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Impact of Small-Group Tutoring Interventions on the Mathematical Problem Solving and Achievement of Third-Grade Students With Mathematics Difficulties

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Abstract

This intervention study compared the efficacy of small-group tutoring on the mathematics learning of third-grade students at risk for mathematics difficulty using either a school-provided standards-based curriculum (SBC) or a schema-based instruction (SBI) curriculum. The SBI curriculum placed particular emphasis on the underlying mathematical structure of additive problems to represent and solve word problems. At-risk students (N = 136) from 35 classrooms scoring below a proficiency level on their district accountability assessment were assigned randomly to treatment groups. Results indicated interaction effects on the word problem-solving (WPS) posttest and retention tests such that SBI students with higher incoming (pretest) WPS scores outperformed SBC students with higher pretest scores, whereas SBC students with lower pretest scores outperformed SBI students with lower pretest scores. No effects were found on number combinations automaticity, and mathematics and reading achievement. Implications to improve the problem-solving performance of at-risk students are discussed.

Keywords

mathematical word problem solving, schema-based instruction, standards-based instruction

Mathematical problem solving represents one of the most important aspects of a school curriculum (National Mathematics Advisory Panel, 2008). The emphasis on story problems, in particular, in school mathematics textbooks and on state accountability tests points to the salience of targeted instruction in story problems. Understanding and solving story or word problems (WPs) not only requires selecting and applying strategies but also understanding the "words, phrases, sentences, and propositions" to generate a "coherent and meaningful interpretation of word problems" (Swanson & Beebe-Frankenberger, 2004, p. 471). Although many students experience difficulties in solving WPs, there is research indicating that children at risk for mathematics difficulty (MD) evidence significant problems in solving simple one-step story problems (Hanich, Jordan, Kaplan, & Dick, 2001; Jordan & Hanich, 2000; Jordan, Hanich, & Kaplan, 2003; Jordan & Montani, 1997) and multistep complex problems, including problems containing irrelevant information (Fuchs & Fuchs, 2002; Parmar, Cawley, & Frazita, 1996; Russell & Ginsburg, 1984). Many researchers consider difficulties not only with specific problem-solving processes (establishing a problem representation and developing a solution plan) but also deficits in several other processes (i.e., arithmetic fact retrieval, multidigit calculation, understanding calculation principles) to account for these children's difficulties with WP solving (WPS; Andersson, 2008).

Findings from meta-analyses of intervention research in mathematics indicate that teaching students with MD to use heuristics and explicit instruction leads to increases in computation and WPS (Baker, Gersten, & Lee, 2002; Gersten

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et al., 2009). Empirical studies have reported benefits that explicit strategy instruction has in improving these students' learning, such as automaticity of basic facts and strategy use (Kroesbergen, Van Luit, & Maas, 2004). Van Luit and Naglieri (1999) noted that explicit strategy instruction occurs when "students are taught to flexibly apply a small repertoire of strategies that reflect the processes most frequently evidenced by skilled students" (p. 99). In addition, the benefits of flexible groupings (i.e., one to one, small groups) are well documented in addressing the needs of at-risk students (Swanson, Hoskyn, & Lee, 1999). Small-group interactions that encourage and prompt students to think aloud as they do mathematics, with peers providing feedback on their strategy use, is known to improve student learning (Van Luit & Naglieri, 1999). Therefore, the purpose of this study was to compare the efficacy of small-group tutoring interventions on the mathematics learning of third-grade students with MD using either schema-based instruction (SBI) or a school-provided standards-based curriculum (SBC). We focused on two critical components of mathematical performance—WPS and automaticity of addition and subtraction number combinations (NCs). Both SBI and SBC include critical elements identified as enhancing student learning (e.g., developing conceptual understanding, actively engaging students by providing opportunities for problem solving, reasoning, connecting, and communicating). The curricula, however, differ in that teachers' use of an inquiry-based, student-directed approach (e.g., student-invented algorithms, diverse ways of representing a problem) is a defining element of standards-based instruction, whereas SBI is characterized by explicit, teacher-mediated instruction (e.g., traditional algorithms, teacher-provided schematic representations specific to a problem type).

SBI

Our SBI approach, which is known to be effective in improving students' understanding of story problems and promote meaningful learning (retention of problem solving; Jitendra et al., 2007), is built on a foundation of schema theory that emphasizes the acquisition of the problem schema, or underlying structure of the problem, as critical to successful problem solving (Kalyuga, 2006). Because multiple elements of information are grouped into and conceptualized as a single schema, recognizing a problem's schema reduces the working memory load during cognitive processing. Furthermore, instruction that stresses the use of a small repertoire of problem types becomes automated with practice and the learner can focus on more complex problems that combine different schemata. There is empirical support for problem-solving instruction in elementary grades that makes use of schemata involving additive problem types (e.g., *Change, Group, Compare*, see Carpenter & Moser, 1984; Marshall, 1995; Riley, Greeno, & Heller, 1983, for a semantic classification of WPs); this type of instruction is also consistent with the national standards (see Common Core State Standards for Mathematics, 2010; National Research Council, 2009).

Although many students have learned to compute answers when solving problems, they may not necessarily understand the procedures or monitor their understanding to effectively solve novel problems. Our SBI approach incorporates effective instructional practices for at-risk students (e.g., making instruction explicit and visible using teacher think alouds and interactive dialogue between teacher and students, providing key representations to aid in the interpretation of WPs and procedural strategy checklists to reduce working memory demands). The primary focus of SBI is on identifying the underlying mathematical structure of WPs. The problem schema (e.g., *Change*) is used as a vehicle to understand the mathematical relations between objects described in the problem text, and the problem is represented using schematic diagrams that "include germane information from the problem supportive of problem solution" (Edens & Potter, 2006, p. 186). SBI also emphasizes problem representation by translating contextual information (nonmathematical) in the problem text to promote understanding. For example, consider the following problem: Eric saw a pine tree in the forest. Later, he saw a maple tree that was 9-feet tall. The maple tree was 5 feet shorter than the pine tree. How tall is the pine tree? (Jitendra, 2007, p. 103). The specific linguistic expression "shorter than" in the relational sentence (The maple tree was 5 feet shorter than the pine tree.) can cue learners to the *Compare* schema. SBI explicates that the relational sentence not only describes the difference (i.e., 5 feet) between the two things compared (i.e., height of the maple tree and height of the pine tree) but also helps identify the bigger (height of the pine tree) and smaller quantities (height of the maple tree), which are then represented in the *Compare* diagram (see Figure 1). Finally, information in the remaining verbal text, which specifies the known or smaller quantity and the unknown or bigger quantity, are represented in the diagram. In sum, recognizing the problem schema and representing problems on the basis of structural features (e.g., *compare* problem) rather than surface features (e.g., the problem's cover story) are key elements of SBI.

The use of "think alouds" is an additional feature of our instructional model that is designed to allow at-risk students to emulate the behavior of good problem solvers by monitoring and reflecting on the problem-solving processes (e.g., problem comprehension, problem solution). SBI emphasizes metacognitive strategy knowledge that goes beyond knowledge of algorithms and heuristics to "a person's awareness of strategies to aid comprehending problem statements, organizing information or data, planning solution attempts, executing plans, and checking results" (Coldberg & Bush, 2003, p. 168).

Previous SBI Small-Group Tutoring Studies

We found four randomized controlled studies conducted with students with MD using small-group tutoring that directly links SBI to measured student outcomes. These studies focused on recognizing the mathematical structure of established problem schemata involving the additive problem structure. In a study by Jitendra et al. (1998), students with MD (identified by their teachers to possess adequate addition and subtraction computational skills but to be poor WP solvers) and students with disabilities (*n* = 34) in Grades 2 through 5 who received about 45 min daily of small group (three to six students) pull-out tutoring for about 4 weeks using SBI from researchers were better able to solve addition and subtraction WPs (including *Change, Group,* and *Compare*) than were students who were instructed in a general problem-solving heuristic for the same amount of instructional time. Following treatment and 1 to 2 weeks later, the effect sizes comparing the SBI group with the control group were moderate to large. Furthermore, transfer occurred to novel problems derived from curricula not used in the treatment.

The more recent work of Fuchs and colleagues (e.g., Fuchs, Seethaler, et al., 2008) has also focused on schema training, with an emphasis on *Total* (i.e., *Group*), *Difference* (i.e., *Compare*), and *Change* problem types. Fuchs et al. tested the efficacy of SBI tutoring intervention for third graders (*n* = 35) identified as having mathematics and reading difficulties (MDRDs, scored at the 10th percentile in math and reading). In this study, SBI also emphasized teaching students to transfer their WP skills by focusing on irrelevant information or novel questions that entail an extra step or relevant information presented in charts, graphs, or pictures. Results suggested that students receiving one-to-one preventative tutoring 20 to 30 min, 3 times a week for 12 weeks from trained tutors (research assistants) outperformed students who received regular classroom mathematics instruction without tutoring. Compared with the control group, students in the SBI group improved their WPS performance with moderate to large effects at immediate posttest. Although the findings indicated that SBI led to improvements on a wide range of WPs, retention of problem-solving skills was not tested in the study.

In another study across two sites, Fuchs et al. (2009) stratified the 133 participants by MD only (scored < 26th percentile on a calculation measure or scored 0 or 1 on a 5-item WP measure and scored > 39th percentile in reading) or MDRD (scored < 26th percentile in mathematics and reading) and randomly assigned them to three conditions: NC tutoring (*n* = 44), WP solving tutoring (*n* = 42), and control with no tutoring (*n* = 47). This study evaluated whether difficulties in mathematics only or a combination of reading and math difficulties differentially impacted WPS learning. Both treatment groups received supplemental tutoring for 20 to 30 min, with three sessions per week for 16 weeks from researchers. Both treatment groups outperformed the control group, with moderate to large effects for NCs and procedural calculations; the differences between WP tutoring and control students were significant on four of five WPS measures. In contrast, the NC tutoring group did not differ from the control group on all five measures. However, the WP tutoring group outperformed the NC tutoring group on two measures (i.e., Number Sentences, Vanderbilt Story Problems).

As another example, Powell and Fuchs (2010) extended this work on SBI WP tutoring to test the efficacy of equal-sign instruction incorporated into WPS tutoring. A total of 80 third-grade students with MD (< 26th percentile in arithmetic and < 36th percentile on problem solving, > 39th percentile on reading) or MDRD (< 26th percentile in arithmetic and < 36th percentile on problem solving, < 26th percentile on reading) were assigned to WP tutoring (*n* = 27), WP tutoring plus equal-sign instruction (combined) tutoring (*n* = 24), or no-tutoring control (*n* = 29). At the end of treatment, students receiving combined tutoring 25 to 30 min, 3 times per week for 5 weeks on WPs involving *Total* problem type from tutors (research assistants) were better able to solve certain types of *Total* problems (part unknown) than students who received WP tutoring alone or continued to receive regular classroom mathematics instruction without tutoring.

The Present Study

Prior studies have demonstrated the efficacy of SBI in increasing tutored students' WPS performance when compared with untutored students (e.g., Fuchs et al., 2008; Powell & Fuchs, 2010) or students receiving traditional NCs (e.g., Fuchs et al., 2009) or WPS instruction (Jitendra et al., 1998). In the current study, we contrasted the effectiveness of WPS tutoring with embedded computation instruction using SBI to tutoring in computation and WPS using a SBC. To address the issue of improving the mathematical learning of at-risk students who may not have "sufficiently high prior knowledge to provide 'internal' guidance" (Kirschner, Sweller, & Clark, 2006, p. 75) to benefit from solely an inquiry-based approach, we designed the study so that students in the SBC group also received instruction under the explicit guidance of a tutor. Furthermore, we designed the present study to extend the previous work on SBI with at-risk elementary students to address the following issues. Whereas the previous studies focused on one-step problems, we addressed more complex problems (two-step problems) that pose significant challenges to students with MD (Greer, 1997; Quintero, 1983). In addition, paraprofessionals from the community, rather than research assistants, provided all tutoring instruction to reflect what typically occurs in schools. Furthermore, we assessed retention of WPS performance 6 weeks following the end of the treatment. Finally, we assessed transfer to mathematics and reading achievement. In summary, we investigated the effectiveness of the tutoring interventions (SBI and SBC) on at-risk third graders' acquisition and retention of WPS skills, addition and subtraction NC automaticity, as well as mathematics and reading achievement.

Method

We used a pretest–intervention–posttest–retention test design. Blocking by teacher/classroom at each school, at-risk students were randomly assigned to either the SBI or the comparison tutoring (SBC) intervention, and then students within each condition at each school were randomly assigned to instructional groups. This resulted in 18 instructional groups per condition.

Participants

Schools. The study was conducted in 12 elementary schools in a large urban school district in the midwestern United States. The district served more than 34,570 students. Of these, 70% were students of color and 66% qualified for free or reduced price lunch.

Criteria for participation. We selected all third-grade students from the 12 schools who were identified as at risk for MD based on scores on the *Measures of Academic Progress* (MAP; Northwest Evaluation Association, 2010). In the current study, we defined students as at risk for MD as those who obtained a MAP-scaled score in mathematics below the cutoff of 189 (i.e., the 40th percentile) and demonstrated at least a beginning second-grade reading level based on the school district norms (i.e., MAP-scaled score in reading above 170; see "Measures and Data Collection" section for description of the screening measures). There are generally no agreed-on criteria for defining children at risk for MD. Because our focus was on WPS, we used measures of mathematics and reading and used the cutoff of 40th percentile in mathematics, which has been used to screen at-risk learners from general education classrooms in early mathematics research (e.g., Clarke et al., 2011). For these students to benefit from WPS instruction, we arbitrarily used a cutoff of at least a beginning second-grade reading level for participation. Students were excluded from participation if they were receiving mathematics instruction in an alternative setting (e.g., special education classrooms).

Student participants. Students from 35 third-grade classrooms in the 12 schools were recruited for the study. Informed consent was obtained for 153 students. The sample was reduced by 17 students, excluding 3 (2%) who moved after randomization but prior to the start of tutoring, 7 (5%) who moved during the school year, 1 withdrawn by the school due to persistent and chronic behavior problems during the school year, 3 (2%) who did not have complete demographic information, and 3 (2%) who did not have pretest or posttest data for the primary outcome measure (WPS test). The final sample comprised 136 students: 72 students in SBI and 64 students in SBC.

The third graders in the study were racially and ethnically diverse, with 40% Hispanic, 27% African American, 22% Caucasian, 5% American Indian, 4% Asian/Pacific Islander, and 1% biracial students. The economic status of the sample, as determined by the percentage of students receiving free or reduced price lunch, averaged 78%. In addition, 12% of the sample consisted of special education students and 46% were English language learners. Table 1 presents student demographic information by condition. Given the randomization procedure, the two groups did not differ in age, gender, ethnicity, free and reduced lunch status, English as a second language status, and special education status (all $ps > .05$).

Tutor participants. A total of 20 tutors (18 women and 2 men), recruited from the community (e.g., parents, instructional assistants, undergraduate students), were randomly assigned to the two conditions. The majority of tutors taught two instructional groups within their assigned condition. Tutors mean age was 34.30 ($SD = 14.67$, range = 20–65). In all, 12 tutors were Caucasian, 5 were Asian American, 1 was African American, and 2 were biracial. A total of 7 tutors had 2-year college degrees, 12 held a bachelor's degree, and 1 had a master's degree. Prior to the study, the tutors averaged 1.43 years ($SD = 1.80$) of teaching/tutoring experience. In all, 9 of the tutors spoke another language in addition to English. Independent samples t tests and chi-square analyses used to evaluate differences between conditions showed no significant differences ($p > .05$) on any of the tutor characteristics (e.g., age, gender, ethnicity, educational background, teaching experience).

Measures and Data Collection

Classroom teachers administered the MAP mathematics and reading tests as part of the districtwide evaluation program. Trained research assistants administered and scored the mathematical WPS tests. These and other assessment data were collected in small-group arrangements.

MAP—mathematics and reading. The mathematics and reading subtests of the MAP were used for screening and for measuring mathematics and reading achievement and growth. We used the fall and spring mathematics and reading assessment scores of the MAP (Northwest Evaluation Association, 2010). The MAP is a benchmark, computer-adaptive multiple-choice test used for predicting student performance on the end of the year statewide assessment. The content of the mathematics subtest is designed to assess number sense, estimation and computation, geometry, algebra, measurement, and statistics and probability. The reading subtest measures word recognition and vocabulary, reading

Table 1. Student Demographic Information by Condition.

Variable	SBI				SBC				Total			
	M	*SD*	*n*	%	*M*	*SD*	*n*	%	*M*	*SD*	*n*	%
Age (in years)	8.81	0.37	71		8.87	0.33	64		8.84	0.35	135	
Gender												
Male			26	36.1			27	42.2			53	39.0
Female			46	63.9			37	57.8			83	61.0
Ethnicity												
American Indian			4	5.6			3	4.7			7	5.2
Asian			3	4.2			2	3.1			5	3.7
Hispanic			27	38.0			28	43.8			55	40.7
Black			24	33.8			12	18.8			36	26.7
White			11	15.5			18	28.1			29	21.5
Biracial			0	0.0			1	1.6			1	0.7
Other			1	1.4			0	0.0			1	0.7
Free/reduced lunch			57	79.2			50	78.1			107	78.7
Special education			10	14.1			6	9.4			16	11.9
ELL			36	50.7			27	42.2			63	46.7

Note: SBI = schema-based instruction; SBC = standards-based curriculum; ELL = English language learner.

comprehension, and literature. The MAP technical manual (Northwest Evaluation Association, 2003) provides evidence of strong reliability and concurrent validity for the mathematics and reading tests. The scores on the MAP are sufficiently precise for making decisions concerning individual students.

Mathematical WPS. We used a mathematical problem-solving test that was modified from the one used in Jitendra et al. (2007). The same assessment was used as a pretest, posttest, and delayed posttest (6 weeks following instruction). The 12-item test included 9 one-step and 3 two-step addition/subtraction WPs. Students were given 50 min to complete the test and show all their work. The examiner read aloud all WPs. The answers were scored for correct representation of the number sentence, with 1 point for one-step problems and 2 points for two-step problems for a total possible score of 15 points. Alpha was .66 for pretest, .73 for posttest, and .76 for delayed posttest. Interscorer agreement assessed by a second rater independently scoring 33% of the protocols was .97, .98, and .97 at pretest, posttest, and delayed posttest, respectively.

Addition and subtraction NC automaticity. A 75-item test of addition and subtraction NCs was completed at pretest and posttest. NCs included digits from 0 to 18. Students were asked to solve as many problems as possible within a 4-min time period. They were instructed to work from the upper left corner and proceed across the page and were allowed to skip items that they did not know. The answers were scored as correct or incorrect.

Tutor Training

Tutors in both conditions received training prior to the onset of the small-group tutoring intervention. During the introductory meeting, training for all tutors included an overview of principles of effective instruction and behavior management techniques to meet the needs of at-risk students. In addition, training emphasized professional behaviors to be observed in schools, as well as research ethics and procedures, including the importance of implementing the assigned intervention with fidelity. Next, tutors in each condition attended separate sessions that focused on their assigned role in the tutoring program (SBI tutor or comparison group tutor).

SBC tutors received one day of training that included (a) an explanation of the district-adopted third-grade mathematics program content and instructional strategies, (b) discussion of how students might approach the problems presented in the program and techniques for analyzing student solutions, explanations, and difficulties, and (c) guidance to use the program's mathematical tools and materials. Training provided opportunities to practice implementing the problem-solving strategies. In addition, SBC tutors were instructed to provide explicit instruction when students struggled with key mathematical concepts or skills.

In contrast, SBI tutors received 2 days of training that included (a) a description and review of the curriculum and materials and (b) guidance to implement essential aspects of the curriculum (e.g., explicitly modeling think-aloud problem-solving behaviors, providing feedback, monitoring student performance, facilitating student think alouds to reflect on and monitor the problem-solving processes). Training entailed viewing a video clip of a teacher implementing a SBI lesson and discussing the importance of interactive tutor–student dialogues to promote strategic problem-solving behavior. Furthermore, tutors had the opportunity to practice implementing the WPS strategy.

Intervention

Students in both conditions received 60 min of core mathematics instruction from their classroom teachers, who used *Investigations in Number, Data, and Space* (Technical Education Research Center, 2008). Students then received 30 min of supplemental mathematics instruction using the assigned tutoring program (SBI or SBC) 5 days a week for 12 weeks from a trained tutor outside the classroom. Tutors in both groups used incentives (e.g., stickers) to encourage student participation.

SBC tutoring. Students received instruction in place value, addition and subtraction, and WPS strategies from their textbook. The *SBC* included lessons from the following units: Trading Stickers, Combining Coins; Collections and Travel Stories; Stories, Tables, and Graphs; and How Many Hundreds? How Many Miles?

Trading Stickers, Combining Coins: Addition, Subtraction, and the Number System. In this unit, students learned to construct ideas about the meaning of operations with whole numbers and the structure of place value using the base-10 number system to generalize about numbers and operations and develop mastery of computational skills. The lessons provided practice with recognizing and representing place value using 2- and 3-digit numbers, and finding different combinations of 100s, 10s, and 1s that comprise a number and recognizing their equivalence. Students received practice adding and subtracting multiples of 10, solving 2-digit addition and subtraction problems, finding the difference between a 2-digit number and 100, understanding addition combinations up to 10 + 10, and estimating the sums of 2-digit numbers by using knowledge of place value and known combinations. The unit emphasized using mathematical tools such as cubes, 100s charts and grids, and number lines to facilitate understanding of critical number concepts and skills.

Collections and Travel Stories: Addition, Subtraction, and the Number System 2. This unit focused on place value and the base-10 number system, addition and subtraction, computational fluency, and generalizations about numbers and operations. Students learned to estimate the sums of 2- and 3-digit numbers using their knowledge of place value and known single-digit combinations, finding the difference between 2- and 3-digit numbers, and solving addition problems with 2- and 3-digit numbers. In addition, they practiced applying strategies to solve addition and subtraction problems. Furthermore, the emphasis was on understanding different types of subtraction situations, such as problems that involve finding a missing part (e.g., "Juan and Kyle are on a 3-day road trip. Their final destination is 145 miles away. On the 1st day, they drove 54 miles. How much farther do they have to drive?"), understanding comparison as the difference between two numbers (e.g., "Ms. Walker's class collected 54 box tops in the first 2 days of their class collection. Mr. Nelson's class collected 134 box tops. How many more box tops did Mr. Nelson's class collect than Ms. Walker's class?"), and problems that involve removal (e.g., "Peter has 95 stickers. He gave 34 to his brother. How many stickers does he have now?"). Story problems provided practice with visualizing and representing a subtraction situation.

Stories, Tables, and Graphs: Patterns, Functions, and Change. Although the majority of this unit was outside the scope of the study, some lessons were included that provided further practice with addition and subtraction story problems.

How Many Hundreds? How Many Miles? Addition, Subtraction, and the Number System 3. This unit focused on addition and subtraction of whole numbers, with an emphasis on enhancing computational fluency. Lessons included solving addition and subtraction problems in the context of money and problems with more than one step in addition to strengthening computational fluency skills taught in previous units. There was a greater emphasis in this unit on using story contexts and representations in problem solving than in previous units. Students were encouraged to apply addition and subtraction problem-solving strategies to solve WPs. Addition strategies included breaking the numbers apart to *add by place* (e.g., 326 + 165 = ___: 300 + 100 = 400, 20 + 60 = 80, 6 + 5 = 11, 400 + 80 + 11 = 491) or *add one number in parts* (e.g., 326 + 165 = ___: 326 + 100 = 426, 426 + 60 = 486, 486 + 5 = 491), *change to a landmark number* (e.g., 326 + 165 = ___: 325 + 165 = 390, 390 + 1 = 491), or *create an equivalent problem* (326 + 165 = ___: 26 + 165 = 191, 300 + 191 = 491). Subtraction strategies included *subtracting in parts* (e.g., 353 − 194 = ___: 353 − 100 = 253, 253 − 90 = 163, 163 − 4 = 159), *adding up or subtracting back* (e.g., 353 − 194 = ___: 194 + 6 = 200, 200 + 100 = 300, 300 + 53 = 353, 6 + 100 + 53 = 159), and *changing and compensating* (e.g., 353 − 194 = ___: 350 − 200 = 150, 150 + 3 + 6 = 159).

We created an instructional package from the SBC for the tutors and students. The tutor package included instructional activities from the four units with directions for implementing lessons. The student package included worksheets that corresponded to daily lessons within each unit. Additional worksheets were included for extra practice with WPs and addition and subtraction computational problems. Activities involving math games (e.g., *Capture 5*) and use of addition and subtraction NC flashcards were used to provide further practice on targeted skills. Student materials included mathematical tools (e.g., blocks, number lines, 100 charts and grids, counter chips).

SBI tutoring. The SBI content included five instructional units (*Change, Group, Compare*, review of *Change, Group, and Compare*, and two-step problems) for a total of 21 lessons. Each unit on solving *Change, Group,* and *Compare* problems included five lessons. The first lesson in each unit included story situations with no unknown information in an attempt to build student understanding

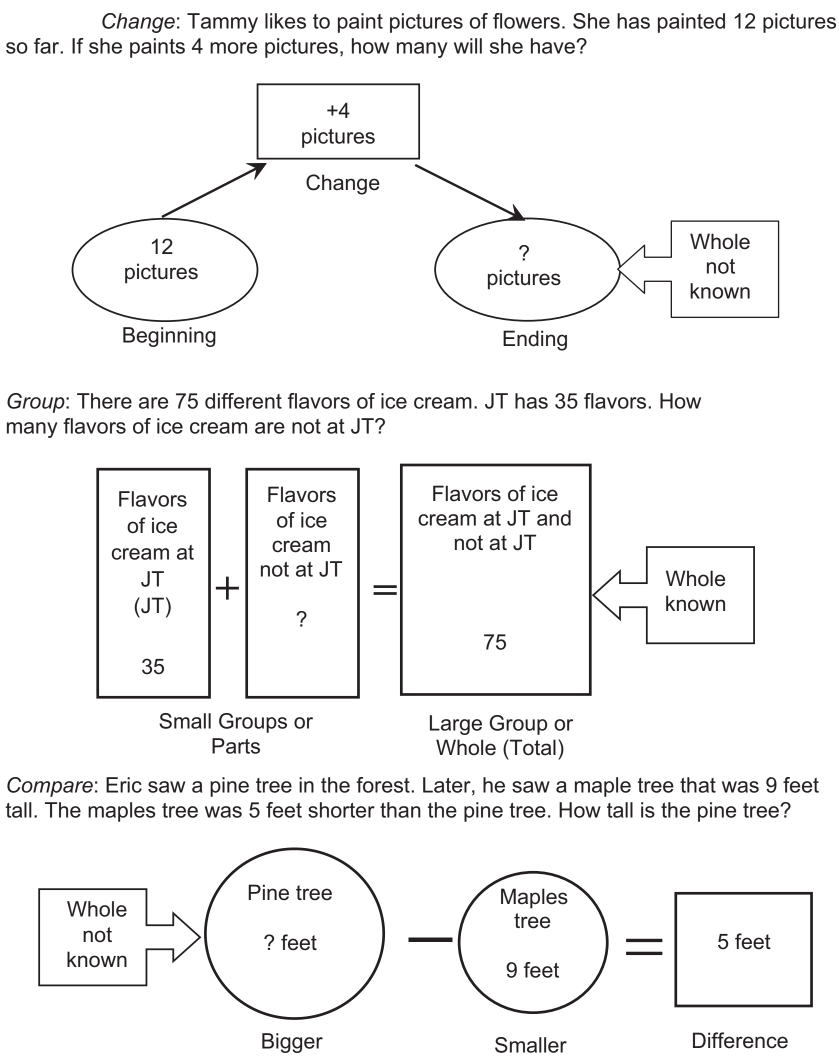

Figure 1. Sample one-step story problems and schematic diagrams for change, group, and compare problem situations.
Note: JT = Julie's Treats.
Source: Adapted from A. K. Jitendra (2007, pp. 18, 59, 103). Copyright 2007 by Pro-Ed, Inc.

of the problem schema. Schematic diagrams and story checklists were included as aids to support problem identification and representation. The next three lessons presented explicit instruction and guidance in solving WPs using schematic diagrams and WP checklists. In the final lesson of each unit on the three problem types, the original schematic diagrams were replaced by student-generated diagrams. Unit 4 included three lessons that reviewed the three problem types. Unit 5 comprised three lessons that introduced two-step problems followed by mixed review of one-step and two-step problems. WPs in the SBI program included a range of problems that are presented in the form of text, graphs, tables, and pictographs and included irrelevant information (nonmathematical).

One-step problems. SBI for solving one-step problems included two phases of instruction—*problem schema* instruction and *problem solution* instruction. During the *problem schema* phase, students were presented with story problems that did not include unknown information and taught to identify the problem type (*Change, Group, Compare*) as well as interpret and represent the information (nonmathematical and mathematical) in the story using the appropriate schematic diagram. For example, consider the following story situation: *Before he gave away 14 marbles, James had 36 marbles. Now he has 22 marbles*. This story situation includes three pieces of information—beginning, change, and ending—that describe an initial quantity (36 marbles), an explicit action (gave away) that decreases (−14 marbles) the initial quantity, and an ending quantity (22 marbles). The information about the beginning, change, and ending sets serves to cue the *Change schema*. Explicit guidance is then provided to translate the information in the story to represent in the *Change* diagram. The sentence, "Before he gave away 14 marbles, James had 36 marbles," contains two pieces of information—change and beginning. The Proposition 14 (marbles) in the expression "Before he gave away 14 marbles" cues a change set, and the Proposition 36 (marbles) in the sentence "James had 36 marbles" cues a beginning set. The now-has proposition in the sentence "Now he has 22 marbles" cues the third set as the ending set. As students are introduced to other schemata, they focus on the similarities and differences between problem schemata. That is, *Change* problems include the three sets (beginning, change, and ending) that have the same object identify (e.g., marbles), and the temporal relation of the change is dynamic (past to present or present to future). In contrast, *Group* problems include two distinct groups or subsets and a larger group or superset. *Group* problems entail the part–whole schema and understanding that the relation between a superset and the corresponding subsets is static (see Figure 1). *Compare* problems involve the comparison of two disjoint sets, with an emphasis on the relation between the two sets that is static.

Problem solution instruction addressed solving WPs that contained unknown information. Metacognitive strategy knowledge was facilitated using a checklist that included the four-step heuristic, **F**ind problem type, **O**rganize information in the problem using the diagram, **P**lan to solve the problem, and **S**olve the problem (FOPS). The tutor used think alouds to model solving WPs using the FOPS strategy. For example, consider the following problem: "Tammy likes to paint pictures of flowers. She has painted 12 pictures so far. If she paints 4 more pictures, how many will she have?" Using Step 1 of the strategy, the tutor identifies the problem type by reading, retelling, and examining information (e.g., beginning, change, and ending) in the problem to recognize it as a *Change* problem via self-instructions (e.g., Are there beginning, change, and ending sets to tell about a *Change* problem?). For Step 2, the tutor demonstrates how to organize information using the schematic diagram (e.g., *Change*). This step includes self-instructions to read the problem to identify critical information in the problem to represent using the schematic diagram. In Step 3, students plan to solve the problem by selecting the correct operation, which involves determining whether the unknown in the problem is the whole or part based on the part-whole schema. In Step 4, students solve the problem using the previously identified operation, justify their answer, as well as check the accuracy of their response.

Overall, SBI prompts students to use think alouds in monitoring and reflecting on the problem-solving process. The four steps of the FOPS strategy guide students to ask a series of questions that foster (a) problem comprehension (e.g., Did I read and retell the problem to understand what is given and what must be solved? Why is this a *Change, Group, or Compare* problem?), (b) problem representation (e.g., How can I organize information in the problem to represent it?), (c) planning (e.g., What operation(s) do I need to use to solve this problem?), and (d) problem solution (e.g., Does the answer make sense? How can I check the answer?).

Two-step WPs. Instruction focused on solving WPs that involve more than one step or problem type. For example, in the problem, "Rob is waiting in line to buy snacks. There are 12 people ahead of him. Three people leave the line without buying anything. Four people buy their snacks and go to their seats. How many people are ahead of him now?" students learned to first identify the primary problem by examining the story context and focusing on the question asked in the problem ("How many people are ahead of him now?"). The primary schema for this problem is Change because the specific linguistic expression in the question, "now," triggers the ending set of the Change schema as well as the beginning set (i.e., "12 people ahead of Rob."), change set (i.e., "Three people leave the line without buying anything."), and another change set (i.e., "Four people buy their snacks and go to their seats."). Students learn that the primary and secondary problems involve a Change schema and map information in the problem using two Change diagrams (see Figure 2). Because the answer to one of the missing elements in the primary Change schema can be derived by solving another Change problem (secondary), students write partial answer for the missing element in the primary Change schema diagram. Students learn that the sequence of steps for solving the two-step problem requires first solving the secondary problem to solve the primary problem.

Students also learn that the problem can be solved alternatively using *Change–Group* schemata and represent information in the problem using both *Change* (primary problem) and *Group* (secondary problem) diagrams. Students first solve for the large group (people who leave the line after buying or not buying snacks) in the *Group* problem, and the answer (7 people) is used to depict the change amount (–7 people) in the primary *Change* schema, which is then solved. The final answer to the WP is, "There are 5 people ahead of Rob now." Because schematic diagrams were faded after each problem-type instruction, the schematic diagrams shown in Figure 2 are student-generated diagrams.

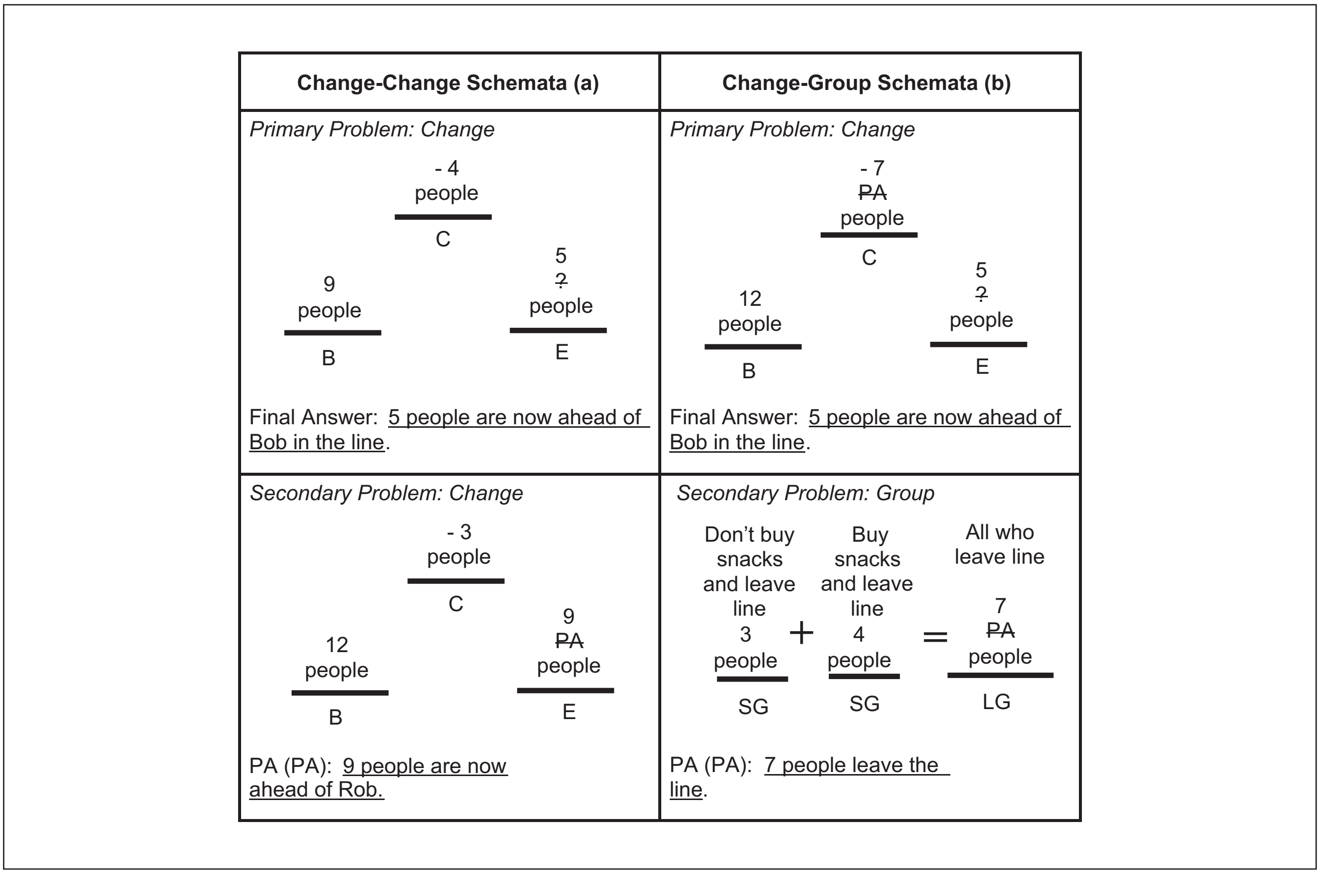

Figure 2. Alternate ways, (a) and (b), to represent and solve a sample two-step word problem.
Source: Adapted from A. K. Jitendra, 2007, pp. 153–154. Copyright 2007 by Pro-Ed, Inc.
Note: PA = partial answer.

Tutor Fidelity

We conducted three observations per condition per tutor to measure SBI and SBC tutors' adherence to the assigned intervention using observation forms that we developed. For the SBI condition, the observation form focused on adherence to the scripted SBI protocols using a checklist of essential tutor instructional criteria (e.g., sets the purpose for the lesson, models/guides students to solve the problem using the FOPS four-step strategy, monitors ongoing student performance). For the SBC condition, the observation form examined adherence to the curriculum using a checklist of tutor behaviors (e.g., models or leads a discussion of critical concepts or terms salient to the lesson, instructs students to use math tools to solve problems). Research assistants audiotaped these observations. The on-site observer measured treatment fidelity to SBI and SBC protocols using a dichotomous rating scale for each intervention step on the observation form. A second observer later viewed and independently rated each audiotaped session using the observation criteria to assess interobserver agreement. The mean interobserver agreement was 95% each for both conditions. The mean treatment fidelity across tutors in the SBI condition was 92.4% (ranged from 73.0% to 100%). The mean treatment fidelity for the SBC condition averaged 85.7%, with a range of 73.3% to 93.0%.

Data Analysis

We first explored the data using a hierarchical linear model to examine the magnitude of variability at the teacher and school levels. The unconditional three-level model included the posttest as outcome and pretest as the only covariate. This resulted in an intercept (student mean) and slope (pretest covariate) at the student level, with a test of the degree to which these coefficients vary at the teacher level and school level. The first test was to assess whether these student-level coefficients varied at the teacher level. None of the measures resulted in significant variation at the teacher level. Although no significant variation was found, the Condition variable was tested at the student level in case residual variance at the teacher level could be explained by the Condition effect. These tests resulted in nonsignificant effects, indicating that the teacher level is not effective for modeling these data. This is consistent with the design of the study because, for the most part, students were assigned to condition within teacher, so each teacher had students who received the SBI intervention and students who did not.

Next, we analyzed two-level models at the student and school level to account for the nesting of students within schools. Intraclass correlations for these two-level models were nonsignificant at teacher/school (three-level model) and school (two-level model) levels. Therefore, we conducted final analyses using the general linear model, a generalized analysis of covariance model, employing the single student level as the unit of analysis, with the pretest as covariate and Condition as the primary indicator variable of interest. We also specified a Condition by pretest interaction effect in the model. Statistically significant interaction effects were followed by paired samples t tests. Final models were tested to control for effects of student background characteristics (i.e., gender, ethnicity, and free and reduced lunch status). Because of the high level of overlap between ethnicity and English language learner (ELL) status and the fewer numbers of students receiving ELL services, ethnicity (White vs. non-White) was used in the models.

$$\text{Posttest}_i = \beta_{0i} + \beta_1(\text{Condition}_i) + \beta_2(\text{Pretest}_i) + \sum \beta_q(\text{Demographics}_i) + r_i$$

The results from this model for the WPS test included the WPS pretest to posttest effects and pretest to delayed posttest effects, including estimates of effect sizes. To estimate the practical significance of posttest effects, we computed effect sizes (Cohen's d) by dividing the covariate adjusted mean differences on the posttests by the square root of the mean square error (Howell, 2001). For pretest to posttest change effects, however, we calculated effect size (Cohen's d) as the ratio of mean difference to the standard deviation of differences. We report effect sizes for all analyses. As Sun, Pan, and Wang (2010) argued, given the sometimes conflicting p value and effect size, "reporting effect size becomes extremely important for both statistically significant and nonsignificant tests" (p. 991).

Table 2. Student Performance by Condition and Measure.

	SBI (n = 72)		SBC (n = 64)		Total (N = 136)	
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*
WPS						
Pretest	6.07	2.91	6.36	3.03	6.21	2.96
Posttest	9.17	3.33	9.38	3.21	9.27	3.26
Adjusted posttest	10.24		10.16		10.20	
Delayed posttest	9.45	3.47	9.47	2.96	9.46	3.23
Adjusted delayed	10.67		10.33		10.50	
Number combinations						
Automaticity test						
Pretest	37.65	16.25	32.42	14.73	35.19	15.71
Posttest	37.75	16.35	40.25	16.93	38.93	16.61
Adjusted posttest	35.41		42.05		38.73	
MAP—Mathematics						
2009 test	182.96	4.61	182.66	4.69	182.82	4.63
2010 test	194.89	8.80	194.00	8.66	194.47	8.71
Adjusted 2010 test	196.55		195.59		196.07	
MAP—Reading						
2009 test	180.90	9.60	181.39	9.41	181.13	9.48
2010 test	189.78	9.73	187.19	10.38	188.55	10.09
Adjusted 2010 test	191.79		188.35		190.07	

Note: SBI = schema-based instruction; SBC = standards-based curriculum; WPS = word problem solving; MAP = *Measures of Academic Progress* (Northwest Evaluation Association, 2010). Scores ranged from 0 to 15 on the WPS.

Results

Outcomes for Student Learning

Equivalence of groups. Independent samples t tests were used to evaluate preexisting differences among subgroups on the pretest measures. On the WPS measures, only free and reduced lunch status resulted in a significant difference ($p < .01$). On the addition and subtraction fact fluency measure, none of the variables resulted in significant differences ($p > .05$). On the MAP, there were significant differences with free and reduced lunch status, gender, and ethnicity (all $p < .02$). However, all three variables were used as covariates in the models to reduce the error variance and increase the statistical power.

Direct treatment effects. Table 2 presents means and standard deviations for all pretests, posttests, and adjusted posttests. Tables 3 and 4 provide the parameter estimates for the WPS posttest and delayed posttest full models. For the WPS posttest, there was a statistically significant effect for condition, $F(1, 129) = 4.42$, $p = .038$. Conditioned on an average pretest score (6.2/15.0), SBC group posttest mean was 10.16 and SBI group mean was 10.24. This resulted in a practically nonsignificant effect ($d = +0.03$). However, the effect of the SBI intervention depended on the pretest score (with a significant interaction effect, $F(1, 129) = 5.84$, $p = .017$). The differences between the tutoring interventions were not consistent across students who had different preintervention WPS scores. That is, for students with lower pretest scores, those in the SBC group tended to gain more to posttest; for students with relatively higher scores, the SBI group gained more. Follow-up paired samples t tests indicated statistically significant pretest to posttest change for SBI, $t(71) = 9.84$, $p < .001$, $d = 1.16$, and SBC, $t(63) = 6.56$, $p < .001$, $d = 0.82$, groups.

Table 3. Parameter Estimates for the WPS Posttest Full Model.

Parameter	*B*	*SE*	*t*	*p*	Partial η^2
Intercept	5.193	0.980	5.299	.000	.179
Gender	1.032	0.467	2.210	.029	.036
Ethnicity	−0.681	0.638	−1.067	.288	.009
Free/reduced lunch	2.093	0.657	3.186	.002	.073
WPS pretest	0.616	0.112	5.496	.000	.190
Condition	2.240	1.066	2.101	.038	.033
Condition × pretest	−0.373	0.155	−2.416	.017	.043

Note: WPS = word problem solving.

Table 4. Parameter Estimates for the WPS Delayed Posttest Full Model.

Parameter	*B*	*SE*	*t*	*p*	Partial η^2
Intercept	5.761	0.951	6.056	.000	.223
Gender	1.736	0.454	3.822	.000	.102
Ethnicity	−0.999	0.619	−1.613	.109	.020
Free/reduced lunch	1.919	0.638	3.008	.003	.066
WPS pretest	0.577	0.109	5.293	.000	.180
Condition	1.940	1.034	1.876	.063	.027
Condition × pretest	−0.367	0.150	−2.446	.016	.045

Note: WPS = word problem solving.

On the delayed posttest, the effect for condition did not quite reach a conventional level of statistical significance, $F(1, 128) = 3.52$, $p = .063$. Conditioned on mean pretest score, delayed posttest mean for the SBC group was 10.33 and the SBI group mean was 10.67, with a practically nonsignificant effect ($d = +0.13$). However, a statistically significant condition by pretest interaction, $F(1, 128) = 5.98$, $p = .016$, was found. Similar to the WPS posttest, the differences between the tutoring interventions on the WPS delayed posttest were not consistent across students who had different preintervention WPS scores. That is, for students with lower pretest scores, those in the SBC group tended to gain more to posttest; for students with relatively higher scores, the SBI group gained more. Follow-up paired samples *t* tests indicated statistically significant pretest to delayed posttest change for SBI, $t(70) = 9.62$, $p < .001$, $d = 1.14$, and SBC, $t(63) = 7.00$, $p < .001$, $d = 0.88$, groups.

For the NC automaticity test, no statistically significant effects were found for condition, $F(1, 129) = 2.88$, $p = .09$, or the interaction between SBI condition and pretest, $F(1, 129) = 0.23$, $p = .632$. Conditioned on mean pretest score, SBC group posttest mean was 42.05, and SBI group mean was 35.41, with a medium effect ($d = −0.55$).

For the MAP mathematics and reading subtests, only 65 students in the SBI group and 59 students in the SBC group had complete data sets and were available for this analysis. The ANCOVA did not show statistically significant effects for condition, $F(1, 117) = 0.39$, $p = .531$, or the interaction between SBI condition and pretest $F(1, 117) = 0.37$, $p = .543$. Conditioned on mean pretest score, SBC group posttest mean was 195.59 and SBI group mean was 196.55, with a practically nonsignificant effect ($d = +0.13$). On the MAP reading test, no statistically significant effects were found for condition, $F(1, 117) = 0.07$, $p = .788$, or the interaction between SBI condition and pretest, $F(1, 117) = 0.16$, $p = .693$. Conditioned on the mean pretest score, SBC group posttest mean was 188.35 and SBI group mean was 191.72, with a medium effect ($d = +0.44$).

Discussion

The overarching purpose of this study was to compare the efficacy of small-group tutoring, on the WPS performance of students with MD, using either SBI or a school-provided SBC. Earlier studies of the impact of SBI on arithmetic WPS performance have produced positive results (Fuchs et al., 2008; Fuchs et al., 2009; Jitendra et al., 1998; Powell & Fuchs, 2010). However, none of the studies addressed the efficacy of SBI WP tutoring to tutoring using a SBC under the explicit guidance of paraprofessionals. In the current study, we extended the prior work by including simple and complex WPs, assessing retention of the treatment effects 6 weeks later, and measuring mathematics and reading achievement. The main question in our study was whether students with MD benefit more from SBI or SBC on WPS and whether the treatment effects are long-lasting. Our results demonstrated that students with higher pretest scores who received SBI showed better WPS performance and maintained the treatment effects 6 weeks later compared with students with higher pretest scores who received SBC tutoring; the reverse was the case for students with lower pretest scores with the SBC group performing better than the SBI group. In addition, two other findings emerged: (a) No significant differences were found between conditions on NC automaticity and (b) no significant differences were found between conditions on mathematics and reading achievement.

Regarding the first finding, although the differences in WPS outcomes between conditions at posttest and delayed posttest were in the expected direction favoring the SBI condition, it is important to note that changes from the pretest to posttests for students in the two conditions were different based on their preintervention WPS scores. Whereas students with lower pretest scores had higher pretest–posttest gains if they were in the SBC condition, students with relatively higher pretest scores had higher gains if they were in the SBI condition. This finding suggests when SBI would be beneficial for students with MD. Because SBI did not focus on computational strategies, many students with MD in our study who entered the study without mastering these basic skills did not benefit as much from the higher level problem-solving strategy instruction as the more able students with higher prior knowledge (Kalyuga, 2007; Kirschner et al., 2006; Rittle-Johnson, Star, & Durkin, 2009). Although previous studies of SBI also included students with MD, students in those studies had already mastered basic computational processes (e.g., Jitendra et al., 1998) or WP instruction for students with MD addressed NCs or other foundational skills, such as addition and subtraction strategies (Fuchs et al., 2008; Fuchs et al., 2009; Powell & Fuchs, 2010). Our finding also demonstrates that students in both conditions improved from pretest to posttests, even when instruction was delivered by paraprofessionals suggesting that instruction that focuses on developing meaningful learning has positive benefits, particularly for students with MD. At the same time, it is important to note that researcher-implemented interventions are generally associated with larger effects than those delivered by practitioners (Swanson et al., 1999). In sum, the present study adds to the literature by showing that students with MD can benefit from instruction delivered by trained tutors from the community rather than researchers, which may more closely mirror what occurs in schools.

The effect sizes comparing the SBI with the SBC condition are marginal (+0.03 for posttest and +0.13 for delayed posttest) when interpreted using Cohen's guidelines (0.2 = *small*, 0.5 = *medium*, and 0.8 = *large*). However, the effect size for delayed posttest is comparable with the immediate posttest effect size (+0.10) found for SBCs and much smaller than the effect size (+0.33) for instructional process strategies (Slavin & Lake, 2008). The relatively stronger retention effects (6 weeks later) of SBI compared with SBC treatment may be attributed to instruction focusing on the similarities and differences among problems involving *Change, Group*, and *Compare*, and the part–whole schema connecting addition and subtraction constructs to develop a firm understanding to enhance and maintain students' problem-solving performance.

The improvement in SBI students' problem-solving performance in this study does not seem to be consistent with the medium to large effect sizes found in prior SBI research with students with MD (Fuchs et al., 2008; Fuchs et al., 2009; Jitendra et al., 1998; Powell & Fuchs, 2010) or third-grade students without MD (e.g., Jitendra et al., 2007). There are several possible explanations for the dissimilarity in the impact of SBI. First, this study involved a comparison of two tutoring interventions that were similar in theoretical underpinnings (i.e., emphasize meaningful learning to develop conceptual understanding), which might have mitigated the effects of SBI. In contrast, previous studies have either compared SBI with WPS instruction using traditional problem-solving approaches (Jitendra et al., 1998; Jitendra et al., 2007) or with a "business as usual" classroom instruction (Fuchs et al., 2008; Powell & Fuchs, 2010) or NC tutoring (Fuchs et al., 2009). Second, our study design ensured that instructional time, instructional grouping, and interventionists were controlled across both conditions that may not be the case when using an untutored control condition. Third, although SBC uses constructivist instruction that has students build their own mathematical knowledge, SBC instruction in our study included a form of enhanced discovery under the explicit guidance of tutors. A recent meta-analysis of discovery-based instruction indicated that although unassisted discovery is not as effective as explicit instruction ($d = -0.38$), enhanced discovery (feedback, worked examples, scaffolding, elicited explanations) benefits learners much more than other forms of instruction ($d = 0.30$), including explicit instruction (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011). Fourth, even though instruction in SBC focused primarily on computation strategies, students were taught to apply those strategies to solve WPs.

Regarding NCs, students in the SBC condition marginally outperformed students in SBI on NC automaticity ($p = .09$) with a medium effect size of 0.55. Given that SBC students received more focused and extensive instruction on NCs relative to WPS, we expected SBC to lead to automatized mastery of the basic addition and subtraction NCs. Although not statistically significant, the medium effect size of 0.55 illustrates the benefits of focused instruction in computational strategies for at-risk students.

To explore the possibility of transfer from instruction in addition and subtraction content and WPS that involves reading, we examined the results of the MAP mathematics and reading achievement tests. On the mathematics achievement test, students in both conditions demonstrated comparable performance. This result suggests the difficulty of transfer of SBI intervention from a narrow domain (number and operation content) to the broader content domain in mathematics. On the reading achievement test, although the SBI condition did not outperform students in SBC, the medium effect size of 0.44 for reading achievement is encouraging because a focus on problem translation and representation in SBI is presumably better for applying basic comprehension processes to understand the written text. Given the relatively strong association reported in the literature between reading comprehension and performance on mathematical WPs, the salience of reading comprehension instruction embedded in mathematical WPS instruction needs to be further explored (Vilenius-Tuohimaa, Aunola, & Nurmi, 2008).

By extending the prior research on SBI, we designed our study to examine the differential impact of SBI and standards-based instruction on the WPS performance of third-grade at-risk students. However, the design of this study presents a few limitations that need to be considered in future research. First, we used a cutoff score of the 40th percentile, which is higher than is typically used in the MD research (10th to the 35th percentile) and did not distinguish students with MD from students with MDRDs. The term *mathematical difficulties* is a broad construct and includes children who score below average to low average on tests of mathematics achievement (Gersten et al., 2005). By using the higher cutoff score, we not only ensured adequate sample sizes (Geary, Hamson, & Hoard, 2000; Jordan, Kaplan, & Hanich, 2002; Mazzocco, 2007), but also reduced the risk of missing students who struggle with mathematics and would benefit from the tutoring intervention. Furthermore, although we did not distinguish students with MD only from students with MD and RD, we ensured that students had sufficient reading skills to benefit from WPS instruction that was the primary focus of our study. Recent research, however, suggests that MD and MDRD children do not differ significantly on problem solving (Andersson, 2008). A second limitation concerns the lack of an untutored condition to control for history and maturation effects. Although previous research has demonstrated the efficacy of SBI compared with an untutored control condition (e.g., Fuchs et al., 2008) or traditional problem-solving instruction (e.g., Jitendra et al., 1998), we are not sure whether either or both treatment conditions in the present study were effective in the absence of a control condition. Future research would benefit from using a commonly agreed cutoff point to study the group of students with MD or MDRD and employing a control group to draw conclusions about the effectiveness of SBI or SBC.

In summary, our results indicate the potential benefits of incorporating SBI into small-group tutoring for at-risk students (especially those with higher incoming problem-solving scores), to enhance their WPS performance. The present findings suggest the need for future research to explore whether embedding NC instruction within SBI WPS instruction for at-risk students transfers to NC retrieval and affects mathematics achievement. Furthermore, future research should examine whether reading comprehension is an important instructional component to a successful WP tutoring program.

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