Effects of Computer-Mediated Versus Teacher-Mediated Instruction on the Mathematical Word Problem-Solving Performance of Third-Grade Students With Mathematical Difficulties

Jayne M. Leh, PhD[1] and Asha K. Jitendra, PhD[2]

Abstract

This study compared the effectiveness of computer-mediated instruction (CMI) and teacher-mediated instruction (TMI) on the word problem-solving performance of students struggling in mathematics. Both conditions integrated cognitive modeling that focused on the problem structure using visual representations with critical instructional elements specifically targeting the needs of at-risk students. Participants were 25 third-grade students with mathematics difficulties who were randomly assigned to either a TMI or a CMI condition. Results indicated no statistically significant between-condition differences at posttest and on a 4-week retention test of word problem-solving. Furthermore, there was no transfer of the word problem-solving skills to a school administered, standardized mathematics achievement test. Implications for educational practice are discussed.

Keywords

mathematics word problem-solving, computer-assisted instruction

Arithmetic word problems play an important role in the elementary school mathematics curricula in terms of developing general problem-solving skills (Verschaffel, Greer, & De Corte, 2007). Word problem solving requires students to apply previously learned mathematical skills and thus promotes the understanding of basic operations and whole number arithmetic (Van de Walle, Karp, & Bay-Williams, 2010). Such applications "provide a good way to transfer students' mathematical experiences to various situations in the real world" (Chen & Liu, 2007, p. 106). However, word problem solving is challenging for many students, especially students at risk for mathematics difficulties who have difficulties with working memory, language, attentive behavior, and simultaneous storage and processing speed of information (Andersson, 2008; Andersson & Lyxell, 2007; Fuchs et al., 2010; Geary, Hoard, Byrd-Craven, Nugent, & Numtee, 2007; Marzocchi, Lucangeli, De Meo, Fini, & Cornoldi, 2002; Swanson, Jerman, & Zheng, 2008).

Research suggests that the low mathematics achievement of many at-risk students is due to lack of motivation (National Research Council [NRC], 2001; see Woodward, 2011). Traditional mathematics curricula typically use rote procedures that do not improve mathematical understanding and are not motivating to students (Woodward, 2011).

Furthermore, a history of unsuccessful learning culminates in math anxiety for many at-risk students (Ashcraft, Krause, & Hopko, 2007). Evidently, getting students engaged using real-world applications and technology is critical to improve their problem-solving skills and increase their productive dispositions (NRC, 2001). Technology, in particular, is touted as an important means to reduce math anxiety and motivate student learning (e.g., Chen & Liu, 2007; Hasselbring, Goin, & Bransford, 1988; Symington & Stranger, 2000). Several policy documents emphasize the importance of infusing technology in mathematics classrooms (National Mathematics Advisory Panel [NMAP], 2008; U.S. Department of Education, 2002) to enrich the learning environment, close the achievement gap, and act as a catalyst to boost the percentage of U.S. college graduates (U.S. Department of Education, 2010).

[1]The Pennsylvania State University, Reading, USA
[2]University of Minnesota, Minneapolis, USA

Corresponding Author:
Jayne M. Leh, Elementary Education Program, Penn State Berks, 237 Gaige Building, Tulpehocken Road, P.O. Box 7009, Reading, PA 19610.
Email: jml53@psu.edu

Computers offer certain affordances that are critical to mathematics learning, such as the ability to graphically represent problems using interactive physical motion (Jackiw & Sinclair, 2009; Noble, Nemirovsky, Wright, & Tierney, 2001; Seo & Woo, 2010) and facilitate the interactive analysis of complex mathematical relationships (Hegedus & Armella, 2009; Noble et al., 2001; Roschelle, Kaput, & Stroup, 2000). Although computer-assisted instruction (CAI) in general leads to increases in motivation, computational skills, and procedural fluency for elementary school students with and without disabilities (Fitzgerald, Koury, & Mitchem, 2008; Hegedus & Armella, 2009; Ke, 2008; Scheiter, Gerjets, & Schuh, 2010; Wilson, Majsterek, & Simmons, 1996), the effectiveness of CAI on mathematics problem solving in particular is less clear for these students, especially students struggling with mathematics (Jaspers & Van Lieshout, 1994; Slavin & Lake, 2008; Stellingwerf & Van Lieshout, 1999). Results of a recent meta-analysis of 11 investigations of CAI in mathematics that included a variety of programs (e.g., drill and practice, tutorials, games) for students with learning disabilities at the elementary and secondary levels demonstrated mixed effects due to several methodological problems, such as lack of control of instructional variables in studies comparing CAI with teacher-directed instruction, short duration of CAI sessions, and problems with the outcome measures (Seo & Bryant, 2009). In general, the effects of research comparing computer-mediated instruction (CMI) with teacher-mediated instruction (TMI) in mathematics are diffuse, with mostly small effects favoring CMI in larger experimental investigations (Dynarski et al., 2007; Lou, Abrami, & D'Apollonia, 2001).

On the basis of findings of CAI studies of word problem solving for students with learning problems (e.g., Gleason, Carnine, & Boriero, 1990; Mastropieri, Scruggs, & Shiah, 1997; Shiah, Mastropieri, Scruggs, & Fulk, 1994-1995), it is not clear whether computer affordances provide a superior learning environment when compared with a teacher-mediated environment. The one study of CAI involving word problem solving (Gleason et al., 1990) that was carefully designed to control for instructional elements (Coyne, Kameenui, & Carnine, 2007; Smith & Geller, 2004) investigated the effectiveness of a Computer-Assisted Story Problems condition and a Teacher-Directed Story Problems condition. Results showed that middle school students in both conditions improved their word problem-solving performance from pretest to posttest. However, the difference between conditions at posttest was not statistically significant, suggesting that CAI is just as effective as TMI, especially when instruction in both conditions incorporated key instructional elements. In sum, the quality of instruction rather than the medium of instruction is critical to improving student learning. In light of recent research on word problem-solving instruction for students with learning disabilities and those at risk for mathematics difficulties,

explicit instruction in priming the underlying word problem structure is known to enhance problem-solving performance (Gersten, Beckman, et al., 2009; Gersten, Chard, et al., 2009; NMAP, 2008). When students are instructed to attend to the underlying problem structure, they are better able to understand the problem, and the use of instructional materials such as visual representations helps them to organize and represent the problem. Furthermore, word problem-solving instruction that addresses the issue of motivation for students struggling with mathematics should incorporate motivational strategies (e.g., praise) or embed appropriate tools that encourage active engagement of students (Gersten, Beckmann, et al., 2009). Animation, for example, is a feature embedded in many CAI programs to motivate different learners, produce positive attitudes, and improve learning (e.g., Rosen, 2009; Scheiter et al., 2010; Scheiter & Gerjets, 2010).

The aim of this study, therefore, was to evaluate the effectiveness of CMI and TMI on the word problem-solving performance of third-grade students struggling in mathematics while controlling and balancing the key instructional features (e.g., priming the problem structure, use of visual representations) deemed critical to successful word problem-solving performance across conditions. Specifically, instruction in both conditions integrated cognitive modeling to identify the problem structure with critical instructional elements (e.g., explicit instruction, providing immediate and corrective feedback) specifically targeting the needs of at-risk students. For the purpose of this study, we used the term *computer-mediated instruction* to refer to instruction provided by the computer similar to CAI. However, CMI differs from CAI in that even though the computer provided all instruction, the teacher operated the software and facilitated implementation of that instruction in CMI. In addition, we examined the maintenance of the word problem-solving skills across time (on a retention test) and the transfer of the learned skills to a school administered, standardized mathematics achievement test.

Method

Participants

The participants of the study were 25 third-grade students attending six classes in a suburban public elementary school in the northeast United States. Students were selected based on scores from the Total Mathematics score of the *Stanford-10 Achievement Test–Tenth Edition* (SAT-10; Harcourt Brace & Company, 2002) from spring of second grade. All third-grade students scoring at or below the 50th percentile ($N = 43$) were selected to participate in the study, but the sample was reduced to 26 students who provided informed parent consent. We selected the 50th percentile as our cutoff score to include children who score below average

Table 1. Demographic and Screening Data by Condition.

Demographic/screening items	CMI (n = 13)		TMI (n = 12)		χ^2/F	df	p
	n	%	n	%			
Gender					3.22	1	.073
Male	4	30.8	8	66.7			
Female	9	69.2	4	33.3			
Ethnicity					1.13	1	.288
Caucasian	13	100.0	11	91.7			
Other	0	0	1	8.33			
Eligible for free/reduced-price lunch	2	15.4	6	50.0	3.44	1	.064
Special education status	2	15.4	3	25.0	0.36	1	.548
Title 1 math	4	30.8	3	12.5	0.10	1	.748
SAT-10 MPS, M (SD)	564.31 (17.59)		567.60 (16.58)		0.15	1, 23	.698
Range	512–576		533–576				

Note: CMI = computer-mediated instruction; TMI = teacher-mediated instruction; SAT-10 MPS = *Stanford Achievement Test–Tenth Edition*, Mathematics Problem Solving subtest.

to low average on tests of mathematics achievement. This cutoff score was used to ensure adequate sample sizes (Geary, Hamson, & Hoard, 2000; Jordan, Hanich, & Kaplan, 2003; Mazzocco, 2007) and also to identify students who would benefit from the word problem-solving intervention. At the same time, we caution readers about the limitation to the study with regard to our sample that could include students in the average range and remind readers that findings of this study are impacted by this sample. Blocking by scores on the Mathematical Problem Solving (MPS) subtest score of the SAT-10, we randomly assigned students to either the CMI or TMI group. The final sample contained 25 students, excluding 1 student in the TMI condition who moved during the school year and did not complete the posttests. Table 1 provides demographic information for participating students.

Three female, Caucasian teachers in the school taught the treatment groups, with one teacher assuming the role of lead teacher and at least one other teacher providing additional support (e.g., answering questions) to students during whole-group instruction for each condition. Based on a total of 15 sessions in each condition, Teacher 1 taught 9 CMI sessions (60%) and 3 TMI sessions (20%), Teacher 2 taught 2 CMI sessions (13.3%) and 12 TMI sessions (80%), and Teacher 3 taught only 4 CMI (26.7%) sessions. All teachers held a master's degree in education and were certified in elementary education. The total number of years teaching was 11, 35, and 9 years for Teachers 1, 2, and 3, respectively.

Intervention

Both conditions. During the daily 50-min core mathematics instructional period, all students received instruction from their classroom teachers using the district-adopted mathematics textbook, *Investigations in Number Data, and*

Space (Kliman, Russell, Wright, & Mokros, 2006). Students in the study then received an additional 50 min of supplemental word problem-solving intervention using the assigned program. The CMI used the *GO Solve Word Problems* computer software program (Tom Snyder Productions, 2005), and the TMI used the *Solving Math Word Problems: Teaching Students With Learning Disabilities Using Schema-Based Instruction* curriculum (Jitendra, 2007). We selected these programs because the word problem-solving interventions are grounded in schema theories of cognitive psychology, with instruction focusing explicitly on the underlying problem structure that has shown to be effective in improving student learning. A review of the two programs revealed that they are more similar than different with regard to instructional practices (see Table 2). Furthermore, we balanced instruction in both programs with regard to sequencing of problem types, instructional time, and opportunities for practice. Because conditions alternated instructional days, students received whole class instruction in their assigned group two to three times per week for 50 min, over a period of 6 weeks. In both conditions, instruction comprised 15 lessons that focused on the same category of word problems (e.g., addition and subtraction one-step and two-step problems involving *Group* or *Parts and Total, Change,* and *Compare* or *Comparison* problems) and taught in the same sequence. The 15 lessons comprised 4 lessons each of the three problem types and 3 review lessons. *Group* or *Parts and Total* problems consist of two distinct groups or subsets that, when combined, form a new larger set. *Group* problems represent a part-part-whole relationship, which is static (see Figure 1a). *Change* problems begin with an initial quantity, and a direct or implied action causes either an increase or decrease in the initial quantity. The three sets of information in a change problem are the beginning, change, and ending. The object

Table 2. Characteristics of Intervention Conditions.

Instructional elements	Conditions	
	CMI	TMI
Priming the underlying mathematical situation		
The program highlights problem types (*Group* or *Part and Total, Change,* and *Compare*)	+	+
Using schematic diagrams		
The program provides schematic diagrams for students to organize information in the problem	+	+
Strategy instruction		
The program uses explicit instruction and cognitive modeling of the word problem-solving process	+	+
Using a think-aloud procedure		
The strategy instruction incorporates think alouds to monitor and reflect on the problem-solving processes	+	+
Instructional paradigm		
The program uses a model/guided practice-independent practice, with a focus on interactive activities during the model/guided practice phase	+	+
Instructional feedback		
The program provides students with immediate and corrective feedback	+	+
Recording word problem-solving activities on worksheets		
Students write on worksheets that include schematic diagrams to organize their work and complete calculations when practicing solving word problems	+	+
Monitoring student progress		
The program allows teachers to monitor and index student growth over time	+	+
Animated instruction		
The program uses engaging animations to illustrate each mathematical situation	+	+
Personalization of word problems		
The program customizes word problems to motivate student learning	+	

Note: CMI = computer-mediated instruction; TMI = teacher-mediated instruction.

identity is always the same for the beginning, change, and ending amounts (see Figure 1b). *Compare or Comparison* problems entail comparing two disjoint sets, and the relation between the two sets is static (see Figure 1c). In the first phase of problem solving instruction for each problem type, all students received one session of instruction in identifying and categorizing the problem type and organizing information in the story situation using the schematic diagrams. This problem identification and representation phase did not require solving for the unknown information and was followed by three lessons on problem solving for each problem type. The text-to-speech feature in CMI or teachers in the TMI condition read all problems to students during the intervention. Student materials included a clipboard, a laminated sheet of scratch paper, and a dry erase marker with an attached eraser and a pencil.

CMI. In the CMI condition, students received word problem-solving instruction from Module 1 (i.e., *Parts and Total, Change, Comparison*) of *GO Solve Word Problems.* To ensure that students had adequate technical and software skills (e.g., mouse usage, keyboarding, software access), they participated in two software and technical training sessions (a total of 65 min) prior to the word problem-solving intervention. One teacher presented the instructional sessions, and at least one additional teacher aided during the lesson. The teacher conducted whole-group instruction by initially projecting the computer program on a large screen in the classroom and discussed the problem solution process as a group before students worked on their individual computers using headphones. Initially, the program demonstrated the importance of understanding word problems by recognizing mathematical situations in word problems followed by planning to solve the problem using addition or subtraction. Then, instruction involved tutorials for each problem type.

In the first lesson, several examples are used to model identifying the problem features specific to each problem type and demonstrate organizing information in the problem using schematic diagrams, including labeling the quantities using drop-down boxes without solving for the unknown (see Figure 1). The second lesson allows students to use the steps learned in the previous lesson to identify and represent the problem and solve the problem by adding or subtracting based on information in the schematic diagram. The third lesson includes more complex problems (see Figure 2), and the fourth lesson consists of problems with large numbers (e.g., "*A band came to town and played at two clubs. At the Paradise Club, the band sold 124 more tickets than at the Castaway Club. At the Paradise Club, the band sold 2,630 Tickets. How many tickets did the band sell at the Castaway Club?*").

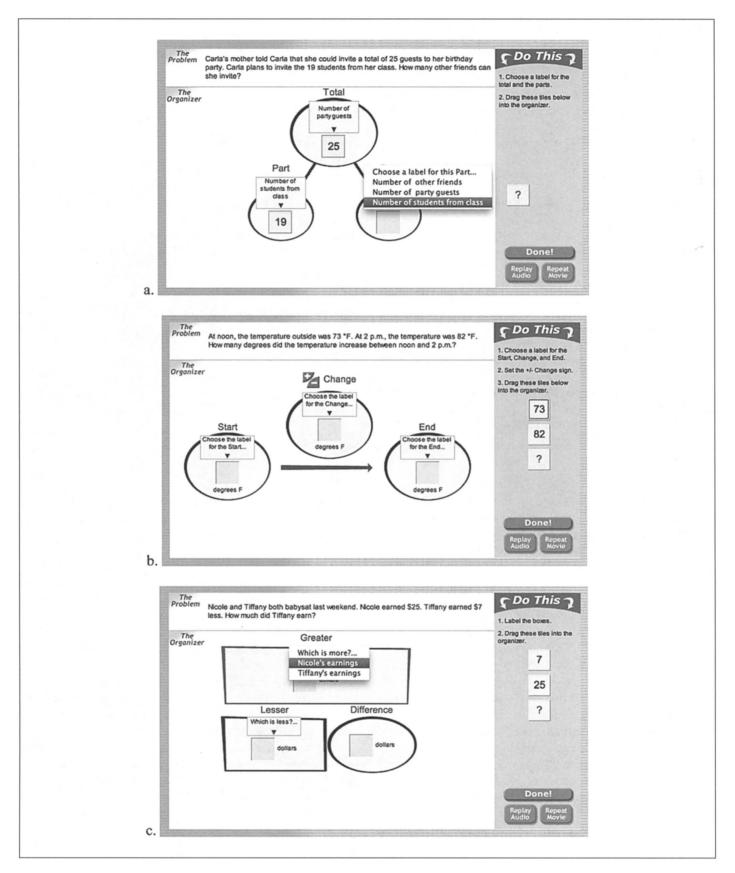**Figure 1.** Screen shots for (a) *Parts and Total*, (b) *Change*, and (c) *Comparison* problem types from the *GO Solve Word Problems*, by Tom Snyder Productions, 2005.
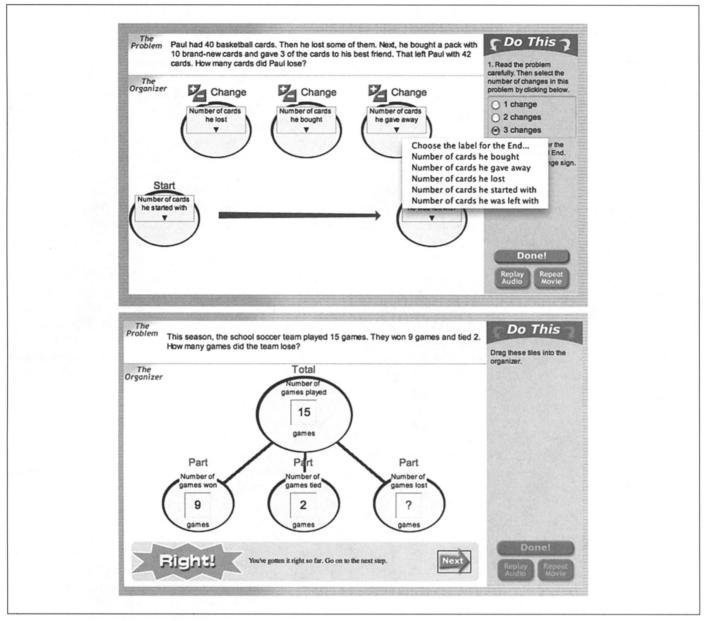Note: Copyright 2005 by Tom Snyder Productions. Used with permission.

Figure 2. Screen shots of multistep problems in the *GO Solve Word Problems*, by Tom Snyder Productions (2005).
Note: Copyright 2005 by Tom Snyder Productions. Used with permission.

To guide the problem-solving process, the program includes a three-step procedure of (a) reading the problem to understand the problem, (b) identifying problem features associated with the problem type to map onto the schematic diagram, and (c) computing the answer based on information in the diagram to guide the problem-solving process. The software also includes text-to-speech features and provides metacognitive hints, which add to the cognitive content of the word problems. Instruction focuses on modeling of metacognitive skills using a think-aloud procedure. For example, in the following *Parts and Total* problem "*There are 15 people in the swimming pool. 7 are adults. The rest are kids. How many kids are in the swimming pool?*" an adult reads the problem and reflects on it. The adult states,

"*In this problem, we know the total and we know one of the parts—the number of adults. It asks: how many kids are in the swimming pool? Remember, before you can solve the problem, you have to make sure you know what the question is asking! So, how would you solve this problem?*" Then a child responds, "*Well, I know that the parts add up to make the total, so to find this part, I could subtract! There are 15 people total. If I subtract the 7 adults, that leaves 8 kids. There are 8 kids in the pool!*"

GO Solve Word Problems incorporates explicit error correction procedures using a text box that provides a hint regarding the type of error whenever students enter labels, number tiles to represent quantities, or answers that are inaccurate. The software also prompts students to place the

tiles to match the information in the problem (e.g., "You need to put the total and parts tiles into the organizer. Remember, the parts add up to the total."). If the student still does not correctly respond, a text box appears that has the student request help from the software. The "help" options either allow students to see one step toward the solution or the correct answer in that sequence of steps.

For independent practice, the program prompts students to personalize the word problems to access the problem context and motivate learning. Furthermore, the computer screen provides students with a digital notebook, a calculator (this option was not used in the study), and three hints (blank schematic diagram, labels, and quantities to enter in the diagram) to access the answer. Following an independent practice session, the program displays individual progress reports that allow the teacher and student to monitor progress, but this feature was not used.

TMI. In the TMI condition, students were taught to solve word problems from the addition and subtraction strand of the curriculum (Jitendra, 2007). This strand consists of 21 lessons, with scripted teaching materials and supporting materials that include schematic diagrams, problem-solving checklists, teaching masters, student worksheets, reference guides, answer sheets, and word problem-solving progress-monitoring probes. To control for the number of sessions and time across the two conditions, we selected a total of 15 lessons for inclusion in the study. This resulted in eliminating 3 lessons related to the fading of schematic diagrams for each problem type and 3 lessons related to cumulative review. In the TMI condition, the emphasis in the first and second lessons is the same as in the CMI condition. The third lesson is an extension of the second lesson and includes multiple examples to provide students with extensive practice of applying the strategy instruction. The fourth lesson consists of problems presented in the form of text, graphs, tables, and pictographs. Unlike the CMI condition, all problems in the program do not include large numbers, because the focus is on problem solving rather than computational skills. Multistep problems that involve chaining two schemata (e.g., *Compare* and *Group*) are introduced after instruction in one-step problems.

Teachers in the TMI condition modeled the word problem-solving strategy instruction through use of think alouds with time for guided practice that involved extensive teacher–student interactions and opportunities for providing feedback to students. When students struggled with organizing information in the problem using the schematic diagrams, teacher instructions directed students to examine the problem features related to the problem type. Following is a description of strategy instruction and embedded think alouds to solve word problems.

Using a checklist of a four-step heuristic, FOPS (*F*ind the problem type, *O*rganize information in the problem using a diagram, *P*lan to solve the problem, *S*olve the problem), students are asked to engage in the first step, Find

the Problem Type. The teacher reads and restates the problem to understand it and asks questions to identify and categorize the problem type. For example, in the following *Compare* problem "*Nathan picked 11 green beans. He picked 7 fewer carrots than green beans. How many carrots did Nathan pick?*" students think aloud, "*The compare words* fewer *carrots* than *in the comparison sentence tell me it is a Compare problem. This problem is comparing the number of green beans to the number of carrots.*" For the second step—Organize Information in the Problem Using a Diagram—students are first taught to attend to the comparison statement to identify the two things compared in the problem (number of green beans and carrots), determine the larger of the two quantities (i.e., carrots), and the difference amount to write in the *Compare* diagram. Next, the teacher has students read the remaining information in the problem to identify the quantities given and not given to write in the diagram. Students summarize the information in the completed diagram and determine what needs to be solved. During this step, students underline important information and circle the given quantities to highlight the relevant information in the problem. Students are prompted to ask questions such as "What is the comparison statement in the problem? How do you know?" In the third step—Plan to Solve the Problem—students are instructed to determine whether to add or subtract to solve the problem. Students learn to reason that because the unknown is the smaller quantity (part), they would have to subtract the difference (part) from the larger quantity (total) to solve for the smaller quantity. Students then solve for the smaller quantity in the final step—Solve the Problem Using the Operation Identified in the Previous Step and Check Your Answer (Does the answer make sense?). Given that student errors typically involve inaccurate representation when translating information in the problem or incorrect computation, feedback and error correction procedures directly address these features in the program. Teacher reference guides and student answer sheets in the program provide worked examples to highlight the problem-solving processes, and written explanations are used to describe the problem-solving process. Although the program includes word problem-solving probes to monitor student progress, they were not used.

Training and Fidelity of Treatment Implementation

All teachers participated in two 4-hr training sessions and two 30-min booster sessions to become familiar with and practice the word problem-solving programs. The training content and focus emphasized word problem-solving instruction, specifically in terms of program features and strategy instruction. Teachers were encouraged to become familiar with the programs prior to implementation. Each teacher completed training sessions with the first author, who assessed for mastery of the program content. Teachers

met with the first author for a 30-min booster session before the implementation of the first lesson on *Change* and *Compare* problem types to discuss and review the critical aspects of each problem type and the FOPS strategy steps.

Two observation instruments were used to measure teachers' adherence to the implemented intervention (CMI or TMI). Three research assistants observed 14 of the 15 lessons and independently completed a checklist of essential features of instruction for each condition in terms of adherence to strategy instruction (e.g., priming the problem structure using visual representations), use of instructional materials (schematic diagrams, worksheets), monitoring student work, and instructional time. The mean percentage of treatment fidelity for each condition was 100%. In addition, interobserver agreement, calculated on 40% of the sessions, was 100%.

Measures

Screening. The screening measure was the Mathematics subtest of the SAT-10 that students completed at the end of second grade as part of the district-wide accountability testing. The SAT-10 is a group-administered, multiple-choice test that includes two mathematics subtests, Mathematics Problem Solving (SAT-9 MPS) and Mathematics Procedures (SAT-9 MP). The MPS subtest includes 46 items and assesses number theory, geometry, algebra, statistics, and probability. The MP subtest measures computational skills with 30 items. Coefficient alphas are .83 for MPS and .80 for MP.

Assessing treatment effects. To assess students' ability to solve word problems, we administered a researcher-developed word problem-solving test (see Jitendra et al., 2007) immediately before (pretest) and after the intervention (posttest) and 4 weeks after the intervention ended (maintenance). Students completed the untimed word problem-solving test, in which word problems were read to students on an as-needed basis. The test included 16 problems (none of which were used for instruction) and represented the 3 taught problem types (*Group* or *Parts and Total, Change*, and *Compare*). The problems were scored to allow credit for the correct number sentence, correct computation and labels in answers. A research assistant scored all protocols using answer keys, and a second research assistant independently rescored 36% of the protocols. Interscorer agreement was 100%. Alphas for the pretest, posttest, and maintenance test were .82, .72, and .76, respectively. Correlations with the MPS score of the SAT-10 were .64, .65 and .71, respectively.

In addition, we collected student scores from spring of Grade 3 on the mathematics subtest of the *Pennsylvania System of School Assessment* (PSSA). The PSSA is a group-administered assessment designed to measure a student's attainment of the academic standards (e.g., number systems

and relationships, mathematics reasoning and connections, measurement and estimation, geometry, algebra, statistics and data analysis). The mathematics test includes both multiple-choice questions and open-ended performance tasks. Reliability exceeds .90. Correlations with the *Comprehensive Test of Basic Skills* (CTBS)/TerraNova and *California Achievement Test, Version 5* (CAT-5) are around .80, and predictive validity with the *Stanford Achievement Test* (SAT) is about .90.

Assessing student attitudes and teacher perceptions. We assessed students' attitudes about solving word problems immediately following the end of the treatment using a modified version of the *Instructional Material Motivation Survey* (IMMS; Huang, Huang, Diefes, & Imbrie, 2006; Keller, 1987). Students were asked to rate 16 items on a 4-point scale of 0 to 3 (i.e., *no, not so much, sort of,* and *yes*). In addition, two questions asked them to indicate what they liked and did not like about solving word problems. The internal consistency estimate, based on Cronbach's alpha, for the original 36-item IMMS survey was .96, and alpha on the 16-item survey for this sample was .76. Teachers in both conditions were asked to rate their perceptions about their assigned program using a 9-item survey with a five-tiered scale and five open-ended items.

Results

Treatment effects. Table 3 shows the means and standard deviations of the measures by treatment. There was no statistically significant between-group pretest difference on the word problem-solving pretest, $F(1, 23) = 1.36, p = .256$. Thus, we conducted separate ANCOVA with the pretest as a covariate to maximize power of the design. On the word problem-solving posttest scores, the ANCOVA showed no statistically significant main effect of treatment group, $F(1, 23) = 0.10, p = .754, d = .15$. Similarly, on the word problem-solving delayed posttest scores, the ANCOVA showed no statistically significant main effect of treatment group, $F(1, 23) = 1.58, p = .221, d = .52$. Because the PSSA was administered only in third grade, we did not have the previous year's PSSA scores and used the commercial problem-solving measure (MPS of the SAT-10) administered prior to the intervention as the pretest covariate. Results of the ANCOVA indicated no statistically significant main effect of treatment group, $F(1, 22) = 0.74, p = .400, d = -.31$.

Student attitudes and teacher perceptions. On the total attitude score, students in the TMI condition reported more positive attitudes ($M = 32.0, SD = 9.3$) than did students in the CMI condition ($M = 28.8, SD = 5.9$), although these differences were not statistically significant, $t(23) = 1.05, p = .307$. On the open-ended questions, students in the TMI condition reported that they most liked doing and understanding word problems, but they were sometimes bored

Table 3. Means and Standard Deviations for Measures by Condition.

| | Condition | | | | | |
| Measure | CM (n = 13) | | TM (n = 12) | | Total | |
	M	SD	M	SD	M	SD
WPS						
Pretest	18.15	4.23	15.50	6.94	16.88	5.73
Posttest	24.04	6.84	26.04	3.57	25.08	5.37
Adjusted posttest	25.37		24.77		25.07	
Delayed posttest	25.46	4.79	21.67	6.71	23.64	5.99
Adjusted delayed posttest	25.03		22.14		23.59	
PSSA mathematics posttest (SS)	1,264.15	70.55	1,301.00	131.55	1,281.84	103.80
Adjusted PSSA posttest (SS)	1,267.44		1,297.44		1,282.44	

Note: CM = computer mediated; TM = teacher-mediated; WPS = word problem solving; PSSA = *Pennsylvania System of School Assessment*; SS = scaled score.

with the instruction. Students in the CMI condition stated that they most liked the materials (e.g., computers, diagrams) but did not like the difficulty of the tasks. Specifically, word problems presented during independent practice were lengthy (sometimes half a page) and included unfamiliar vocabulary.

All teachers believed that both programs were comparable in terms of providing students with appropriate levels of engagement, feedback, as well as enhancing students' word problem-solving performance. Teachers rated *GO Solve Word Problems* to be more efficient in providing immediate and personal feedback. Two of the three teachers noted that they were more likely to use the TMI program again as opposed to the CMI program. Concerns with CMI included the unpredictability of the software, inflexibility of moving between modules, and the excessive time necessary to become familiar with the software. In addition, teachers mentioned that the success of the instruction depended on available technical support and reported that the software was difficult to implement seamlessly in whole-group instruction; however, they expressed that the diagrams in the program piqued students' interest and were beneficial. One teacher noted the benefits of using the reports generated by the computer (even though this feature was not used in the study), and because children work at their own pace and are offered immediate feedback, this would free teacher time to address the needs of other students. Overall, all three teachers indicated their preference for TMI. Specifically, they mentioned the benefits of the FOPS checklists, schematic diagrams, underlining and circling important information, organizing information, retelling the problem, and learning to solve using a paper-and-pencil format.

Discussion

The present study did not support the benefits of CMI over TMI when controlling for critical instructional variables.

Students in both conditions performed comparably on the word problem-solving measure immediately following the intervention and 4 weeks later. These findings converge with prior findings that the quality of instruction rather than the learning environment is more important (Chang, Sung, & Lin, 2006; Gleason et al., 1990). Given that we controlled for all critical instructional variables (except for the presence of animation in CMI condition) across the two conditions, the finding that the mode of delivery is not consequential to the word problem-solving outcome is revealing when considering the evidence supporting the use of technology for representing mathematical relationships (Noble et al., 2001; Roschelle et al., 2000). Preliminary research on computer images suggests that simple visual graphics result in few conceptual errors in word problem solving, whereas rich visual graphics lead to more procedural errors (McNeil, Uttal, Jarvin, & Sternberg, 2009). However, because the *GO Solve* program used simple animations that were not distracting, this issue of the presence of animations is moot. Although the results did not indicate a statistically significant between-condition effect on the retention test, the medium effect size ($d = .52$) favoring the CMI condition is practically significant. This effect is notable given that at-risk students have difficulty maintaining the learned skills over time. Although the nonsignificant differences may be due to chance, there is a need for future research involving a large-scale experimental study with appropriate power to yield statistically significant differences.

We also examined students' outcomes on the statewide mathematics achievement test with no significant between-condition effects. Although this finding was not surprising as the focus of the study was on improving students' word problem-solving performance without expected improvements on overall mathematics achievement, previous research with TMI (i.e., schema-based instruction) has shown positive effects for low-achieving students and students

with disabilities (Jitendra et al., 2007). Even though the result was not statistically significant, the effect size ($d = -.31$) favoring the TMI condition has considerable practical significance. This finding is encouraging given that transfer of learning is difficult to effect for at-risk students, again suggesting the need for large experimental studies to examine the effects on at-risk students. We also examined the extent to which students in the two conditions differed on a measure of student attitudes associated with solving word problems, with no significant effects.

We interpret the findings from this study to suggest that 6 weeks of word problem-solving instruction that incorporates essential instructional elements (e.g., priming the mathematical structure, using schematic diagrams) is effective and feasible for schools to implement using computers or teachers. However, considering that all three teachers in this study preferred the TMI program compared with the CMI program, it may be necessary to provide not only teacher training but also technical support to alleviate teachers' discomfort and unpreparedness to infuse technology into instructional practices (Fouts, 2000; Rowand, 2000).

Limitations

The randomized design and the control of critical instructional variables across the two conditions are two strengths of the study. However, we caution readers regarding interpretation of the results in light of the small sample size and the risk of Type II error (i.e., failure to detect statistically significant effects due to low power). Although not statistically significant, the gender imbalance between conditions is another potential limitation of the study, given that twice as many males as females were in the TMI group compared with more than twice as many females as males in the CMI group. However, the impact this might have had on the study is not clear given that findings from studies on gender differences in the prevalence of mathematics learning disability are mixed. Some studies indicate a preponderance of male ratio of 1.6 to 2.2:1 for math calculation and reading difficulties (Badian, 1999; Barbaresi, Katusic, Colligan, Weaver, & Jacobsen, 2005), and other studies show no gender differences (Shalev, Auerbach, Manor, & Gross-Tsur, 2000).

It is worth noting that although there were some technical problems during implementation of the CMI (e.g., nonfunctional headphones and failed log-in attempts), these problems were fairly limited and are typical of those encountered in computer classrooms, and the critical content covered in the instructional sessions was completed on schedule. However, we reduced the TMI curriculum in the study from 21 lessons to 15 lessons to be able to complete the study in 6 weeks, and the teacher deviated, albeit infrequently, from the teaching script by including concrete materials to represent information in the problem when

students evidenced difficulty in understanding the underlying concepts/quantities. Another limitation is that with teachers sharing teaching responsibilities (cofacilitated) across conditions, the percentage of lessons taught by teachers varied by condition. This concern is an artifact of a teacher facilitating rather than implementing the intervention or teacher availability based on scheduling. At the same time, a potential risk of contamination of instruction in the two conditions was not an issue because materials for the computer condition were never accessed during TMI, and the risk of transfer from TMI to CMI was moot given that the computer provided all instruction.

Implications for Practice

Several implications for practice are relevant given the caveat of pending additional research. First, both CMI and TMI that incorporate critical instructional elements should be useful to teachers as they implement instructional practices that allow at-risk students to access challenging mathematics content (i.e., word problem solving). Second, results show that CMI and TMI can be used in a complimentary fashion with technology supporting the teacher rather than replacing the teacher. Following teacher-implemented instruction, technology may be used to further support students struggling in mathematics.

Declaration of Conflicting Interests

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