shortage of qualified mathematics/special education teachers, researchers have worked to establish the effectiveness of CAI for students with learning difficulties. (Xin et al., 2017).

Huang, Liu, and Chang (2012) examined the effectiveness of the CAI mathematics problem-solving system. This program was developed as a tool for remedial education in the form of a web-based instruction focusing on solving word-based addition and subtraction. The program design used a graphical representation strategy, and all questions were divided into four types: (a) Put-Together, (b) Change-Get-More, (c) Change-Get-Less, and (d) Compare.

This developed program was based on Polya’s four basic principles for solving mathematics problems. These four steps are: (a) understand the problem, (b) devise a plan, (c) carry out the plan, and (d) look back and reflect. The first principle refers to the students’ complete understanding of the meaning of a sentence in the problem. The second step suggests choosing the most appropriate strategy among many problem-solving skills. The next step is to implement the planned problem-solving with persistence and patience. The last step proposes that students need to examine the answers carefully to verify their solutions.

In this study, 2nd and 3rd-grade students, who were low achieving in mathematics, despite having basic learning abilities, were identified by the class advisor. Seventeen students were assigned to the experimental group while eleven students were assigned to the control group. The experimental group received the mathematics problem-solving intervention during an afterschool program while the control group did not receive the CAI intervention.

The outcome indicated that participants in the experimental group demonstrated significantly improved scores after receiving the computer-assisted mathematics-problem solving program. In the pretest, 2nd and 3rd-grade students in the experimental group scored on average of 11.27 and 11.33 respectively while students of each grade in the control group scored 12.00 and 15.20. In posttest average scores, 2nd and 3rd-grade students in the experimental group showed 15.00 and 13.83 respectively while students in the control group showed 11.67 and 14.80. Therefore, after the intervention, the mean score of the 2nd-grade students in the experimental group increased by 3.73, and the 3rd-grade students in the experimental group gained 2.50 points in mean score whereas the mean scores of the control group decreased slightly.

Seo and Bryant (2012) examined the efficiency of interactive multimedia computer-assisted instruction based on the multiple-probe-across-subjects design. This study developed an interactive multimedia CAI program, called *Math Explorer*, to enhance word problem-solving skills. *Math Explorer* was based on four cognitive steps: reading, finding, drawing, and computing. Each cognitive step included three metacognitive strategies: doing, asking, and checking activities. Additionally, *Math Explorer* adopted several instructional design features which were identified as crucial for mathematical improvement for students with MD. For example, *Math Explorer* incorporated explicit instruction with a clear goal, provided guided/independent practice, and reviewed mathematical vocabulary and prerequisite mathematics skills. This CAI also enabled visual representations and text-to-speech functions that facilitated the feedback.

Math Explorer was created using Macromedia Flash Professional 8. Problems in *Math Explorer* consisted of one-step addition and subtraction word problems with single- or double-digit numbers. For program fidelity, the computer program was evaluated using the multimedia evaluation checklist, created by Alessi and Trollip (2001). The checklist considered design structure, language and grammar, and offline resources. Also, after evaluation, with the checklist, disagreements were discussed and revised. Usability testing was also implemented based on guidelines by Nielsen, Snyder, Molich, and Farrell (2000).

To study the effectiveness of *Math Explorer*, four 2nd or 3rd-grade students with MD were selected based on teachers' ratings of students' mathematical competence. The four participants were in the process of identification of learning disabilities through a response to an intervention model. All testing problems were randomly selected from *Math Explorer*, and data were collected over three phases: baseline, intervention, and follow-up. During baseline, students were provided computer- or paper/pencil-based tests without introducing *Math Explorer* or any strategies. During two consecutive weeks of intervention, in regular succession, students participated in the program at the most five times a week, for 20-30 minutes a day. Once one student solved the problems with 70% accuracy, the next student began the intervention phase. At the end of the intervention, students were provided the computer- or paper/pencil-based tests for 10 minutes to collect the data.

The outcomes demonstrated that the multimedia CAI program was effective in improving the accuracy of mathematical performance. All four students showed a gradual improvement with an increasing trend and exceeded the criterion level. Specifically, at baseline, the students' accuracy performance remained around zero, but after the intervention, the four students' scores improved to 16%, 16%, 27%, and 22% respectively. These increased scores were found on computer-based tests as well as paper-based tests, which indicated that the performance gains on the computer-based tests could be generalized to paper/pencil-based tests. Finally, follow-up studies showed that three out of four students maintained their intervention gains, although they showed slightly decreased scores compared to the intervention.

Fede, Pierce, Matthews, and Wells (2013) examined whether a CAI with a schema-based intervention was effective for improving word problem-solving skills of low-performing fifth-grade students. In this study, 32 fifth-grade students with low-performing mathematics scores were selected based on several criteria: (a) scoring below 30th percentile on the Process and Application subtest of Group Mathematics Assessment and Diagnostic Evaluation (GMADE), (b) being without severe developmental disabilities, and (c) having reading skills above 25th percentile in the 3rd-grade of level Dynamic Indicators of Basic Early Literacy Skills of oral reading fluency probes. Thirty-two participants were randomly assigned into either experimental or control groups equally. Six out of 32 participants were receiving special education service, two were English Language Learners, and one had a section 504 plan.

The math intervention program was *Go Solve Word Problem* which was developed by Snyder (2005). This program consisted of three modules: (a) addition and subtraction, (b) multiplication and division, and (c) advanced multiplication and division. The lessons within this program were delivered in a sequential process of targeted tutorials, focused, guided practice, and mixed practice. The tutorials provided a word problem and demonstration of its corresponding graphic organizer which consisted of short animations and interactive guided practice activities. After the tutorials, students were asked to solve word problems determined by students' performance history. Lastly, students solved mixed word problems at the end of the session.

While students in the control group participated in regular math classes with their math teachers, students in the experimental group participated in *Go Solve Word Problem*. This computer-assisted intervention took 45 minutes and occurred twice a week for three weeks, resulting in six sessions. Students in the experimental group worked at their own pace, and they could proceed to the next level when they demonstrated at least 85% accuracy on the mixed practices for two consecutive sessions.

To measure the efficiency of schema-based CAI, the research evaluated the participants in both groups by three assessments: Massachusetts Comprehensive Assessment System (MCAS), biweekly examiner-made probes, and the Process and Application subtest from the GMADE. Participants in the experimental group were additionally asked to complete a survey regarding their satisfaction with the *Go Solve Word Problem*. The general results showed mixed outcomes. There was statistically no significant difference between the two groups on the Process and Application subtest from the GMADE, while there was a significant difference on MCAS and biweekly examiner-made probes.

On the Process and Application subtest from the GMADE, the experimental group mean scores increased by 3.50 points on average, while the control group increased by 1.94 points. Although the gain of the experimental group was larger than the increase in the control group, T-test results showed no statistically significant differences between the two groups ($t=1.06$, $p=.075$). In contrast, t-test of MCAS scores between the two groups demonstrated that the experimental group achieved significantly larger improvement compared to the control group ($t=2.16$, $p=.019$). The experimental group's mean score increased by 4.25 points while the mean score of the control group increased by 1.56 points. On biweekly examiner-made probes, both groups showed similar increases through the fourth probe, but the experimental group demonstrated a noticeable increase on the fifth probe.

Kanive, Nelson, Burns, and Ysseldyke (2014) compared a computer-based intervention with a conceptual intervention to evaluate the effects on math fluency and solving word problems, especially for multiplication 6s through 9s. A total of 90 fourth- and fifth-grade students identified as struggling in mathematics by the classroom teachers with scores at or below the 25th percentiles on the Measures of Academic Progress Mathematics subtest (Northwest Evaluation Association, 2010). Participants were randomly assigned into three groups: (a) computer-based intervention, (b) conceptual intervention, and (c) control group. Computer-based and conceptual interventions were conducted in the computer lab or small classrooms. Each intervention lasted 15 minutes and consisted of two sessions, resulting in a total of 30 minutes while the control group did not receive any additional interventions (i.e. treatment as usual).

The computer-based intervention used a software program, Math Fact in a Flash (MFF; Renaissance Learning, 2003) which was designed to enhance computational fluency in addition, subtraction, multiplication, and division. This program consisted of 62 hierarchical levels, but in this study, students only participated in level 29 or 30 which were designed for the practice of multiplication 6s through 9s. Each level was comprised of 40 items, and students could proceed to the next level when they answered all items correctly within the 2-minute time limit. After submission, the program provided immediate feedback showing the correct answers.

The conceptual intervention was implemented using activities developed by Van de Walle and Lovin (2006). Graduate students delivered the lesson following the experimental process. During the first session, students were presented with problems and guided to the solution, and they solved multiplication problems for 6s through 9s with using manipulative blocks. The second sessions included mathematical games related to learning multiplication facts. The two interventions occurred in addition to regular mathematics class, and therefore the control group received only regular mathematics instruction.

The results indicated no significant effects for either the computer-based practice or conceptual intervention on solving word problems. The two groups which received additional interventions did not show significant improvement compared to the control group, $F(2, 79) = 1.58$, $p = .21$. However, in math fluency, students who received either the computer-based practice or conceptual intervention increased their mean scores compared to the control group. Specially, the computer-based practice group (M= 7.04, SD = 12.94) had a significantly larger mean score than the conceptual intervention group (M = 3.38, SD = 13.16) and the control group (M = 1.39, SD = 5.27).

Comparison of Computer and Teacher-mediated Instruction

Research has indicated that CAI is beneficial for students with MD because of individualized curriculum, visual representation, and less emotional pressure. However, it is not clear whether the CAI provided a more effective learning environment than explicit teachers' instruction. Leh and Jitendra (2012) conducted a study to determine whether there is a difference between teacher-mediated instruction (TMI) and computer-mediated instruction (CMI) on mathematical word problem-solving performance of third-grade students with mathematical difficulties. In this study, a total of 25 students were selected based on scores below the 50th percentiles on the *Mathematics Problem Solving* subtest of the *Stanford Achievement Test* (SAT-10) (Harcourt Assessment, 2004). Participants were randomly assigned to either the TMI or CMI group; 13 students were assigned to CMI group and 12 students were assigned to TMI group.

In both groups, the TMI and CMI students received daily mathematics instruction from their homeroom teachers. This regular mathematics instruction took 45 minutes and used the district-adopted textbook, *Investigations in Number Data, and Space* (Kliman, Russell, Wright, & Mokros, 2006). In addition to teachers' instruction, each group participated in the assigned intervention, either the CMI or the TMI. The interventions were implemented two or three times per week for 50 minutes over six weeks, resulting in the total of 15 lessons which focused on word problem skills. During the intervention, the text was read out loud for students in both groups by either a computer or a teacher.

The CMI students participated in technical training sessions to ensure their adequate prerequisite skills before receiving the computer-mediated intervention. The training took a total of 65 minutes and referred to the use of keyboard or mouse and software access. After the training, the CMI students received word problem-solving instruction through a word problems software, *Go Solve Word Problems*. The program included tutorials for four problem types: (a) group, (b) parts and total, (c) change, and (d) compare or comparison. The screen consisted of a word problem, a graphic organizer, and a hint for additional support. The first lesson demonstrated how to determine and use correct information from word problems such as organizing information into schematic diagrams, labeling quantities, and using drop-down boxes. The second lesson provided students opportunities to practice their learned skills from the first lesson. As the lesson proceeded, students were provided more complex problems with large numbers.

The TMI students received the instruction from three qualified teachers. The TMI group used the schema-based mathematical curriculum designed by Jitendra (2007). Each lesson was delivered based on word problem-solving strategies such as thinking aloud, the interacting between teachers and students, and providing feedback and error-correction. Like the CMI lessons, the first and second lessons emphasized on organizing information using schematic diagrams for solving word problems.

The results showed there was no statistically significant difference between the two groups. The word problem-solving skills of the two groups were assessed through pretest, posttest, and after four weeks as a maintenance period. The pretest ANCOVA was $F(1,23) = 1.36$, $p = .256$. and the posttest ANCOVA was $F(1, 23) = 1.58$, $p = .221$, $d = .53$., which means no significant effect of the treatment group. The ANCOVA of norm-referenced tests, Pennsylvania System of School Assessment and Mathematics subtest of the SAT-10, also indicated no significant main effect of treatment group, $F(1, 22) = 0.74$, $p=.400$, $d = -.31$.

Xin et al. (2017) compared the effects of mathematics intervention in a computer-assisted program and a teacher-delivered intervention. To examine whether there was a difference between the two interventions, the researcher identified a total 17 students based on teachers' referrals and scores below the 35th percentiles on the SAT-10. Some of the selected students were identified with a learning disability, attention deficit hyperactivity disorder, mild intellectual disability, or were learning English as a new language. Participants were randomly assigned into two groups - CAI intervention and Teacher-delivered intervention (TDI). Nine students were assigned to CAI intervention while eight students were assigned to TDI. Both interventions had sessions lasting 25 minutes and happened four times a week, resulting in a total of 36 sessions.

In this study, the computer-assisted intervention was developed based on conceptual-based problem solving and was named *Please Go Bring Me-Conceptual Model-Based Problem Solving* (PGBM-COMPS). This web-based program was designed to improve multiplicative reasoning and problem-solving skills for elementary students with MD. The PGMB was devised to promote students' essential ideas in multiplicative reasoning, and the COMPS focused on representing word problems in mathematical model equations.

The PGBM-COMPS tutoring program consisted of four modules. All participants went through these four modules individually and in sequence. The first module focused on multiplicative double counting. The second module pertains to developing ideas in unit differentiation and multiplicative mixed unit coordination (MUC). The third module involves quotative division tasks, grouping the total amount into equal-sized parts for the solution. The last module presented partitive division problems, figuring out the number of one equal-sized group. Like other CAI, the PGBM-COMPS provided individual feedback, scaffolded curriculum based on students' performance, and provided indirect hints.

In the TDI condition, two licensed school teachers delivered instructions using similar word problems to those presented in the PGBM-COMPS. During the intervention period, teachers provided instructional strategies and practice as their regular mathematics class period. Based on *Common Core*, teachers adopted mathematics curriculum and used textbooks such as *enVisionMath: Common Core Edition* (Charles et al., 2012), *Math in Focus: The Singapore Approach* (Ramakrishman & Soon, 2009), and *Harcourt Math* (Maletsky et al., 2004).

A pretest-posttest comparison group design was used to evaluate the outcomes. The results showed that not only that the PGBM-COMP and the TDI groups improved their word problem skills after interventions ($F=41.62$, $p<.001$), but both groups also maintained the gains observed in their posttest performance. However, the PGBM-COMP group demonstrated much higher scores at posttest than the TDI group's score. Specifically, the mean SAT-10 score of PGBM-COMP group was 18.78 at pretest which increased to 29.00 at posttest. The PGBM-COMP group's mean score increased by 10.22, while the TDI group's performance had a considerably smaller SAT-10 mean score increase from 21.33 to 23.67.

Comparison of Computer and Paper-based Learning

Gunbas (2014) compared students' mathematics word problem-solving achievement in computer-based and paper-based settings. This study was conducted for three weeks during school hours. The total 128 participants included 77 males and 51 females between the ages of 11 and 13-years-old. In the first week, participants were pretested to determine their mathematics achievement level. In the second week, students were randomly assigned into three groups: the computer story (CS), the paper story (PS), and the isolated word problems (IP). During the last week, participants were post-tested to examine the differences between the three groups.

The CS group was provided mathematics word problems in the computer-based story format. For students' story comprehension, the text was narrated along with synchronous highlighting of the story. In addition to text reading, all questions and buttons were completely narrated for students, and illustrations and pictures were displayed on the screen. Once students submitted their answers, they received the feedback immediately. The feedback included either partial or full solutions with correct answers. The PS group solved mathematical word problems in the paper-based story format. The PS group was provided the same word problems and story text as given to the CS group through a paper-based and traditional format. Although the story text and word problems were all the same, the story in a paper-based format did not include any pictures. Lastly, the researcher usded the IP group as a control group, presenting the mathematics problems in words but without any stories or pictures through a paper-based format.

The ANCOVA test results indicated that after the treatments, there was a significant difference in students' pre- and post-testing scores, among all three groups. Specifically, the outcome of the comparison between computer-based story and paper-based story indicated that students in the CS group achieved significantly higher than those in the PS group. The mean scores on posttests were 48.55 in the CS group, versus 39.35 in the PS group. The standardized mean difference was 18.14, which was statistically significant ($p<0.05$, $se=3.12$). Additionally, students' comprehension of the story was analyzed in the CS and PS treatment. The results showed that the CS group understood the story significantly better than the PS group. ($t=2.08$, $p<0.05$).

This study also compared the story groups to the non-story to determine whether the story format affected the students' mathematical achievement. The CS group demonstrated significantly higher posttest scores than students in the IP group. However, the PS group did not show a significant difference when compared to students in the IP group. Although the same story was delivered to CS and PS groups, the effectiveness of the story was different. In other words, when the story was presented on a computer, the story was more effective in teaching mathematical word problems.

Students' Attitude toward the Technology

Some research worked on the effectiveness of CAI has examined students' attitude toward the technology for solving word problems. Huang, Liu, and Chang (2012) collected information related to the attitude toward the computer program from participants in the experimental group. The questionnaire consisted of five sections: (a) system use attitude, (b) system assistance cognition, (c) mathematics problem-solving process cognition, (d) cognition of each stage of the problem-solving process, and (e) preference of each stage of the problem-solving process. According to the attitude outcomes, most students positively responded to the computer system. They indicated that the system operation and instruction were easily understood and using a computer was easier than completing a paper test sheet. However, half of the students still felt that word problems were not simple even though a computer was used.

Leh and Jitendra (2012) compared the attitudes of two groups who received either teacher-medicated instruction (TMI) or computer-mediated instruction (CMI). There was no statistically significant difference between two groups, showing $t(23) = 1.05$, $p = .307$. However, students who received the TMI reported more positively than students in the CMI group. In open-ended questions, the students in TMI group reported that they mostly understood the solution for word problems but sometimes felt bored with the teacher's instruction. Students who received the CMI reported that they liked using the computer but felt it was difficult to understand the lengthy words on the computer screen.

Fede, Pierce, Matthews, and Wells (2013) asked participants to complete survey questions related to the computer program, *Go Solve Word Problems*. The questionnaire consisted of 17 questions based on a Likert which used Likert rating scales as well as seven open-ended questions. Most students agreed that they learned a lot through the computer program with a response mean of 6.06 out of 7, but many participants indicated that the program caused them some frustration with a response mean of 2.31. Also, some students' responses showed that they liked the graphics and personalized word problems. The answers of open-ended questions indicated that most students expressed a positive attitude toward the program.

Summary

This synthesis examined studies exploring CAI interventions on mathematical word problems published between 2012 and 2017. First, CAI has been shown to be significantly effective in improving skills for mathematical word problems, but the degree of the effectiveness varies and depends on the computer program. Also, students who received computer-based intervention showed significantly higher improvement compared to students who received the paper-based intervention. Most students attitude toward the technology was positive. However, it was not clear whether the CAI was more effective than qualified teachers' instruction with using evidence-based models. In this study, seven studies were discussed in evaluation of the computer-assisted instruction. Table 2 summarizes the finding of these studies; they are presented in the same chronological order as in the chapter. Conclusions, recommendations for future research, and implications for current practices are discussed in Chapter 3.

Table 1

Summary of Chapter II Studies

AUTHORS	STUDY DESIGN	PARTICIPANTS	PROCEDURE	FINDINGS
Huang et al. (2012)	Pretest-posttest experimental design	Low achieving 2nd or 3rd students in a math class were identified by the class advisor - 17 students were in the experimental group, and 11 students were in the comparison group	- As an afterschool program, treatment group was provided computer-assisted mathematics practice based on Polya's problem-solving process while the control group did not receive it.	Participants who attended computer-assisted mathematical problem-solving program demonstrated significantly higher mathematics problem-solving skills, compared to the control group who did not receive any interventions.
Leh & Jitendra (2012)	Pretest-posttest experimental design	- 25 third-grade students who were below the 50th percentiles on SAT-10 were identified - Participants were randomly assigned to either computer or teacher-mediated instruction.	- Participants received 45-minutes mathematical lessons emphasizing word problems, a total of 15 lessons over 6 weeks. - One group received the CAI for solving word problems. Another group received instructions from qualified teachers.	Computer-mediated instruction integrating cognitive modeling was not statistically significant compared to teacher-medicated instruction.

Seo & Bryant (2012)	Multiple-probe-across-subject design	Four 2nd and 3rd-grade students with mathematics difficulties, aging of 7 and 9-years-old	- Participants received the CAI for 18 weeks, through Math Explorer, which was developed for addition and subtraction word problem-solving program based on cognitive and metacognitive strategies.	Three out of the four students successfully maintained their improved word-problem-solving performance levels during the follow-up phase.
Fede et al. (2013)	Experimental design	The total of 32 fifth-grade students who were low-achieving in Mathematics, aging of 10 and 11 years old were selected.	- The CAI integrated a schema-based strategy - The experimental group received CAI for 3weeks, twice a week, resulting 6 sessions which took 45 minutes. - Control group received a regular test review lessons with their math teachers.	-There was no statistically significant difference between the two groups on the Process and Application subtest of the GMADE, but there was a significant difference on MCAS and biweekly examiner-made probes.
Gunbas (2014)	Pretest-posttest experimental design	128 sixth grade students including 77 boys and 51 girls, aging of 11 and 13-years-old.	Participants were pretested on paper, and then randomly assigned to three groups: the computer story, the paper story, and isolated. They received the intervention for one week and were then post-tested.	Participants that received the computer story intervention showed significantly higher achievement scores than students who received the paper story intervention and isolated word problems intervention.

Kanive et al. (2014)	Experimental design	90 fourth- and fifth-grade students were identified as struggling in math by the classroom teachers and scored at or below the 25th percentile on the statewide norm-referenced test.	- Participants were randomly assigned to three groups: computer-based, conceptual interventions, and control group. - The interventions were conducted twice, and each lasted 15 minutes in addition to regular mathematics class.	-There was no significant effect of either computer-based or conceptual interventions on solving word problems. -In math fluency, both computer-based and conceptual interventions were significantly effective, but students receiving computer-based intervention showed much higher mean scores.
Xin et al. (2017)	Experimental design	17 students were identified based on teachers' references and scores below the 35th percentiles on the SAT-10.	Participants were randomly assigned to either CAI or Teacher-delivered intervention (TDI). The sessions lasted 25 minutes and happened four times a week, resulting in a total of 36 sessions. The CAI used conceptual-based problem-solving while TDI used instructional strategies and practice similar to their regular mathematics class period.	Both CAI and TDI groups showed statistically significant differences between pretest and posttest, showing improvement after interventions. However, CAI group showed much greater improvement, compared to TDI group.

Chapter 3: Conclusions and Recommendations

The purpose of this research paper is to evaluate computer-assisted instruction (CAI) for mathematical word problems for elementary students with mathematical difficulties (MD). Chapter I provides background information on the topic, and Chapter II presents a review of the research literature. In Chapter III, findings, recommendations, and implications of research findings are discussed.

Conclusions

Seven studies that examined CAI for mathematical word problems for elementary students with MD were discussed. This paper presented the results of implementing CAI for solving word problems in four categories: (a) effectiveness of computer-based intervention (b) comparison of computer- and teacher-mediated instruction, (c) comparison of computer- and paper-based learning, and (d) students' attitude toward the technology.

- *Effectiveness of Computer-assisted instruction.*

Meta-analyses studies of mathematical interventions for students with MD generally demonstrated the effectiveness for low-achieving students in improving mathematical performance (Maccini, Mulcahy, and Wilson, 2007; Zhang and Xin, 2012) However, regarding word problems solving skills, it was not clear whether the computer-based interventions effectively contributed to improving students' mathematical skills. Four studies out of seven, which were reviewed in this study, concluded that the computer-based teaching or learning was significantly effective in enhancing word problems solving skills for students with MD. Two studies concluded no difference between the computer-based interventions and traditional methods and one study showed mixed outcomes.

- *Comparison of computer- and teacher-mediated instruction*

In comparing computer- and teacher-mediated instruction, mixed results were reported regarding the effectiveness of the computer-based interventions in mathematics classes for students with MD. Leh and Jitendra (2012) stated there was no statistically significant difference between two groups who received either teacher-mediated instruction or computer-mediated instruction which were delivered on the schema-based mathematical curriculum. The computer-mediated instruction was not developed by the researcher but used a word problem software, *Go Solve Word Problems*. Additionally, Kroesbergen and Van Luit (2003) evaluated the mathematical interventions in problem-solving and found that direct teacher-led instruction was more effective in teaching numeracy or computation skills than the peer- or computer-assisted techniques.

However, Xin et al. (2017) demonstrated a different outcome related to this comparison between two interventions. In this study, the group that received computer-mediated instruction improved more than the group that received teacher-delivered instruction. This study developed the computer program, *Go Bring Me-Conceptual Model-Based Program Solving* (PGBM-COMP) which used conceptual-based problem-solving. The teacher-delivered instruction was also designed similarly. With these mixed outcomes from all reviewed studies, it is not clear whether CAI is more efficient than qualified teachers' instruction with using the evidence-based model.

- *Comparison of computer- and paper-based learning*

This paper reviewed literature which compared computer- and paper-based interventions. Computer-based learning provided a more effective environment than paper-based learning for students solving mathematical word problems. Gunbas (2014) compared students' achievements with mathematical word problems in the different settings: computer- and paper-based learning. In this study, the students who were provided a computer-based setting achieved significantly larger mean scores than the students who received paper-based learning.

Also, Seo and Bryant (2012) discussed that students' performance regarding two different types of questions on either computer- or paper-based setting. When solving easy problems, most students with MD achieved higher scores on the computer-based setting than working on the paper-based setting. In contrast, students showed slightly higher achievement on paper-based tests on difficult problems. The study proposed that difficult problems may require students to spend more time to apply the strategies, which they were more readily able to do on the paper-based setting.

- *Students' attitude toward Computer-based intervention*

According to the survey results, most students had positive attitudes toward computers. Huang, Liu, and Chang (2012) collected information related to the attitude toward the computer program from participants in the experimental group which supported students' favorable impression of the program. Specifically, the instruction on the computer was easily understood and using a computer was easier than the test sheet. However, half of the students still felt that word problems were not simple even though a computer was used.

Another survey compared the attitude of two groups who received either teacher-mediated instruction (TMI) or computer-mediated instruction (CMI) (Leh and Jitendra, 2012). Students who received TMI were more likely to report positive attitudes than students in the CMI group. On open-ended questions, the students in the TMI group indicated that they mostly understood the solution for word problems but sometimes felt bored with the teacher's instruction. Students who received the CMI reported that they liked using the computer but felt it was difficult to understand the lengthy words on the computer screen. Fede, Pierce, Matthews, and Wells (2013) showed support for students' positive attitudes on the program, but also indicated the program caused students some frustration.

Recommendations for Future Research

Although more than half of the examined studies concluded CAI was effective in enhancing students' performance, it still remains unclear whether students' gains were really from the intervention because many computer programs incorporate other effective strategies. For example, Seo and Bryant (2012) created the multimedia CAI program based on cognitive and metacognitive strategies which had already proven their effectiveness from previous research. The program also adopted several instructional design features which were identified as crucial for academic improvement for students with MD. Huang, Liu, and Chang (2012) developed the web-based program based on Polya's four basic principles for solving mathematical problems. Future research may need to examine what components of CAI influence the mathematical achievement of students with MD.

Also, the literature which examined the effectiveness of CAI used different computer programs. In four studies, the researcher developed the computer program to improve mathematical skills of students with MD based on their specific research questions (Huang, Liu, and Chang, 2012; Seo and Bryant, 2012; Gunbas, 2014; Xin et al., 2017). Three studies used a software program which was previously released for unspecified individuals (Leh and Jitendra, 2012; Fede, Pierce, Matthews, and Wells, 2013; Kanive, Nelson, Burns, and Ysseldyke, 2014;).

Four studies which developed their program concluded that CAI was significantly effective in improving students' performance while the other three studies which used previously established programs showed mixed outcomes. Future studies should design their computer programs with careful attention to minimize potential extraneous influences.

As a dependent variable, standardized tests may provide a more relevant measurement than the researcher-developed test questions. One researcher expressed concerns regarding the validity and reliability of their measurements because the researcher developed the assessment questions, which consisted of randomly selected questions from the computer program (Seo and Bryant, 2012). Another research evaluated participants by three assessments: Massachusetts Comprehensive Assessment System(MCAS), Group Mathematics Assessment and Diagnostic Evaluation (GMADE), and biweekly examiner-made probes. Students with MD did not show significant improvement on the GMADE, but showed a significant improvement on MCAS and examiner-made probes (Fede, Pierce, Matthews, and Wells, 2013)

Finally, future studies regarding application and generalization of the CAI are necessary. Six studies implemented CAI for three weeks or less than three weeks. One study did not describe the intervention period at all. Also, maintenance assessment studies were conducted either immediately after the intervention period or were not examined at all.

Implication for Current Practice

Since the No Child Left Behind Act (NCLB) of 2001, all students regardless of their disability status are required to make progress in general curriculum, and special education teachers have struggled to improve school performance of students with disabilities in the inclusive educational setting. In addition, mathematics teachers have been consistently in high demand because of teacher shortage rate for decades. While students with mathematical difficulties need extra or supportive intervention programs, many school systems do not have time or human resources for students with MD. In considering these limited resources and the shortage of teachers, CAI can be one solution for students with MD.

As students grow up, many are less likely to enjoy mathematics classes. To enjoy mathematics, students need to have fundamental and basic math skills which require large amounts of mathematical exercises and practices. This easily makes students with MD feel overwhelmed or stressed in mathematics. Mathematical anxiety may affect the performance of students with MD. Fede, Pierce, and Matthews (2013) stated that computer-assisted learning contributed to a decrease in students' emotional pressure in mathematics. Effective intervention in decreasing math anxiety could contribute to increasing mathematical achievement of students with MD.

Also, since many students with MD are not engaged or motivated in mathematics classes, educators need to implement strategies to encourage their learning. According to the previously discussed surveys, students' attitude toward technology is mostly positive when they were provided computer-based learning. Students with MD feel comfortable with CAI and are excited to use a computer for learning. Rather than traditional instructions, computer-assisted instruction seems to be more attractive to students with MD. Therefore, teachers could use computer-based technology in their lessons to motivate learners with MD.

Summary

As technology improves, teachers have been implicitly required to apply technology such as computers in the educational setting. Without knowledge in technology, teachers cannot maximize their capability in school anymore. Many classrooms have a smartboard, computers, and other technology devices. No one doubts the necessity of using computers in the educational setting. However, the effectiveness of computer-based teaching or learning varies depending on how the computer programs are used. The computer program may be used as presentation, guided practice, or independent practice. This difference in application might affect the efficiency of CAI. Also, some programs may be developed by researchers, focusing on targeted tasks, while other programs might be a commercial program without specific target skills. The difference of a developed setting could affect the results.

Computer-assisted instruction has been used to improve problem-solving skills in mathematics curriculum, but the effectiveness of CAI is still in the infancy stage of research and continues to be developed. More research is needed to measure the efficiency of the CAI intervention. Future research may need to examine the function of different components of CAI and implement studies to determine the effectiveness of this emerging intervention.

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