A Strategy-Based Intervention to Improve Math Word Problem-Solving Skills of Students with Emotional and Behavioral Disorders

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Abstract

It is a persistent challenge to meet the academic needs of students with emotional and behavioral disorders (EBD) particularly in the area of math word problems. This study used a multiple-baseline across participants design for three elementary-aged students identified as emotional/behavioral disordered. The intervention consisted of an empirically-based teaching strategy that focused on conceptual understanding, fluency and problem solving delivered by the classroom teacher who had received training via teacher workshops. For all three participants, the intervention resulted in increased on-task behavior and percentage of problems solved correctly. Implications and directions for future research are discussed.

It is a persistent challenge to meet the academic needs of students with emotional and behavioral disorders (EBD). Co-occurring academic deficiencies, in addition to the externalizing and internalizing behaviors that accompany the EBD label, are a well documented phenomenon. In regard to academics, students with EBD have been described as “academically deficient” (Trout, Nordness, Pierce & Epstein, 2003, p.204), they are less likely to earn a grade of A or B in any class (Bradley, Henderson & Monfore, 2004), they typically perform at least a year below grade level (Kauffman, Cullinan & Epstein, 1987), and they make less progress across grade levels than typically developing peers (Wagner, et al., 2006).

Nelson and colleagues (2004) determined that there was a negative relationship between increasing externalizing problem behaviors and decreasing academic achievement (Nelson, Benner, Lane &...
Smith, 2004). This reciprocal connection between academic difficulty and challenging behavior is clear and is a powerful factor in explaining the fact that students with EBD face the worst life outcomes of any disability groups (Kauffman & Landrum, 2009). Regrettably, the need to remediate the academic deficits of students with EBD to prevent these outcomes might go unmet due to a lack of research into effective teaching strategies and inadequate training opportunities for teachers to address students’ needs in key academic areas. A meta-analysis of mathematics interventions for students with EBD that was conducted by Templeton and colleagues (2008) revealed only 15 studies published in the last 20 years and a similar review of the literature conducted by Hodge and colleagues (2006) yielded a similar number of studies (13) with only one study that focused on solving mathematics word problems.

Hodge, et al. (2006) expound that “The lack of published studies examining the use of effective instructional practices in improving problem-solving and higher-order mathematics skills for students with EBD is alarming, and the need for additional research is critical” (p.305). To that point, Jackson and Neel (2006) examined the instructional practices of teachers in general and special education (EBD) classrooms and noted that teachers of students with EBD spent up to three times the amount of time teaching algorithms instruction as opposed to conceptually oriented instruction (72% versus 25%). This is almost the inverse of what is occurring in general education settings in which teachers were observed teaching conceptual instruction for 60% of the instructional time versus algorithmic instruction for 30% of the time (Jackson & Neel, 2006). The National Council for Teachers of Mathematics underscored the critical importance of mathematics word problems because they represent the realistic application of mathematics skills to real world problems (NCTM, 2000). Shortcomings in the ability to effectively use problem-solving strategies have been emphasized in numerous government studies including Goals 2000: Educate America Act (U.S. Congress, 1994), and What Work Requires of Schools: A SCANS Report for America 2000 (U.S. Department of Labor, 1991).

The National Mathematics Panel (2008) recommends an integrated instructional approach that blends skills and ideas for developing conceptual understanding, fluency and math word problem-solving. Research supports that instruction focused on connecting meaning and understanding through math word problem-solving helps build skills and ideas (Fuson & Briars, 1990; Hiebert & Wearne, 1993; Knapp, Shields & Turnbull, 1992; and Baroody, 2003). Teaching math word problem-solving through real contexts and situations puts the
students in a position to learn the content by figuring out the mathematics and deepening their own conceptual knowledge. A key part of word problem-based learning is designing quality tasks that build student understanding of mathematics. With consideration of these recommended elements, the intervention used in this study grounded the teacher training in the empirically-based model outlined in the book *Elementary and Middle School Mathematics: Teaching Developmentally* (Van de Walle, Karp and Bay-Williams (2010). This book is widely regarded as the ‘gold standard’ in mathematics instruction. Citing a wide array of research, Van de Walle and colleagues propose that to teach mathematics effectively the teacher must comprehend the material, transform the mathematics into a form that could be taught and then reflect on the student learning (Shulman, 1987; Van de Walle, et al, 2010). This informed the method we used to provide professional learning of word problem-based teaching for this intervention.

The guiding questions for this study were: (a) Does the intervention (teacher training workshops) improve ‘on-task’ behavior during the mathematics instructional period? (b) Does the intervention improve students’ daily percentage of mathematics word problems completed correctly according to a four-point rubric?

**Method**

**Setting and Participants**

This study was conducted in a self-contained classroom for students identified with emotional and behavioral disorders in a public elementary school in a lower SES neighborhood in a Midwestern city. The participating teacher and a classroom paraprofessional served the students in this classroom. All students were identified as emotional and behavioral disordered as their primary exceptionality according to their Individual Education Programs. Consent forms were sent home for all five students in the class and the first three that were returned were selected for this research study. All procedures described in this study took place in the students’ classroom. The classroom was arranged with the students’ desks in two parallel rows and a semicircular teachers’ table 15 feet away on the perimeter of the classroom. In the baseline phase, students worked at their desks on the mathematics problem-solving worksheets and in the intervention phase they received instruction at the teacher’s table and then completed the worksheets while seated at their desks. To address treatment diffusion the teacher and paraprofessional insured that students in baseline were not attending treatment interventions through constant monitoring and teacher voice volume control.
There were two male participants and one female participant in this study. All three participants were African-American. Victor was a fourth grade male, aged 9 years, 5 months. He was identified with a primary disability of EBD but was also identified as having a mild mental disability with an overall IQ of 67 as measured by the WISC III. Larry was a fourth grade male, aged 9 years, 10 months. He was identified with a primary disability of EBD but also was identified as having a specific learning disability in reading comprehension and an overall IQ of 89 as measured by the WISC III. Julie was a first grade female, aged 6 years, 9 months. She was identified with EBD as her primary disability with an IQ of 101 as measured by the WISC III.

Dependent Measures

Baseline and intervention assessment data were collected for two dependent measures for this study: percentage of mathematics word problems solved correctly and percentage of time on-task during the independent work session.

**Percentage of mathematics word problems solved correctly.** Correct completion of mathematics word problems was evaluated according to four identified criteria that mirror current evaluation techniques when scoring mathematics word problems (Van De Walle, Karp & Bay-Williams, 2010). Each problem was scored awarding one point for each criterion item met and thus a total of four points could be earned for each problem completed. The four criterion items were: (1) evidence of a clearly written problem-solving strategy (e.g. a picture drawn, a table or chart) (2) correctly found and labeled solution to the problem (3) correct use or retrieval of basic facts or operation chosen (participant still gets a point if there is a computation error) (4) underlining the key mathematic vocabulary in the problem. The total points earned were divided by the total points possible in order to determine the percentage of problems solved correctly.

**On-task behavior.** Students ‘on-task behavior’ was defined as each student having their eyes oriented toward their paper, and working on the assigned mathematics word problems. If the student was looking at the teacher during communication about the problems (e.g. when the teacher was reading difficult words aloud to the student) or looking at a number line posted above the chalkboard this was also included in the definition of ‘on-task behavior.’

Materials

The third author produced the math word problem-solving activities. Each problem-solving worksheet had five mathematics problems that addressed the following mathematics concepts: determining
the correct operation (i.e. addition, subtraction or multiplication), identifying key information, finding the pattern to predict what number comes next, and performing arithmetic correctly. The problems on each worksheet began with easier concepts and moved to more challenging. The problems were designed so students could employ one of the following strategies: Draw a picture, Guess and check and Make a Table or Chart (Van De Walle, Karp & Bay-Williams, 2010) to solve. The problems were written to give students a familiar context through use of the classroom names, teachers, principal and situations common for students in the intervention. Four problem structures were the basis of the created problems. These structures are important for teachers to know so that they are intentional in providing their students with a variety of mathematical problem-solving situations (Van de Walle et al., 2010). The problem structures are: (1) join, (2) separate, (3) part-part whole (4) compare problems. Each problem used a number family such as 11, 5, 6 and the different types and operations to use to solve depend on which number is the unknown.

Data collection and Inter-observer Agreement

In order to score the mathematics word problems, first the daily completed worksheets were photocopied and the problems were evaluated independently by the first and third authors and then compared. The first author served as primary coder and the third author served as the reliability coder. Inter-coder agreement ranged from 97-100% with an average agreement of 99%. Percentage of time on-task was measured using real time observation and momentary time sampling in 30-second intervals for each participant across the 15-minute work session. Percentage of time on-task was calculated by dividing the number of intervals the student was rated as on-task by the total number of intervals. The third author and a trained graduate student served as the primary and reliability observers, respectively. Inter-observer agreement was collected for 90% of the observations with an average of 94% agreement and a range of 88% to 98%.

Implementation Fidelity

The primary observer monitoring ‘on-task’ behavior completed a treatment fidelity checklist for every observation. The observer completed a dichotomous (yes or no) rating, presented in Figure 1, to insure that baseline conditions remained stable and that the intervention was implemented with fidelity.

Fidelity of implementation ranged from 75% to 100% with an average of 97% fidelity. When the fidelity checklist went below 90% for any given session, a brief 15-minute booster was provided to review key concepts.
Figure 1. Treatment Fidelity Checklist.

Mathematics Problem Solving Strategy Intervention Fidelity

Directions for completing Fidelity Checklist:

This checklist is divided into two parts. Part 1 represents the intervention—a teaching session between teacher and student(s) that will take place for fifteen minutes prior to the work session. Part 2 is the 15-minute work session that is the same for both the baseline and the intervention conditions. For Part 1, observe the teaching session and complete the checklist to insure that all instructional components of the problem solving strategy are completed. Then for Part 2 review that all elements of the work session are present.

Teacher Name: ______________________________   Date: _____________________

Location:____________________________________ Observer initials: ____________

Part 1 Intervention Time Started: _________Part 1 Intervention Time Ended: ______

Part 2 Work Session: Time Started: ____________

Part 2 Work Session: Time Ended:_____________

Part 1 Instructional Section

Circle the strategy being taught:

<table>
<thead>
<tr>
<th>Guess &amp; Check</th>
<th>Draw a picture</th>
<th>Make a Table or Chart</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Students Receiving Instruction</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

___ 1. Does the teacher introduce the goal of becoming a better math problem solver?
___ 2. Does the teacher introduce the strategy that is being taught?
___ 3. Does the teacher review the critical elements of this problem-solving strategy
___ 4. Does the teacher state the importance of writing down what you know, circling key information and showing in writing what strategy you used to solve the problem?

Introduction of first sample problem

___ 5. Does the teacher present a sample problem to use the strategy being taught?
___ 6. Does the teacher read the problem to the student?
___ 7. Does the teacher ask: “What question are we trying to answer?”
___ 8. Does the teacher ask “What key mathematical information is given to us in this problem?”
___ 9. Does the teacher give the student an opportunity to identify and circle the key mathematical information in the problem?

If the student is unable to decipher the key mathematical information in the problem:

___ 9a. Does the teacher model how to find the key mathematical information (a think- out loud) and circling the key mathematical information?
___ 10. Does the teacher model how to solve the problem using the problem-solving strategy and writing down all important information (see step 4)?

Introduction of second sample problem

___ 11. Does the teacher give the student a sample problem to try and solve?
___ 12. Does the student read the problem with the teacher?
___ 13. Does the student identify the question in the problem?
___ 14. Does the student identify and circle the key mathematical information in the problem?
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____ 15. Does the student model and write down the strategy (Guess and Check, Draw a picture or Make a Table or Chart) while working with the teacher?

____ 16. Does the student have an opportunity to solve the problem?

If the student is unable to complete any of the steps in the second sample problem:

____ 16a. Does the teacher prompt by probing which problem solving strategy the student should try and then model how to identify key information, and use the identified problem solving strategy?

____ 16b. Does the teacher use a model, manipulatives or any other type of visual aid?

If yes, explain how the model, manipulatives or other materials were used:

Describe scaffolding used by the teacher to guide student understanding: i.e. re-reads problem; repeats questions; models a think-aloud; repeats student’s thoughts; gives real life example.....

Quality of classroom management during the intervention      Low   Moderate    High

How were other students in the classroom engaged during the intervention?

Part 2 Work Session

____ 17. Does the teacher’s assistant read words aloud for all students who requested assistance but not provide any other assistance?

____ 18. Did all students received the same daily math word problem worksheets?

____ 19. Do all students have sharpened pencils?

____ 20. Are all students visible to primary (and reliability) data collector?

____ 21. Did work sessions last exactly 15 minutes?

Design

A concurrent multiple-baseline design across students was used to evaluate the impact of this teacher-implemented mathematics problem-solving strategy. The dependent measures were students’ performance on a problem-solving worksheet assigned after strategy instruction and their level of on-task behavior during these independent work sessions.

Procedures

This study involved three phases: (a) a baseline phase when students were asked to complete worksheets of five mathematics word problems with the 15-minutes of mathematics instruction that was typically provided by the classroom teacher (direct instruction), (b) a teacher training phase in which the classroom teacher attended a workshop to learn how to implement teaching strategies to guide students to use when solving mathematics word problems and (c) the intervention phase in which the teacher delivered instruction for approximately 15-minutes based on the workshop information to students in the intervention phase. Following the lesson students completed a 5-problem worksheet during a 15-minute interval.
Baseline. During the baseline condition, the teacher continued with typical math instruction as it was aligned with the district-wide curriculum. Immediately following the scheduled math time, a 15-minute block was sanctioned and students were presented with a math word-problem worksheet and given 15 minutes to complete the five problems on the math word problem worksheet. The paraprofessional worked with the students who were in the baseline phase or were not participating in this research study. All three participants were given assistance with reading any words that they did not recognize in the problem by the paraprofessional in the classroom. No other assistance was provided.

Teacher training. Two workshops were conducted with the participant teacher by the second author. The first workshop took three hours and the second workshop took about an hour. The workshop began with a clarification of how math word problem-based learning would be used and the teaching strategies that are necessary for the problem-based approach to succeed. The outcome would be to reframe the teacher’s method of problem-based teaching that would enhance the students’ mathematical ability to decode, use a strategy and solve a variety of problems. The next step in the workshop was to gather information about the mathematical performance levels of the students in the class in order to guide the selection of the best strategies for them to use in approaching a mathematical problem. The teacher identified Guess and Check, Draw a Picture and Making a Table or Chart as the best for the student participants. With this information the next phase of the training was to use a modified scripted lesson format from Van De Walle, et al. (2010) for each of the problem-solving strategies. The researcher modeled an example of a scripted lesson for the strategies with the teacher acting as the student.

A focus was placed on how to ask questions that will get students talking about their thinking and take more ownership for their learning how to apply this strategy to solve problems. In addition, the teacher was introduced to the four components that would make up the rubric evaluating successful completion of the math word problems (e.g. evidence of a clearly written problem-solving strategy, correctly found and labeled solution to the problem…) The final part of the workshop was to have the teacher practice using the scripted lessons for each of the strategies. The workshop concluded with a debriefing on how the strategies would roll out in the intervention plan.

Classroom implementation. The classroom implementation phase had three stages. First, was a broad discussion about problem-solving that was delivered to the students by the classroom teacher. This instructional session had a number of distinct characteristics. They
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Figure 2. Example of Scripted Lesson Format

**Teacher:** Today we are going to learn about a problem-solving strategy titled Guess and Check. Who has guessed at answer for a problem before?

**Teacher:** First listen to me read the problem. Now, I want you to read the problem with me and be prepared to tell me what the problem is asking us?

**Teacher:** What information are we given in the problem that may help us to solve the problem? (Scaffold questions to make sure that students can identify critical information needed to solve the problem).

**Teacher:** Let’s review what the question we are trying to answer?

**Teacher:** To use Guess and Check we need to begin by making a guess. We do not need to make a wild guess because we have some information we can use. Make a guess and tell me what information you used to make that guess.

**Teacher:** Write your guess down. (Depending on the student performance, the teacher may want students to make a second guess and talk about what they did differently from the first guess).

**Teacher:** Now, let’s check to see if our guesses were close to the actual answer.

**Teacher:** Now, I want you to try one by yourself, but I am going to ask you essential questions as you go through to see how you are thinking and using guess and check.

included: a rationale for becoming a better problem-solver, reviewing critical problem-solving strategies and using two sample problems to model effective strategies. A full reflection of these instructional components can be reviewed in the treatment fidelity checklist. Second, the teacher transitioned into the more focused scripted lesson. These two phases took approximately 15 minutes each day. The third stage was the 15-minute independent work session when participants were asked to complete a five-problem worksheet. After the first four sessions of the intervention for the first participant, a review of Victor’s outcomes indicated a need for the teacher to have additional tools to foster more student discourse about their thinking process and to identify what problem-solving strategy they were using. The researchers conducted a one-hour review and follow-up training at the school site to provide feedback and provided additional cuing for the students to use. The teacher was given more examples of scaffolding cues like: “tell me the question in your own words”, “what will the answer tell us i.e. pennies, milk bottles, books”; and “does your solution make sense.” This additional cuing used the following format: (1) What is the problem in the question? (2) What pictures or words could show how you solved the problem? (3) What answer did you get when you solved the problem? (4) What information did you use to solve the problem? As students transitioned from baseline to intervention they joined the direct instruction group until all three students were in the intervention group.
Figure 3. Percentage of Problems Correct and Time On Task
Results

Figure 3 shows the percentage of problems solved correctly and the percentage of intervals of on-task behavior by Victor, Larry and Julie. Victor was in the baseline condition for four sessions until a relatively stable baseline was established. Victor solved an average of 23% of problems correctly with a range of 5%-35% in baseline and an average of 52% with a range of 20-92% in the treatment condition with an accelerating trend from sessions 9 to 23. There was a phase change, indicated by the dotted line between sessions 10 and 11, to signify the introduction of a cuing form as part of the intervention protocol. Larry was in the baseline condition for 10 sessions. Larry solved an average of 14% of problems correctly in baseline with a range of 0-25% and solved 50% of problem correctly in intervention with a range of 30-67%. Julie was in the baseline condition for 14 sessions. Julie solved an average of 18% of the problems correctly in the baseline condition with a range of 0-35% and 48% of the problems correctly in the treatment condition with a range of 30-92%.

An error analysis was conducted by the first and second authors to look for response patterns and predictable errors. Overall, participants did well with criterion items 1 and 4: evidence of a clearly written problem-solving strategy (e.g., a picture drawn, a table or chart and underlining the key mathematic vocabulary in the problem). Their difficulties continued to be in criterion items 2 and 3: correctly found and labeled solution to the problem and correct use or retrieval of basic facts or operation chosen.

Figure 3 also shows the percentage of intervals on-task for Victor, Larry and Julie. Victor was in baseline for four sessions. Victor was on-task for 54% of the intervals in baseline with a range of 46-59% and was on-task for 86% of the intervals in the treatment condition with a range of 60-97%. Larry was in baseline for 10 sessions. Larry was on-task for 62% of the intervals in baseline with a range of 23-93% and was on-task for an average of 85% with a range of 57-100%. Julie was on-task for 67% of the intervals in the baseline condition with a range of 23 to 100% and in the interval condition she was on-task an average of 87% of the intervals with a range of 63-97%.

Social Validity

Two social validity interviews were conducted with the teacher. One was conducted immediately upon completion of this study. The second was completed six months (with three months of summer vacation) after this study. In the initial interview, the teacher indicated that he found the training useful and believed the intervention was acceptable and effective for providing instruction for mathematics word
problems. He further indicated that this training was a paradigm shift moving from algorithms to concepts and was not something he was exposed to during his university teacher preparation classes. He indicated that learning to “let students struggle before jumping in” was the most valuable element of the intervention that he learned during the workshop. In the six month follow-up interview, the teacher indicated that he continued to use these strategies with his new class of students and that they were having greater success solving math problems even more quickly than the participant students in this study.

Discussion

This study extends the current knowledge base in the area of remediating academic deficits, specifically solving math word problems, for students with EBD. This study pilot tested a model for teacher training that sought to change the manner in which mathematics instruction was provided, moving from an algorithmic to a problem-based conceptual approach to math word problems. The use of the cuing format that asked probing questions to further students’ conceptual understanding of problem strategies also played a critical role in improving student results in both percentage of problems solved correctly and time on-task. Finally, the shift in the evaluation process that focused on variables beyond the ‘ultimate’ right answer to evaluate student performance represents an important paradigm shift for this teacher’s approach to teaching mathematics. It may be hypothesized that only focusing on the end product of the right answer does not allow teachers to gain a depth of information in order to evaluate progress students are making in applying mathematical skills to be successful in problem-solving.

Results indicated that during the intervention condition students’ mean levels of problem-solving accuracy and on-task behavior increased, as compared to data from the baseline condition. Differentiation between baseline and intervention is apparent via visual inspection for all three participants. During the intervention phase, each student improved on the average percentage of math problems solved correctly and their average percentage of on-task behavior. However, it should be noted that the levels did not approach instructional (80%) or mastery levels (90%) as suggested by Rosenshine and Stevens (1986). Perhaps most interesting was the impact that this training had on the teacher’s conceptualization of effective math instruction. As indicated in his social validity interview, focusing more on conceptual understanding of problems and strategies to improve a students approach to the problem as opposed to plugging in the correct algorithm
and getting the right answer was a paradigm shift for him. This supports the research that the teacher must learn to acknowledge student strategies and not do their thinking for them. Students must have an environment to explore mathematics conventions and methods that will foster this mathematical proficiency (Shulman, 1987; Hiebert et al., 1996).

Consistent with previous research, the connection between academics and behavior for students with EBD was demonstrated as the percentage of problems solved correctly increased, so did students’ on-task behavior. While the intervention appeared to impact both problem-solving skills and on-task behavior, there were a number of overlapping data points with regard to their on-task behavior. This may be attributed to a high level of reactivity during the baseline phase as this study had a new protocol of instruction being provided. In the initial sessions of the baseline phase, all students were content to write down any number in order to answer each problem as evidenced by a review of their completed work. This is consistent with Skinner’s (2002) ‘discrete task completion’ hypothesis that completed tasks (e.g. word problems) may serve as conditioned reinforcers. In other words, writing down anything is better than writing down nothing and will keep students on-task for a period of time. The instability is also indicative of how labile students with EBD are, in which they can demonstrate high-levels of on-task behavior one day and low levels the next. The compelling element to the intervention is the way that the intervention stabilized their levels of on-task behavior.

Several limitations must be considered when interpreting the findings from this study. First, this study was conducted in a single classroom with students in a highly specific environment (a self-contained classroom for students with EBD). Related to this is the limited sample size of three students which impacts the generality of these findings and replication studies are necessary to improve the external validity of these findings. In addition the teacher did not have a strong preparation program in how to teach mathematics. Unfortunately, this limitation is prevalent among studies in the literature that involves interventions for the academic difficulties of students with EBD. Additionally, the issue of external validity must also be considered because the intervention was neither faded, nor were generalization probes conducted. Other than the follow-up interview conducted during the next school year, when the teacher related that he continued to used these strategies, no measurement of their impact was conducted. Thus, there are minimal measures of the durability of the effect of the intervention. Furthermore, the level of intensity and amount of time required in the instruction provided to the classroom
teacher may not be palatable or even possible for many schools as they are often overloaded with other workshops and competing demands on teacher time. While this method of mathematics instruction has been successful with larger student groups, it is incumbent on schools to make this type of in-service teacher training a priority.

The results of this study support the use of this intervention to improve math problem-solving skills of students with EBD, however other future research is necessary. Future directions of this research line will include implementing this type of teacher training program with greater numbers of teachers and students. In addition measuring teacher beliefs about teaching mathematics as well as their pedagogical content knowledge (PCK) before and after the intervention may guide the direction of the professional development for the teachers. Future research directions may include using different, briefer problem solving heuristics. Additionally, teacher training workshops could be expanded to implement this intervention with larger numbers of teacher and students and addressing students without exceptionals and with other exceptionals.

References


emotional and behavioral disorders. Behavioral Disorders, 31, 297-311.


