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The Effects of Schema-Based Instruction on the Mathematical Problem Solving of Students With Emotional and Behavioral Disorders

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Abstract

The current study examines the effects of schema instruction on the problem-solving performance of four second-grade students with emotional and behavioral disorders. The existence of a functional relationship between the schema instruction intervention and problem-solving accuracy in mathematics is examined through a single case experiment using a multiple baseline across participants design. Visual analysis and a non-parametric effect size (ES) demonstrate improvement in problem-solving accuracy for grade-level word problems involving addition and subtraction of two-digit integers without regrouping. Tau-*U* ESs for four participants ranged from 63% to 98%. The students and special education teacher reported the intervention package was socially valid.

Keywords

emotional and behavioral disorder, mathematics, problem solving, schema instruction, single case experimental design

Historically, students with emotional and behavioral disorders (EBD) exhibit deficits in mathematics when compared with same age peers with and without disabilities (Nelson, Benner, Lane, & Smith, 2004; Reid, Gonzalez, Nordness, Trout, & Epstein, 2004; Wagner, Kutash, Duchnowski, Epstein, & Sumi, 2005), which contributes to frequent failure on competency exams (Lane, Barton-Arwood, Nelson, & Wehby, 2008) and lower graduation rates. Only 50% of students with EBD graduated with a high school diploma in 2012–2013 (U.S. Department of Education, Office of Special Education and Rehabilitative Services, Office of Special Education Programs, 2016). Reid and colleagues (2004) reported students with EBD performed significantly worse across academic domains when compared with same aged peers, with the largest deficit in mathematics. Two longitudinal studies reported students with EBD (a) had mathematical deficits that worsened with age compared with their same age peers (Trout, Nordness, Pierce, & Epstein, 2003) and (b) demonstrated limited mathematical progress over a 2-year period (Siperstein, Wiley, & Forness, 2011).

Recent meta-analyses on mathematical interventions for students with EBD highlight two major weaknesses in the literature. Research studies tend to focus on either (a) basic mathematical concepts or (b) self-regulatory behaviors rather than skill or strategy acquisition (Hodge, Riccomini, Buford, & Herbst, 2006; Mulcahy, Maccini, Wright, & Miller, 2014; Ralston, Benner, Tsai, Riccomini, & Nelson, 2014; Templeton, Neel, & Blood, 2008). Problem solving is an integral component of mathematics curricula (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010) and a lack of adequate instruction will inhibit students from reaching proficiency on high-stakes assessments.

We identified five studies targeting the mathematical problem solving of students with EBD in the published literature. The five studies reflect the work of four author teams, including 16 students. Although four of the five studies used an experimental design, none reported effect sizes (ESs). Four studies (13 participants) found strategy instruction on a problem-solving process increased students' problem-solving performance (Alter, 2012; Alter, Brown, & Pyle, 2011; Maccini & Ruhl, 2000; Mulcahy & Krezmien, 2009). Jitendra, George, Sood, and Price (2009; two participants) found strategy instruction effective in improving problem solving, and were the first to analyze the effects of a schema instruction on the problem-solving performance of students with EBD. However, a limitation was the researchers did not use a single case experimental design

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(SCED) to determine whether a functional relationship existed between schema instruction and problem-solving performance.

Increased expectations in mathematics and mathematical problem solving in state and common core standards (Powell, Fuchs, & Fuchs, 2013) are a cause for concern given the noted problems in mathematics for students with EBD. This issue is further compounded by the limited research base on effective instruction in mathematical problem solving for this population (Hodge et al., 2006; Ralston et al., 2014; Templeton et al., 2008). One study (Jitendra et al., 2010) analyzed the effects of schema instruction on students with EBD; however, not through an SCED. Thus, we aimed to empirically test the effects of schema instruction on the problem-solving performance of students with EBD by using a SCED.

Schema Instruction Literature

Schema instruction has a thorough literature base demonstrating its efficacy in increasing students' problem solving (Jitendra, Petersen-Brown, et al., 2013); however, successful demonstrations to improve problem-solving performance of students with EBD are limited. The term *schema* traces its roots to psychological and philosophical theory. Schema is a framework developed to solve a problem, organize knowledge, and support future instruction and learning (Marshall, 1995). The application of schema instruction to problem solving involves explicitly teaching students to classify word problems into types by analyzing the underlying structure of the word problem. An appropriate solution method is identified based on the structure (i.e., the type) of the word problem.

Several randomized control trials in general education classrooms demonstrated positive effects of schema instruction on the mathematical problem-solving performance for students with and without learning disabilities (Fuchs et al., 2008; Fuchs et al., 2004; Fuchs et al., 2009; Fuchs et al., 2010; Jitendra, Dupuis, et al., 2013). Powell (2011) summarized the schema literature and found 12 group design studies implemented schema instruction with students with learning disabilities and yielded positive effects on students' mathematical problem-solving performance. However, no meta-analytic procedures were used, so an aggregated ES was not reported. Schematic diagrams (viz., graphic organizers), in addition to schema instruction, were incorporated across some of the studies (Jitendra, Dupuis, et al., 2013; Jitendra et al., 2009; Jitendra, Griffin, Deatline-Buchman, & Sczesniak, 2007; Jitendra, Rodriguez, et al., 2013). Another component included in some studies was a mnemonic prompting the four critical steps of problem solving: (a) understand the problem, (b) devise a plan, (c) carry out the plan, and (d) look back (e.g., Fuchs et al., 2008; Fuchs et al., 2010; Jitendra et al., 2007; Jitendra, Rodriguez, et al., 2013).

In theory, the components of a schema instruction package address characteristics associated with students with EBD. First, schematic diagrams aid in organization and add a level of concreteness that benefits students with EBD (Gersten et al., 2009; Jitendra, Nelson, Pulles, Kiss, & Houseworth, 2016). Second, the incorporation of a problem-solving mnemonic provides support in memory and self-regulation, two deficits faced by students with EBD (Lane, Wehby, Little, & Cooley, 2005). Last, all of the studies that implemented schema instruction used an explicit instruction approach, which has been shown to benefit students with EBD (Doabler et al., 2015; Mulcahy et al., 2014).

Current Study

The current study extends the previous literature by empirically testing the effects of schema instruction for students with EBD. In addition, most of the literature has been conducted with students in third grade and up; in this study, the authors implemented schema instruction with second-grade students. Furthermore, we sought to analyze maintenance effects on a larger sample of data than previous studies. Last, we tested the likelihood of students generalizing to two-step word problems. Specifically, we examined the effects of schema instruction on the mathematical problem-solving performance of four second-grade students with EBD. The intervention package included explicit instruction on schema usage and a problem-solving strategy, self-monitoring strategy usage, and reinforcement for task completion. We used a multiple baseline across participants design to evaluate the following research questions:

Research Question 1: What are the effects of a schema instruction package on students' accuracy in solving word problems?
Research Question 2: How well do students maintain effects post intervention?
Research Question 3: Do students generalize to two-step word problems?
Research Question 4: What is the social validity of the intervention for students and the teacher?

Method

Setting and Participants

The study was conducted in an elementary school in the south-central United States. The school enrolled 465 students in pre-k through fifth grade. The school was diverse ethnically and linguistically (68% Hispanic, 20% African American, 10% Caucasian, and 1% multi; 30% English language learners). In addition, 93% of students received free or reduced meals. One self-contained adaptive behavior class operated on campus. The class enrolled six students with EBD; they received all academic instruction in this setting as mandated by their Individualized Education Programs (IEPs). A seventh student transferred out of the class during the first week.

Before the initiation of the study, the special education teacher and paraeducator provided all academic instruction to the students. The teacher was a Caucasian male and the paraeducator was a Hispanic female. The teacher had 2 years of teaching experience in special education settings. The teacher was dual certified to teach special education in early childhood through 12th grade and general education in kindergarten through fifth grade. The paraeducator's prior experience and training are unknown. A pre-service teacher was present in the classroom 2 days per week. The pre-service special education teacher observed and provided instructional support at the teacher's discretion.

The first author approached the special education teacher to recruit students with EBD as participants for a study on schema instruction to improve mathematical problem solving. To be nominated, students must have met the following criteria: identified with EBD, dedicated instructional time in mathematics, IEP objectives aligned with mathematical problem solving, and deficits in problem solving. The teacher nominated four second-grade students, all of whom met the inclusion criteria. The four students were African American males and received free or reduced meals. The affiliated University Institutional Review Board (IRB) and the school district IRB granted permission for the study. Participants, parents, and teachers were not blinded from the study.

Four observations across 3 weeks indicated the participants received all instruction in the self-contained class and did in fact receive mathematics instruction. Furthermore, all instruction was provided by the special education teacher and paraeducator with the student teacher providing support. The observations confirmed that no schema or strategy instruction on using a problem-solving mnemonic was provided by the teacher or used by students. Typical instruction consisted of whole-group instruction followed by individualized feedback and included manipulatives, pictorial representations, and key word strategies. The grouping structure depended on the objective for the day and individual student needs. Guided and independent practice included one-on-one assistance by the teacher, paraprofessional, or pre-service teacher. A token economy was used to encourage appropriate academic behaviors. An informal interview with the teacher validated the observation findings.

Experimental Design

We used a multiple baseline design across participants to assess the effect of the intervention package on problem-solving performance. A multiple baseline design fit the purpose of the study because the dependent variable was a learned skill and not expected to reverse. Experimental control is demonstrated through the introduction of a variable (i.e., schema instruction) to evoke a desired behavior to one of the conditions (i.e., one of the participants) while the remaining conditions (i.e., students) continue baseline. To establish a functional relationship, Kratochwill and colleagues (2010) recommended a minimum of three changes in the desired behavior. We addressed this by varying onset of the intervention across four participants.

We administered five baseline probes (i.e., the minimum number suggested by Kratochwill et al., 2010) for each participant and opted to begin intervention with Student 1 based on the recommendation from the classroom teacher. We pre-determined that students would receive two sessions on schema identification, three sessions for each problem type, and three sessions for mixed problems. We believed three training sessions would be sufficient for students to attain mastery, and three data points are sufficient to identify the trend.

Dependent Variable

The operational definition of problem solving included accuracy in solutions of word problems requiring addition/subtraction of two-digit numbers without regrouping. All four students' IEPs included a goal matching the dependent variable. Probes consisting of word problems were used to measure problem-solving performance. To control for variations in problem difficulty, the text complexity and computational expectations were held constant across probes. Computation was limited to double-digit numbers not requiring regrouping across all probes. To minimize text complexity, contextual information relevant to students' prior knowledge was used in problem construction (e.g., using student/teacher names, hometown characteristics, popular athletes). All probes were researcher created and are available on request. To assess face validity of the probes, the special education teacher reviewed approximately 25% of the probe sheets (i.e., for alignment with grade-level mathematics standards and readability) and reported 100% of the word problems matched the instructional level on the students' IEP goals. All students received the same probes because their IEP goals related to mathematics were the same. A sample probe is provided in Figure 1.

We administered seven probes: baseline, schema identification, part-part-whole, change, compare, mixed, maintenance, and generalization probes. Baseline probes contained two problems per schema type (i.e., part-part-whole, change, compare; six total problems). The structure of part-part-whole, change, and compare probes was the same; each probe contained three problems fitting the target schema. The structure of mixed and maintenance probes was similar; each probe contained one problem per type (three total problems). The generalization probe contained three two-step word problems that were generalizations of each schema type (i.e., part-part-whole, change, compare; three total problems). All probes were scored as percentage of items

- It was 98 degrees outside. In the shade it was only 80 degrees. How much cooler was it in the shade?[a]
- I spent 11 minutes on math homework and 15 minutes on reading homework. How much total time did I spend on homework?[b]
- It was 55 degrees in the morning. It gradually got warmer throughout the day. It was 80 degrees in the afternoon. How much warmer did it get throughout the day?[c]

Figure 1. Sample mixed problem probe.
[a]Compare problem.
[b]Part-part-whole problem.
[c]Change problem.

answered correctly. We also administered a schema identification probe, which contained two problems per schema type, after providing initial instruction in schema identified. Because this probe did not measure actual problem-solving performance or align with other probes, it was not considered in visual analysis or used for ES calculations.

Intervention Package and Data Collection

The first author (i.e., the interventionist) assumed instructional responsibility at the start of baseline to control for a Hawthorne effect during intervention. The interventionist had 2 years of teaching experience in an elementary school and was certified to teach special education for kindergarten through 12th grade. The interventionist served as the primary data collector. A non-author independently scored measures and collected fidelity of implementation through fidelity checks and inter-observer reliability. The first author provided instruction and administered probes individually to students in their study carrels throughout the academic day while the remaining participants engaged in academic tasks led by the classroom teacher.

A token economy was used across all phases. Participants earned a secondary reinforcer (i.e., check mark) for each question they attempted. A check mark for all questions on the probe sheet provided access to a primary reinforcer (e.g., fruit snack). The reinforcer was identified as desirable through conversations with the students, met approval of the special education teacher, and fell within district guidelines.

Baseline phase. Baseline conditions approximated typical classroom instruction, except all instruction was provided individually. The interventionist presented the baseline probe and volunteered to read each problem. Time to complete the probe was commensurate with the task and ranged from 15 to 20 min; no time limit was given. No feedback was provided regarding correct or incorrect answers.

Schema identification instruction. The interventionist provided explicit instruction on how to identify the unique features of each schematic problem (see Table 1). For each problem type, the interventionist provided three schematic diagrams and worked examples. The interventionist modeled the use of the strategy by engaging in a think-aloud activity. The think-aloud included reading the problem aloud, posing three guiding questions (i.e., "Is there a whole value with different parts?" "Is there a value changing over time?" "Are two values being compared to one another?"), and a discussion of the problem characteristics to identify the problem type.

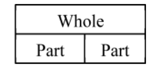
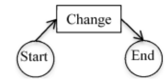
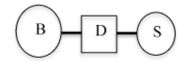
Guided practice opportunities involved the presentation of a word problem to the student with the three schematic diagrams (i.e., part-part-whole, change, compare) and the choice to have the problem read aloud. The student asked himself, prompted if not initiated, each of the three guiding questions aloud to identify the appropriate schema. If the student attempted to provide an answer before asking the questions, the interventionist asked the student, "What three questions do you need to ask yourself?" The student classified the word problem; corrective feedback was provided if an incorrect answer was provided.

During independent practice, the student sorted a stack of 10 sentence-strip word problems (12 in × 3 in) into the appropriate schemas. Corrective feedback followed any incorrect response. Once sorting was 100% accurate, the student received the schema identification probe. Students received schema identification instruction on two consecutive days; instructional duration was approximately 25 to 30 min per session.

Strategy instruction. Each intervention session began with a discussion of the purpose and rationale for problem solving using age-appropriate, relatable examples. A strategy checklist depicted the problem-solving steps of STAR (see Table 2). The objective was stated for the day's learning (objectives are listed in Table 3) followed by modeling of two to four problems.

First, the interventionist engaged in "Searching the problem" by reading the problem aloud and underlining the important information (i.e., values, labels, the question). The interventionist placed a check next to the S to model self-monitoring of the strategy. Next, the interventionist engaged in "translating the problem into a schematic diagram" by posing the three guiding questions to identify the appropriate schematic diagram. The interventionist drew the relevant schematic diagram and filled in the appropriate information; a question mark identified the unknown value in the problem. The interventionist placed a check next to the T. Next, the interventionist engaged in "Answering the question" by identifying an appropriate solution method. The interventionist referred back to the underlined question in the word problem to label the solution. The interventionist placed a check next to the A. Finally, the interventionist engaged in "Reviewing the solution" by posing the question, "Is my answer reasonable?" followed by a discussion

Table 1. Unique Features for Each Schema Type.

Schema	Points of emphasis	Guiding questions	Schematic diagram
PPW	Static situation Whole value can be categorized into parts	Is it static? Is there a value that can be broken into parts?	
Change	Change over time Start amount increases or decreases	Is there a value changing over time?	
Compare	Static situation Values being compared	Is it static? Are there two values being compared with one another?	

Note. PPW = part-part-whole.

Table 2. STAR Strategy Checklist.

STAR strategy		Example
S	Search the problem	Ben has 24 coins in his car. 13 of the coins are quarters, the rest are pennies. How many pennies does Ben have?
T	Translate the problem	24 coins 13 quarters? | pennies
A	Answer the problem	24 − 13 = ? ? = 11 pennies
R	Review the problem	13 + 11 = 24

Table 3. Learning Objectives for Intervention Lessons.

Lesson no.	Topic	Learning objective
1–2	Schema identification	Given a word problem, you will be able to match the word problem to its given schema and schematic diagram
3–5	Part-part-whole	Given a part-part-whole word problem, you will be able to fill in the schematic diagram with the given information and solve for the solution
6–8	Change	Given a change word problem, you will be able to fill in the schematic diagram with the given information and solve for the solution
9–11	Compare	Given a compare word problem, you will be able to fill in the schematic diagram with the given information and solve for the solution
12–14	Mixed	Given a word problem, you will be able to choose the appropriate schematic diagram, fill in the appropriate information, and solve for the solution

of the reasonableness of the answer. The interventionist placed a check next to the R.

Guided practice included the presentation of two to three word problems to the student. If the student were unable or unwilling to initiate the task, the interventionist would prompt the student by stating, "What does the S stand for in our problem solving strategy STAR?" Prompts were provided to enable the student to engage in the problem-solving process. The student placed a check after the completion of each step (i.e., S, T, A, R) to monitor strategy usage. The interventionist informally assessed the student's ability to engage in the problem-solving process by tracking the number of prompts provided. Additional guided practice opportunities were provided if the student required multiple prompts.

During the independent practice opportunities, the interventionist provided the student with a word problem and told him to solve the problem independently. The interventionist offered to read the problem aloud. No prompts were provided while the student engaged in the problem-solving process. After the student finished, the interventionist analyzed the schematic diagram and solution. If errors were present, corrective feedback was provided. Errors resulted in additional independent practice opportunities for the student. The probe containing three items of the relevant problem type was administered to the student once he solved two consecutive problems correctly. Explicit instruction on the use of the STAR was only provided on the first day of part-part-whole instruction. Students were expected to use the strategy throughout the remaining schema instruction.

Lessons were approximately 20 min on the first day of instruction for a new problem type and were reduced to approximately 15 min for the second and final day of instruction. The total instructional duration was approximately 250 min.

Maintenance. Maintenance started directly after the conclusion of the interventions. The interventionist presented the probe. The interventionist offered to read the problems aloud. No instruction was provided. Potential of 3 points per maintenance probe.

Generalization. The generalization probe was administered directly after maintenance. The interventionist presented the probe. The interventionist offered to read the problems aloud. No instruction was provided. Generalization probes were two-step word problems, whereas all other probes were one-step. An example of a two-step part-part-whole problem is, “The farmer owned 12 cattle, 13 sheep, and some pigs. If he owned 39 animals in all, how many pigs did he own?”

Data Analysis Procedures

Visual analysis of mean level, trend, stability, consistency, and intercept gap (Horner et al., 2005) is accompanied by ESs with confidence intervals (CIs) to identify the presence of an effect. The interpretation of the ES rests in the context of the visual analysis and comparisons with the related literature (Vannest & Ninci, 2015).

Effect size. The Tau-*U* ES is consistent with the nonoverlap approach of dominance statistics that uses all pair-wise score comparisons (Huberty & Lowman, 2000) and combines elements of the Mann–Whitney *U* and Kendall Tau ESs (Parker, Vannest, Davis, & Sauber, 2011). Dominance translated to SCEDs is defined as the probability that a randomly selected score from one phase will exceed that from another phase (Parker, Vannest, & Davis, 2011). The Tau-*U* ES is able to account for undesirable baseline trend and takes into account data variability making it a more robust ES than other nonoverlap statistical methods (Parker, Vannest, & Davis, 2011).

The Tau-*U* ES was selected as an acceptable or recommended non-parametric ES (Kratochwill et al., 2010) to corroborate visual analysis. Tau *U* is based on the “S” distribution, which has 91% to 95% power of parametric tests such as *t* tests or ordinary least squares regressions when data are “ideal” (i.e., normally distributed and constant variance). Power exceeds 100% when data are skewed and nonnormal, a more typical scenario in SCEDs (Parker, Vannest, Davis, & Sauber, 2011). Tau *U* combines the respected Kendal’s and Mann–Whitney *U* tests and reflects the percentage of data improvement.

Baseline data were notated as Phase A. The following conditions were notated as Phase B: part-part-whole, change, compare, mixed, and maintenance. To calculate Tau *U*, we compared all Phase A and Phase B data. An ES was calculated for each participant and ESs were aggregated to calculate an ES for the entire study. The aggregation of Tau-*U* ESs weight each participant’s data and error by using the inverse of the variance for the participants. The weight takes into account the variability of each student’s data and the amount of data provided. A 90% CI was reported to gauge the likelihood of the ES.

Social validity. Before the maintenance phase, the students and special education teacher completed a brief social validity questionnaire. Questions were scored via a Likert-type scale, ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). The student version used emoticons to represent varying degrees of satisfaction (adapted from Butler, Miller, Crehan, Babbitt, & Pierce, 2003). To attain valid responses, the student survey was read and student questions were answered verbally. The teacher form included an option for open response. To assess the social validity of behavior change, we set 80% as a criterion for proficiency when analyzing student performance. This decision, although subjective, is a socially valid approach for determining the effectiveness of an intervention. Students’ goals written into their IEPs typically set 80% as the criterion for attaining proficiency.

Interrater reliability. An undergraduate student in special education received training and used an answer key to score each probe type. Reliability checks took place for 89% of baseline and 54% of intervention and maintenance phases. Interobserver agreement was calculated by adding all agreements and dividing by the total number of opportunities to agree. Agreement was 100% for baseline and 100% for intervention and maintenance probes.

Fidelity of implementation. An undergraduate student in special education evaluated instructional lessons using a fidelity checklist adapted from Alter et al. (2011). Training included examples and non-examples of the instructional components. Fidelity of implementation reflects 8 of 56 (14%) intervention sessions, which were sampled across phases. The overall fidelity of implementation was 93% with a range of 87% to 100%.

Results

This study included four second-grade participants identified with EBD and tested the effects of a schema intervention package on their mathematical problem-solving performance. Graphed results for each participant can be found in Figure 2. Overall, visual analysis supports a functional relationship between the intervention package and problem-solving performance for three of the students. Increases in accuracy of problem solving are evidenced by an immediate, consistent change with the onset of intervention for three participants. Baseline streams between 5 and 12 sessions were relatively stable for three participants; intervention and maintenance data were less stable. The number of data points is of sufficient length to meet current standards (Kratochwill et al., 2010). The aggregated Tau-*U* ES for this study was 83%, 90% CI [63, 100], which can be interpreted as 83% of Phase B data was improved from Phase A with the “true” score likely falling between 63% and 100%. This ES is consistent with the visual analysis.

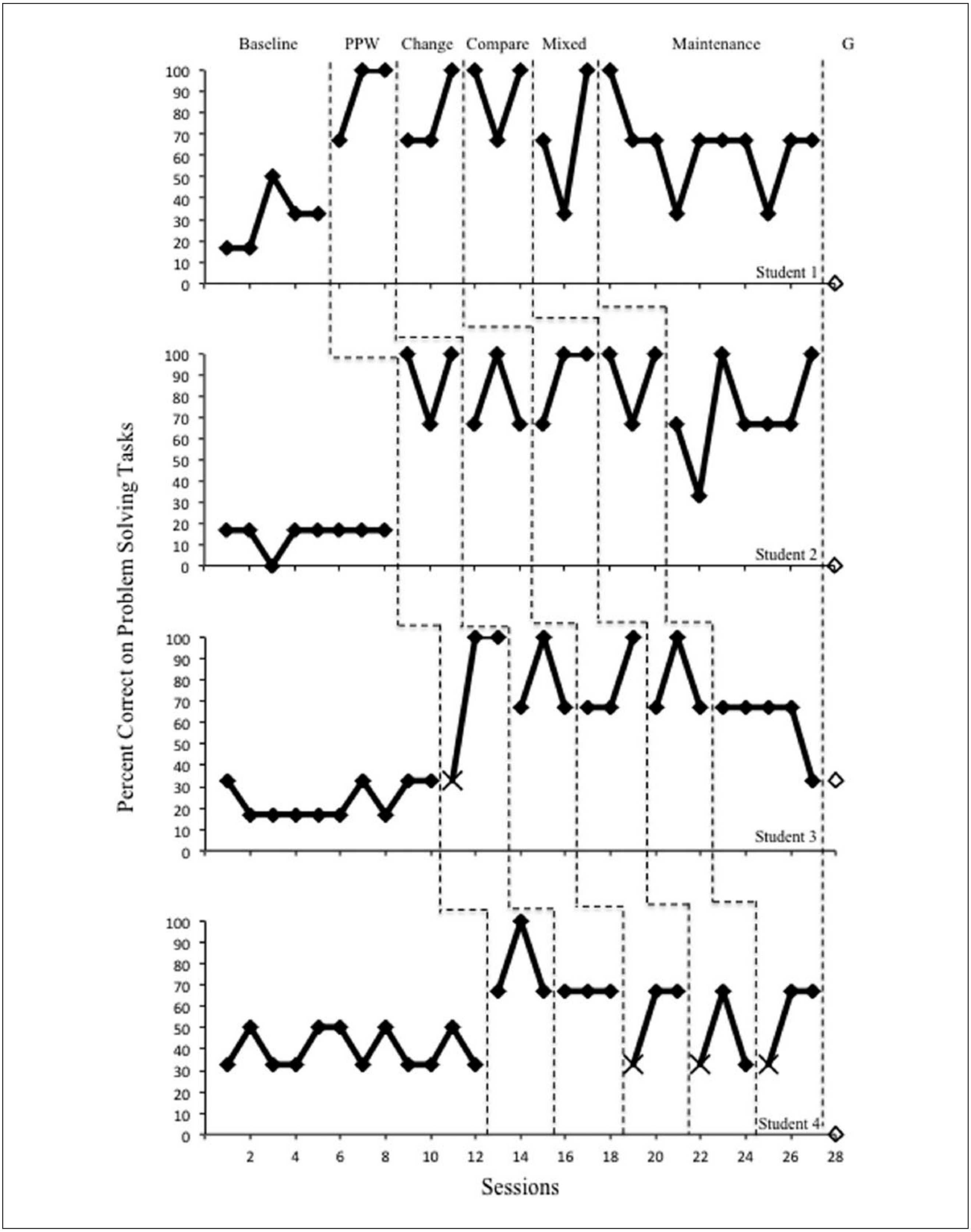


Figure 2. Student problem-solving performance.
Note. PPW = part-part-whole.

Student 1

Data stability in baseline was low with data ranging from 17% to 50%. The baseline mean was 30%, intervention mean was 81% (range = 33%–100%), and maintenance mean was 63% (range = 33%–100%). The mean level change from baseline to intervention and maintenance was 51% and 33%, respectively. Analyzing the standard deviations (SDs), the variability increased from baseline to intervention and maintenance, 8% and 5%, respectively. Immediately after starting the intervention, the student's score increased 34%. Intervention data overlapped with baseline data on three instances. The student reached 80% proficiency at least once for each schema; however, the student only reached this proficiency mark once during maintenance. The Tau-*U* ES was 85%, 90% CI [38, 100], interpreted as 85% of the treatment data was improved from the baseline data. The large CI reflects the variability within the data. The student did not generalize to two-step problems.

Student 2

Data stability in baseline was high with all of the data points registering at 17% except one registering at 0%. The baseline mean was 15%, intervention mean was 86% (range = 67%–100%), and maintenance mean was 71% (range = 33%–100%). The mean level change from baseline to intervention and maintenance was 71% and 56%, respectively. The variability, as measured in SDs, increased from baseline to intervention and maintenance, 11% and 17%, respectively. Immediately after starting the intervention, the student's score increased 83%. There were zero data points that overlapped between baseline and intervention data. The student reached 80% proficiency at least once for each schema; however, the student only reached this proficiency mark twice during maintenance. The Tau-*U* ES was 98%, 90% CI [57, 100], interpreted as 98% of treatment data was improved from baseline. The student did not generalize to two-step problems.

Student 3

Data stability in baseline was high with data ranging from 17% to 33%. The baseline mean was 23%, intervention mean was 78% (range = 33%–100%), and maintenance mean was 60% (range = 33%–67%). The mean level change from baseline to intervention and maintenance was 55% and 37%, respectively. Immediately after starting the intervention, the student's score remained constant; however, this was in part due to his refusal to complete the entire probe. The variability, as measured in SDs, increased from baseline to intervention and maintenance, 13% and 7%, respectively. There were two data points that overlapped between baseline and intervention data. The student reached 80% proficiency at least once for each schema except maintenance. The Tau-*U* ES was 89%, 90% CI [51, 100], interpreted as 89% of treatment data was improved from baseline. The student answered one two-step problem correctly.

Student 4

Data stability in baseline was medium with data ranging from 33% to 50%. The baseline mean was 40%, intervention mean was 61% (range = 33%–100%), and maintenance mean was 56% (range = 33%–67%). The mean level change from baseline to intervention and maintenance was 21% and 16%, respectively. The variability, as measured in SDs, increased from baseline to intervention and maintenance, 10% for both. Immediately after starting the intervention, the student's score increased 34%. Intervention data overlapped with baseline data on four instances. The student reached 80% proficiency for only one of the schemas. The Tau-*U* ES was 63%, 90% CI [63, 100], interpreted as 63% of treatment data was improved from baseline. The student did not generalize to two-step problems.

Social Validity

The teacher reported he strongly agreed or agreed that the intervention targeted important behaviors, the effectiveness of the intervention, and the ease of implementation in the classroom. The teacher stated in his open response,

> This intervention has hit on just about every area of math that we do as it addresses the foundations of problem solving. . . . Approach is concrete and simple and allowed my students, who are plagued with a lack of confidence, to begin working on attempting problems they never would have thought possible.

Three of the four students self-reported that they agreed or strongly agreed with the statement, "Math class is interesting"; Student 4 reported he was neutral. Three of the students strongly agreed with the statement, "I like the math activities"; Student 4 reported that he disliked the mathematics activities. Three of the students disagreed or strongly disagreed with the statement, "The math activities did not help me learn the math"; Student 4 reported he was neutral. Finally, all four students reported agreeing or strongly agreeing with the statement, "I feel confident about mathematics."

The social validity results indicated that three of the four students found the intervention to be socially valid. The teacher reported the intervention was relevant and applicable in his classroom learning environment. Analysis of student data indicates improvement was made on students' problem-solving performance. However, students' performance during maintenance was below socially significant levels (i.e., 80%).

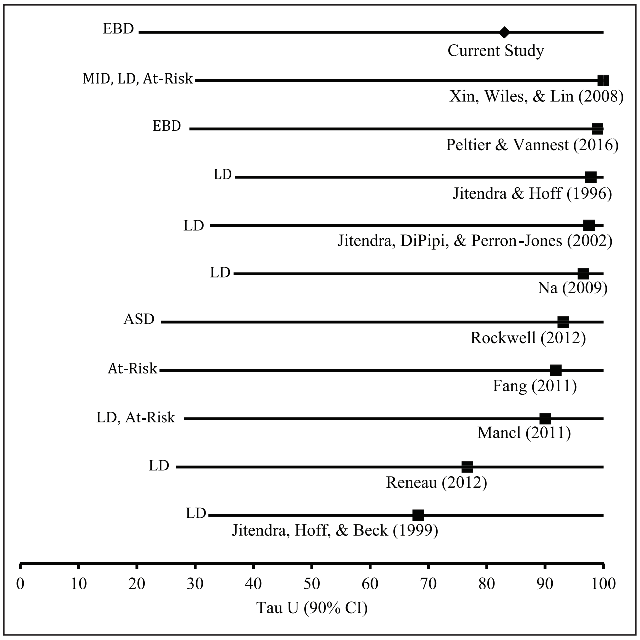


Figure 3. Tau-*U* ES and 90% CIs for related studies, with disability area of participants noted.
Note. ES = effect size; EBD = emotional and behavioral disorders; MID = mild intellectual disability; LD = learning disability; ASD = autism spectrum disorder; CI = confidence interval.

Discussion

This study investigated the effectiveness of a schema instruction package on the mathematical problem-solving performance of four second graders with EBD. A functional relationship was demonstrated through a multiple baseline design across participants. The students demonstrated improvement from baseline to intervention and maintenance with some variability, as is typical in the academic performance of students with EBD (Pierce, Reid, & Epstein, 2004). The maintenance data decreased from intervention data across all four participants. However, each student's mean performance during maintenance remained greater than the mean of one's baseline. This is corroborated by the Tau-*U* ES for each student. These effects are consistent with the effects we calculated for other SCEDs implementing schema instruction with different special education populations (see Figure 3).

The effects for the current study were not as large as another SCED that implemented schema instruction for students identified with EBD (Peltier & Vannest, 2016). The lower effects observed in the current study may be due to it involving second-grade participants, whereas Peltier and Vannest's (2016) study involved fourth-grade participants. In addition, the current study focused on three problem types requiring addition/subtraction, whereas Peltier and Vannest (2016) focused on one problem type involving multiplication/division.

Before the intervention, students were answering approximately one or two of six questions on baseline probes correctly without appearing to understand the underlying schemas or utilizing a problem-solving mnemonic. The students appeared to choose addition or subtraction at random as evidenced by many of the students adding or subtracting without listening to the entire problem read aloud. Another common error was computational mistakes. After STAR instruction, students were trained to carefully read or listen to the problem fully and underline the important information. Three students appeared to thoughtfully make decisions about the schema and appropriate operation needed to solve the problem as evidenced by students underlying key information and drawing a schematic diagram to aid in a solution method. The students were more likely during intervention and maintenance probes to write out the addition and subtraction algorithm or invented strategy resulting in a reduction of computational errors. On occasion, computational errors occurred. In a few other schema studies, researchers included a number sense and computation component in the schema instruction package to reduce the computational errors (Fuchs et al., 2008; Jitendra, Rodriguez, et al., 2013).

We expected that students would require three instructional sessions to become proficient with the skills. Students 1, 2, and 3 demonstrated proficiency (80%) at least once per schema probe. However, implementing a criterion (i.e., two consecutive sessions of 80% accuracy) may have increased automaticity in the skill. When compared with the current study, the instructional duration was much longer for related schema studies (Powell, 2011). Increasing the duration through either frequency (i.e., number of sessions) or dosage (i.e., length of sessions) may have increased and stabilized student performance.

The results from the social validity survey are promising given that student acceptance of instruction is essential in building motivation and willingness to engage in mathematical tasks (Harrison, Evans, & Schamberg, 2015). Overall, the responses provided by Students 1, 2, and 3 suggest a socially valid intervention. The responses provided by Student 4 suggest he did not find the intervention to be socially valid, which is demonstrated by his reluctance to engage in the tasks on four occasions. He was unwilling to engage in drawing the diagrams and often was reluctant to identify schemas or use the schema to aid in his choice of operation. This was observed by watching him solve the problem and then go back and draw a schematic diagram. Student 3 was reluctant to work on the task on two occasions because he complained, "it was too hard." The token economy was only embedded within the probe sheet to reinforce task completion. However, future researchers may wish to embed the token economy within instruction. Problems with motivation and persevering through tasks are two common characteristics for students with EBD (Bandura, 2006;

Nelson et al., 2004); however, token economies have been used to increase task completion and academic behaviors within mathematics interventions (e.g., Alter, 2012; Alter et al., 2011).

The responses from the special education teacher suggest that the intervention had a practical impact on his students and he believed the package was feasible for him to implement within his classroom conditions. Results for the special education teacher are promising, though a constellation of factors such as intervention complexity, time, materials, perceived effectiveness, and teacher motivation all influence treatment integrity and implementation (Lane, Bocian, MacMillan, & Gresham, 2004).

Implications

Before the intervention, the students received generic problem-solving instruction embedded within the curriculum (e.g., using manipulatives, draw a picture, look for a pattern, write an equation); however, they did not demonstrate proficiency in the problem-solving process. The students used the STAR strategy without prompting when working on maintenance probes. However, the students did not retain proficiency utilizing the schematic diagrams when working independently during maintenance. Three recommendations to increase and maintain student performance are (a) a longer duration of instruction in each of the schemas in addition to the mixed problem types, (b) a mastery approach requiring students to reach 80% criterion on consecutive probes, and (c) spiraling instruction by providing quick booster instructional sessions. The intervention sessions were approximately 15 to 20 min each to make the application feasible for a special education teacher working with this student population. Increasing the dosage either by increasing session lengths, providing more sessions, or both could lead to greater student outcomes.

Many students with EBD exhibit deficits in on-task engagement, which affects the effectiveness of strategy instruction. The token economy system motivated three of the four students to engage in the desired behavior; however, a more intensive behavioral system appears needed to evoke the desired behavior for non-responders, such as Student 4. The token economy for this study focused on improving student's willingness to engage in the mathematical task; however, attention to instruction was not a behavior that was reinforced. We recommend embedding attention to instruction as an additional behavior to reward via the token economy system for non-responders such as Student 4.

Limitations

We elected to maximize procedural fidelity by the researcher serving as interventionist. Thus, the researcher provided instruction and engaged in research, which leaves unanswered questions about the feasibility of a teacher's ability to implement the intervention package. Social validity or treatment acceptability was assessed by asking for teacher feedback and comment but not by observing to see if the practice was actually adopted. Future research using a classroom teacher may identify procedural differences or lack of fidelity that impacts effects. Future studies may also consider analyzing the effectiveness of training teachers to teach the strategies to students with EBD in small group or whole class settings.

Another limitation is the lead author served as the interventionist and primary data collector, posing a threat to the internal validity of the study. We attempted to control for this threat by having an independent non-author collect interrater reliability (on 89% of baseline and 54% of intervention probes) and fidelity checks, albeit on only 8 of 56 sessions. Infrequent assessment of implementation is, then, an additional limitation. In addition, the items were scored as correct or incorrect, which could potentially lead to an invalid representation of the students' problem-solving performance. For example, if a student identified the correct schema, filled in the schematic diagram correctly but made a simple computation error, the student received no credit for the item. A final limitation was the limited number of data points for intervention phases (i.e., three data points for PPW, change, compare, and mixed phases); however, there were a large number of data points for baseline and maintenance.

Conclusion

This study adds to the nascent literature base on mathematical problem-solving interventions specific to the population of students with EBD. Findings suggest that schema instruction improved the problem-solving performance of three of four students with EBD. However, performance during maintenance regressed somewhat and may not be socially significant. In addition, the study adds to the schema literature by experimentally testing a schema intervention package on the mathematical problem-solving performance of students with EBD. Current curriculum and mathematics trends place an emphasis on problem solving. Thus, we encourage teachers to implement practices with empirical support, and researchers to continue studying interventions targeting higher level mathematical concepts.

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