Second Paper Presentation - Abstract

Title: The Impact of Small-Group Tutoring Interventions on the Mathematical Problem Solving and Achievement of Third Grade Students with Mathematics Difficulties

Author: Asha Jitendra, University of Minnesota

Background / Context: Mathematical problem solving is a critical part of a school curriculum (National Council of Teachers of Mathematics, [NCTM], 2000). The emphasis on story problems in school mathematics textbooks and on state accountability tests point to the salience of targeted instruction in story problems. In primary grades, story problems serve to elucidate and connect the different meanings, interpretations, and relationships to the mathematical operations (Van de Walle, 2004). Students with MD often evidence problems in understanding and remembering key mathematical concepts and principles as well as applying mathematical skills in flexible ways to solve novel problems (Gersten, Jordan, & Flojo, 2005; Hegarty, Mayer, & Monk, 1995). In addition, these students experience difficulties with strategic learning that poses inordinate challenges for problem solving because not only do they experience difficulties working through the steps of a strategy, but they often do not understand which strategy to apply and when.

There is a robust literature in special education that provides support for initially introducing concepts with a high degree of clarity and providing instruction that continues to reinforce the most critical topics for students with MD (Chard, Ketterlin-Geller, & Jitendra, 2008). Specifically, teaching these students to use heuristics and explicit instruction leads to increases in computation and word problem solving (Baker, Gersten, & Lee, 2002; Gersten, Chard, Jayanthi, Baker, Morphy, & Flojo, 2009). Compared to a constructivist approach, there is empirical support that explicit strategy instruction improves low achieving students’ learning such as automaticity of basic facts and strategy use (Kroesbergen, Van Luit, & Maas, 2004). In addition, the benefits of flexible groupings (i.e., one-to-one, small groups) are well documented in addressing the needs of low achieving students (Swanson, Hoskyn, & Lee, 1999). In the present randomized controlled study, we compared the efficacy of small group tutoring, on the mathematics learning of third grade students identified as having mathematics difficulties, using either a school-provided standards-based curriculum (SBC) or a schema-based instruction (SBI) curriculum. We focused on two critical components of mathematical performance – word problem solving and automaticity of addition and subtraction number combinations.

SBI is a potentially effective approach to improve students’ understanding of story problems and promote meaningful learning (retention of problem solving) (Jitendra, Griffin, Haria, Leh, Adams, & Kaduve toor, 2007). SBI 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.

In the present study, we built on four randomized controlled studies of small group tutoring that explored the effectiveness of SBI with elementary school students with MD (Fuchs, Powell, Seethaler, Cirino, Fletcher, Fuchs, et al., 2009; Fuchs, Seethaler, Powell, Fuchs, Hamlett, Fletcher, 2008; Jitendra, Griffin, McGoey, Gardill, Bhat, & Riley, 1998; Powell & Fuchs, 2010). Similar to the work of Fuchs and colleagues, we targeted students from urban schools, the majority of who came from culturally diverse and economically disadvantaged homes. However,
our sample of students with MD was broadly defined as those who scored below the 40th percentile on a statewide mathematics achievement test and had a threshold level of reading skills (i.e., beginning second grade) to benefit from word problem solving instruction. Prior studies have demonstrated the efficacy of SBI in increasing tutored students’ word problem solving performance when compared to untutored students or students receiving traditional mathematics instruction. As such, the goal of the present study was to contrast the effectiveness of word problem solving tutoring in SBI to tutoring in both computation and word problem solving using a standards-based curriculum (SBC). 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 word problem solving performance 6 weeks following the end of the treatment. Finally, we assessed transfer to mathematics and reading achievement.

Purpose / Objective / Research Question / Focus of Study/Setting: The aim of the present study was to determine whether students with MD benefit from small-group tutoring interventions that focus more on instruction in computation strategies and less on word problem solving using the SBC under the explicit guidance of a tutor or from SBI that focuses primarily on word problem solving also presented under the explicit guidance of a tutor. The following were our hypotheses:

1a. Students who receive SBI will improve more in word problem solving than students receiving SBC, and (1b) will retain the problem solving skills six weeks following the end of the treatment. We expected that SBI students who received more focused instruction on word problem solving, including developing a firm understanding of the problem schemata, would do better than SBC students on word problem solving at immediate posttest and demonstrate retention of problem solving skills over time.

2. Students who receive SBC will improve more in addition and subtraction number combinations automaticity than students receiving SBI. Given that SBC students received focused and extensive instruction on number combinations, SBC may lead to automatized mastery of the basic addition and subtraction number combinations.

3a. Students in both conditions will show the same scores on mathematics achievement; however, (3b) students in SBI condition will show higher reading scores than students in the SBC condition. Given that both tutoring interventions focused on a narrow content domain (addition and subtraction problems), we did not expect transfer to the broad mathematics achievement test. The focus of SBI on problem comprehension, including an emphasis on problem translation and representation of both mathematical and nonmathematical information may result in better performance in reading.

Students from 35 classrooms of third-graders from 12 elementary schools in a large urban school district participated in the study. The sample was racially and ethnically diverse, with 40% Hispanic students, 27% African American students, 22% Caucasian students, 5% American Indian students, 4% Asian/Pacific Islander students, and 1% biracial students. The economic status of the sample averaged 78%. In addition, 12% of the sample consisted of special education students and 46% were English language learners. Blocking by teacher/classroom at each school, students identified as having MD were randomly assigned to either the schema based instruction (SBI) or the comparison tutoring (standards-based curriculum, SBC) intervention.
A total of 20 tutors (18 females and 2 males) recruited from the community were randomly assigned to the two conditions and provided all instruction in the study. Twelve tutors were Caucasian, five were Asian American, one was African-American, and two were biracial.

Intervention / Program / Practice: Students in both conditions received the initial 60 minutes of mathematics instruction from their classroom teachers using their mathematics textbook, *Investigations in Number, Data, and Space* (TERC, 2008). This standards-based curriculum emphasizes inquiry-based approaches and invention of problem-solving strategies, while de-emphasizing rote memorization of basic facts. For the next 30 minutes of the math instructional period, participating students received the assigned supplemental tutoring intervention 5 days per week for 12 weeks (January to April) from a trained tutor outside the classroom. Tutors in both groups modeled new skills and supported students in their transition to independent work by monitoring and providing them with immediate corrective feedback. Students assigned to the SBC group received instruction from their textbook. Lessons in SBC that focused on addition and subtraction problems in the number and operations strand of the curriculum were selected to reflect the content focus of the experimental condition. The SBC content addressed place value, addition and subtraction, and word problem solving strategies.

The SBI intervention focused on teaching word problem solving. 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. The goal of the SBI program was to teach students to identify the underlying structure of problems (e.g., Compare), use schematic diagrams (insert Figure 1 here) to represent the problem, and solve the problem. The SBI program included FOPS, a four-step problem solving procedure (F – Find problem type, O – Organize information in the problem using the diagram, P – Plan to solve the problem, S – Solve the problem) and a checklist of the four steps to anchor student learning and promote metacognitive strategy knowledge. 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?).

To examine the extent to which students learned to solve word problems, an experimenter-designed mathematical word problem-solving (WPS) test was administered. The same 12-item assessment was used as a pretest, posttest, and delayed posttest (6-weeks following instruction). Coefficient alpha for this measure was .66 for pretest, .73 for posttest, and .76 for delayed posttest. Students also completed a 75-item test of addition and subtraction number combinations at pretest and posttest. We used the fall and spring mathematics and reading subtests of the MAP for screening and for measuring mathematics and reading achievement and growth (Northwest Evaluation Association, 2010). In addition, tutoring sessions were audiotaped and observed and subsequently analyzed for treatment fidelity.

Research Design / Analysis: First, we examined the data using a hierarchical linear model (HLM) to examine the magnitude of variability at the teacher and school levels. None of the measures resulted in significant variation at the teacher level. Next, we tested the Condition variable at the student level. These tests resulted in nonsignificant effects, indicating that the teacher level is not effective for modeling these data. We also analyzed 2-level models at the
student and school level to account for the nesting of students within schools. Intraclass correlations for these 2-level models were nonsignificant at both teacher/school (3-Level model) and school (2-level model) levels. Therefore, we conducted final analyses using the General Linear Model (GLM), 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. 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 ELL status and the fewer numbers of students receiving ELL services, ethnicity (white v. nonwhite) was used in the models.

To estimate the practical significance of posttest effects, we computed effect sizes (Hedges’ $g$) by dividing the covariate adjusted mean differences on the posttests by the square root of the mean square error (Glass, McGaw, & Smith, 1981). 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 – both statistically significant and nonsignificant tests (see Sun, Pan, & Wang, 2010).

Findings/Results: On the WPS posttest, there was a statistically significant effect for condition ($p = .038$, $g = +0.03$). However, the effect of the SBI intervention depended on the pretest score (with a significant interaction effect, $p = .017$). The differences between the tutoring interventions were not consistent across students who had different pre-intervention word problem solving 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 (insert Figure 2 here). Follow-up paired samples $t$-tests indicated statistically significant pretest to posttest change for both SBI ($p < .001$, $d = 1.16$) and SBC ($p < .001$, $d = 0.82$) groups.

On the delayed posttest, no statistically significant effect was found for condition ($p = .063$, $g = +0.13$). However, a statistically significant condition by pretest interaction ($p = .016$) 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 pre-intervention word problem solving scores (insert Figure 3 here). Follow-up paired samples $t$-tests indicated statistically significant pretest to delayed posttest change for both SBI ($p < .001$, $d = 1.14$) and SBC ($p < .001$, $d = 0.88$) groups.

For the Number Combinations Automaticity test, no statistically significant effects were found for condition ($p = .09$, $g = −0.55$) or the interaction between SBI condition and pretest ($p > .05$). On the MAP mathematics test, no statistically significant effects were found for condition ($p > .05$, $g = +0.13$) or the interaction between SBI condition and pretest ($p > .05$). On the MAP reading test, no statistically significant effects were found for condition ($p = .07$, $g = +0.44$) or the interaction between SBI condition and pretest ($p > .05$).

Conclusions: Our results indicate the potential benefits of incorporating SBI into small group tutoring for students with MD to enhance their word problem solving performance. The present study adds to the literature by showing that these students can benefit from instruction delivered by trained tutors from the community rather than researchers, which may more closely mirror what occurs in schools. Future research should number combinations instruction within SBI word problem solving instruction for students with MD and its impact on overall math achievement and reading comprehension.
Appendix A. References


**Appendix B. Figure 1**: Sample One-Step Story Problems and Schematic Diagrams for Change, Group, and Compare Problem Situations. Diagram adapted from *Solving Math Word Problems: Teaching Students with Learning Disabilities Using Schema-Based Instruction* (pp. 18, 59, 103), by A. K. Jitendra, 2007, Austin, TX: PRO-ED. Copyright 2007 by PRO-ED, Inc.

**Change**: 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?

**Group**: There are 75 different flavors of ice cream. Julie’s Treats has 35 flavors. How many flavors of ice cream are not at Julie’s Treats?

**Compare**: Eric saw a pine tree in the forest. Later, he saw a maple tree that was 9 feet tall. The maples tree was 5 feet shorter than the pine tree. How tall is the pine tree?
Appendix B. Figure 2: Pretest–Posttest Correlation.
Appendix B. Figure 3: Pretest–Delayed Posttest Correlation.