A Functional Writing Package and Middle School Special Education Students' Math Algorithms

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ABSTRACT

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In 2 experiments, I tested the effects of a writing/editing package for middle school students with disabilities who performed below grade level in math and reading. The participants were grouped into dyads based on math grade level, and each dyad consisted of an editor and writer. There were 8 participants in Experiment 1. The design was a multiple probe across 4 dyads design. The dependent variables were : 1) algorithm components including functional and rationale descriptions; 2) functional accuracy of a written math algorithm; 3) structural components of written responses including grammar, spelling, and punctuation; 4) social validity measure to determine whether the was a significant difference in the means of scores assigned by naïve readers for pre- and post-intervention samples; 5) resistance to extinction measures for solving above grade level algebra problems as a measure of reinforcement value. During the pre-intervention assessments, each participant was given a word problem which corresponded to their math performance level. Participants solved the word problem, then wrote an explanation so a naïve adult reader could complete the steps of the problem to produce the solution without seeing the problem. Participants also wrote responses explaining the rationale for the operations used in the word problem and the practical application for the word problem. Participants were then given untaught algebra equations to measure resistance to extinction. In Experiment 1, the independent variable was an editing and writing package for producing a written explanation for specific steps to solve a multi-step math problem. The participant as the writer produced a written math algorithm, and the participant as the editor provided questions to the writer so that a

rewrite would help the editor solve the math problem correctly. Structural elements were not consequated, and rationale components were not directly taught. Criterion for the independent variable was achieved when the writer produced a written explanation with all four necessary functional components and required no additional rewrites. The results demonstrated a functional relationship for functional accuracy and functional components. A functional relationship was not shown for the rationale. In Experiment 2, the dependent variables remained the same. The independent variable was changed so that the experimenter only edited the first round of the writer's responses for structural elements, and the writer corrected for structural elements. The editor also had to write a word problem based off the writer's written algorithm. Results for Experiment 2 show a functional relation for functional accuracy, functional components, and rationale components.

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DEDICATION

I dedicate this dissertation in memory of my father, who taught me how to solve problems, to always extend a helping hand, and who imparted on me the value of taking the back roads.

Chapter I

INTRODUCTION AND REVIEW OF THE LITERATURE

Introduction

According to the United States Department of Education (USDOE), 16 percent of American high school seniors are proficient in math and interested in Science, Technology, Education, and Mathematics (STEM) career. The United States is ranked 36th in math and 22nd in science among developed nations (PISA, 2015). The USDOE also funds the Race to the Top (2009) program by providing funding to support more individualized instruction supported by technology. (National Research Council, 2011) While these are steps in the right direction, there is still a need for better curriculum design in America.

The Common Core State Standards (CCSS) were developed to align the educational expectations of all the states to establish a consensus on expectations for the acquisition of skills in grades K-12. The federal government pushed for the states to adopt the CCSS and the U.S. Department of Education (USDOE) awarded $330 million to help develop assessments aligned with the CCSS to establish a national curriculum in reading and mathematics (National Governors Association, 2010). The difference between the CCSS and the previous individualized state standards is that some would argue the CCSS “revealed a shift toward greater emphasis on higher order cognitive demand,” (Porter, McMaken, Hwang, & Yang, 2011, p. 10). The CCSS was one step towards making a national curriculum, which had more rigor and focused objectives. The higher order cognitive demand which Porter, McMaken, and colleagues, (2011) refer to includes the wider skill of problem solving or critical thinking. Problem solving can be addressed in a variety of topographies within the classroom, particularly in the areas of writing and editing.

Literature Review

Problem Solving

Problem solving is a broad repertoire that teachers must address in the classroom (National Governors Association, 2010). Critical thinking "comprises the mental processes, strategies, and representations people use to solve problems, make decisions, and learn new concepts," (Sternberg, 1986, p.2). According to Schmaltz, Janson, and Wenckowski, (2017), teaching critical thinking is a difficult task, because of the lack of clarity in definition and the many methods teachers use to attempt to instill scientific thinking in students. While teachers learn what types of questions to ask, (Bloom, 1956) the students still need to learn how to problem solve. There have been many definitions of problem solving including analytical thinking, (Dewey, 1933), heuristic problem solving (Polya, 1971), and the behavior analytical perspective (Skinner, 1957).

According to Dewey (1933), "Thinking is not a case of spontaneous combustion; it does not occur just on 'general principles.' There is something specific which occasions and evokes it," (Dewey, 1933, p. 4). What is the source of that suggestion for the solution to the problem? Dewey (1933) argues that experience has something to do with it:

> If the person has had some acquaintance with similar situations, if he has dealt with material of the same sort before, suggestions more or less apt and helpful are likely to arise. But unless there has been experience in some degree analogous, which may now be represented in imagination, confusion remains mere confusion. There is nothing upon which to draw in order to clarify it. Even when a child (or a grown-up) has a problem, to urge him to think when he has no prior experiences involving some of the same conditions, is wholly futile (Dewey, 1933, p. 4).

Teachers are urged to teach problem solving skills and students often learn specific procedures for breaking down tasks and may simplify a problem to find the solution. Teachers often instruct their students to use heuristic techniques, (Polya, 1971). Heuristic comes from Greek which means “to discover” and generally students are given a “rule of thumb” in order to solve problems, (Hughes, 1971). Experts in education have turned this technique into “the discovery method” where students learn by trial and error (Hughes, 1971). Schemas have been used to recognize problems and apply a solution, (Powell, 2011).

From a behavioral perspective, B. F. Skinner (1969) said there are two components to problem solving. The first is the situation where the individual identifies a response that has not been previously reinforced, and the second component is which the behavior brings about a solution, (Skinner, 1969). Skinner also argued that there is a source of automatic reinforcement in problem solving where the speaker must create his own stimuli “to supplement other behavior already in his repertoire,” (Skinner, 1957, p. 442). Skinner stated that to problem solve, one must manipulate the environment or manipulate the behavior of others via communicated behaviors towards the successful solution. Skinner (1957) suggested problem solving behaviors such as rule-governed behavior and contingency shaped behavior contribute to solving problems. Contingency shaped behaviors are performed as a function of the embedded stimuli. Rule governed behavior, or verbally mediated behavior are those under the control of written or spoken verbal stimuli (i.e. rules such as “No running in the hallway”).

Rule-governed behavior. Rule-governed behavior or verbally governed behavior is defined as behaviors controlled by verbal stimuli (i.e. language, expression, tone) (Greer, 2002). Rule-governed behavior is part of problem-solving behavior because the individual follows a set of rules (possibly an algorithm) to solve a problem. Skinner also used the term *induction* to refer to rule-governed behavior, and he defined induction as “Stimuli which evoke behavior appropriate to a set of contingencies” (Skinner, 2014, p.143) Induction is not necessarily the creation of a rule because of certain instances, but the establishment of a rule, which then creates behavior that is appropriate to a set of contingencies. An individual who gets lost in the woods relies on clues marking the trail in the woods to find the correct path. As Skinner says, “A trail is blazed, for example, precisely because it is more easily followed,” (Skinner, 2014, p. 124).

Contingency-shaped behavior. Contingency shaped behavior relies on “genuine” consequences, (Skinner, 2014, p 153). Instead of following directions, one may “fly by the seat of one’s pants”. The contingencies exist before the rules are formed. A person who is in the woods after a fresh fall of snow cannot use clues to find his way back to his car, that person must “discover the truth” as he slowly develops his own trail back to the car.

Problem solving can occur at many different levels of development. A child who cannot reach his juice box learns to emit a pointing response towards the cup on the counter while looking at his mother to solve his thirst problem. A third grader who cannot solve multiplication problems learns fact families and rules prior to studying the process of multiplying one-digit equations. A teenager who will soon take a driver’s test studies the manual but does not actually acquire the operants necessary to pull the car out of the driveway until she gets in the driver’s seat. (Skinner, 2014, p.159). Many individuals acquire these skills incidentally, however for those who do not, there are behavior analysts who use the Verbal Behavior Developmental Theory (VBDT) to research and provide the interventions needed for these individuals to acquire these milestones (Greer & Ross, 2008; Greer & Speckman, 2009).

Verbal Behavior Developmental Theory

Greer and Ross (2008), and Greer and Speckman (2009) built on Skinner's verbal behavior theory (Skinner, 1957) to develop a trajectory that includes verbal milestones which children need to become truly verbal. This VBDT utilizes a series of cusps and capabilities (Rosales-Ruiz & Baer, 1996) to organize the verbal behavior milestones to categorize and operationally define how humans develop language and become truly verbal. The levels of verbal development have been defined as 1) pre-verbal foundational cusps, 2) listener behavior developmental cusps, 3) speaker behavior developmental cusps, 4) joining of listener and speaker cusps (truly verbal), 5) the joining of print stimulus control to the speaker and listener cusps. (Greer & Ross, 2008). In order to induce these cusps, researchers who use VBDT use "learn units" (Albers & Greer, 1991) as instruction. A learn unit is a three-term interlocking operant which considers the motivating operation (i.e. a setting event such as a child not eating breakfast) when introducing the antecedent to the student, the behavior or response of the student, and the consequence to that response (reinforcement for a correct response, correction for an incorrect response). The learn unit is a measure of both student behavior and teacher effectiveness and has shown to increase student accuracy and learning, (Albers & Greer, 1991; Greer & Ross, 2008).

Cusps and Capabilities

Skinner's six verbal operants provide the foundation for an individual to access his environment. VBDT takes these operants further and organizes them into verbal behavior milestones called cusps and capabilities (Rosales-Ruiz & Baer, 1996). A cusp enables children to contact contingencies in new ways, accelerates their learning, and enables them to learn in new ways. A capability allows the child to learn in ways that the individual could not learn before, (Rosales-Ruiz & Baer, 1996). These cusps include the pre-listener repertoires (i.e. where children learn to attend to faces and voices), listener (i.e. children can follow vocal directions), speaker (i.e. children can emit mands, tacts), speaker as own listener (i.e. children can respond to own voice), reader (i.e. children can textually respond to words, comprehend text), and writer (i.e. children can write to affect the behavior of others) stages of verbal development. Cusps and capabilities are used to set a trajectory of learning within the levels of verbal development, which children need to acquire to become truly verbal, (Greer & Ross, 2008).

VBDT and Truly Verbal

For an individual to be truly verbal, the individual must have speaker as own listener cusps and capabilities within their repertoires (Greer & Ross, 2008; Greer & Speckman, 2009). While speaker and listener behavior develop separately, the individual does not become truly verbal until the speaker joins with the listener, (Skinner, 1957). There are three cusps as capabilities (cusps that are also new learning capabilities) within the speaker as own listener repertoire, which include say-do, self-talk, and Bi-Directional Naming.

Say-Do. A child has the cusp of say-do when he says what he is going to do and then the child goes and does it. For example, the child says, “I will go read a book,” and then the child goes and picks up a book and begins reading, (Greer & Ross, 2008).

Self-Talk. An individual has acquired the cusp of self-talk when he alternates between speaker and listener behavior. For example, a child is playing alone with action figures and emits self-talk conversational learn units with the action figures, (Lodhi & Greer, 1989; Greer & Ross, 2008).

Bi-Directional Naming (BiN). Bi-Directional Naming (BiN) is a capability where the speaker and listener behaviors are joined. An individual must acquire BiN to be considered truly verbal (Barnes-Holmes, Barnes-Holmes, and Cullinan, 2000; Greer & Ross, 2008; Greer & Longano, 2010). Horne and Lowe (1996) first used the term to define when individuals learn the names of objects incidentally (Greer & Longano, 2010). Horne and Lowe (1996) defined BiN or Naming as a higher order bidirectional and circular relation which combines the listener and speaker behavior within a person's skin. Individuals who do not acquire BiN naturally, require intervention. Multiple Exemplar Instruction (MEI) is an intervention used to help the BiN capability emerge, (Fiorile & Greer, 2007; Gilic, 2005; Greer & Keohane, 2005; Greer & Speckman, 2009; Greer, Stolfi & Pistoljevic, 2006; Greer & Ross, 2008).

Reader

Subsequent cusps and capabilities fall into the functional categories of reader and writer levels of verbal development (Greer and Ross, 2008; Greer and Speckman, 2009). Individuals who function as readers and writers can affect their environment through new topographies. In VBDT, readers respond to textual stimuli, and can read and act, or read and have his or her emotions affected. An individual has acquired comprehension when the reader has BiN and has mastered "phonemic decoding", (Greer, 2008; Greer & Ross, 2008). This means that students who can decode words do not understand what they have read unless they have not acquired the capability of BiN or incidental learning (Reilly-Lawson, 2008).

Writer

Most writing curricula are concerned with structural components of writing (grammar, capitalization, punctuation, spelling), (National Governors Association, 2010) which can be measured and improve upon; however, as Skinner (1957) said "child must learn to *use* writing as well as learn to write," (Skinner, 1957, p. 193). In VBDT, Greer and Ross (2008) place an emphasis on the function of writing. A writer can affect the behavior of a reader (listener) even if the writer is not present. Students who control contingencies of the environment through producing marks on the page in the form of words are known as writers (Greer & Ross, 2008). In VBDT, the two categories of writing include technical writing (e.g. writing "how-to's") and aesthetic writing (e.g. poetry). Good writers can write for functional and aesthetic effect, thus affecting the reader as one would affect the listener. In technical writing, a writer produces specific written responses which direct a reader to emit specified behavior (i.e. making a sandwich or solving an algorithm). In aesthetic writing, the function of writing is to affect the emotion of the reader (Greer & Ross, 2008). Students who do not acquire the function of writing naturally need simulated conditions where they can acquire functional writing through educational intervention, (Greer & Ross, 2008).

Functional Writing. Vargas (1978) was the first to suggest how to teach functional writing by having the writer observe the reader actively reading the writing, thus establishing the "need to write" (Greer & Ross, 2008). The participants were assigned a writing task asking they provide directions for a reader to complete a certain task. The reader completed the task based on written information. If reader could not complete the task, the writer edited the directions until the writer could do so. This procedure established functional writing, as the writer learned to affect the behavior of the reader through written responses. Research in VBDT focused on replicating conditions found in Vargas (1978) to establish functional writing (Madho, 1997; Reilly-Lawson & Greer, 2006; Helou, Lai and Sterkin, 2007; Broto & Greer, 2014). See Table 1 for writer and editor research in VBDT.

In two experiments, Madho (1997) tested effects of responses of a reader on functional and structural writing components for middle school students with developmental delays. Participants wrote a set of directions for a peer to follow. Rewriting and corrections were implemented until peer followed directions correctly without revisions. Participants were asked to write about an object without writing the name of the object. A naïve adult reader was asked to read the writing and provide feedback in written form. If the reader could not guess the object, he gave the directions back to the writer, and the writer had to redo the written directions with the feedback. Writers completed rewrites until they met 100% criterion on functional components of writing and the reader accurately guessed the described object. Results showed a participant writer could change his writing behavior to affect the behavior of a reader. Results also showed that editor behavior caused the change in the behavior of a writer. Succeeding research replicated these conditions and led to the Writer Immersion procedure (Reilly-Lawson & Greer, 2006).

Writer Immersion. Writer immersion is a procedure which establishes a motivating operation by creating an environment where all communication between the teacher and the student is done through writing, and without any vocal or gestural communication (Helou, Lai, & Sterkin, 2007; Jodlowski, 2000; Madho, 1997; Reilly-Lawson & Greer, 2006; Visalli-Gold, 2005). A writer cannot achieve his goal without communicating through writing, thus establishing reinforcement value for acting as a writer. A writer produces written responses for a reader to complete a task. If the reader is unable to, the writer rewrites the task until the reader can accurately complete the given assignment. Immersion is used in all the functional writing studies to establish a motivating condition similar to when one only receives a preferred item such as a cookie if a mand is produced.

Table 1
Writer and Editor Research in VBDT

Authors	Participant	Dependent Variable: Structure vs. Function	Independent Variable: Editor vs. Writer	Conceptual or Experimental	Number of Studies
Vargas, (1978)	Sixth graders	Function	Writer	Conceptual	
Madho, (1997) unpublished dissertation	Middle school students with developmental delays	Function Structure	Writer Editor	Experimental	2 studies
Reilly-Lawson & Greer, (2006)	Middle school students	Function Structure	Writer	Experimental	2 studies
Helou, Lai and Sterkin (2007)	Middle school students	Function Structure	Writer	Experimental	1 study
Marscio, (1998) unpublished dissertation	Third grade-Eighth grade	Function	Editor-self	Experimental	2 studies
Jodlowski, (2000) unpublished dissertation	Third-grade	Function Structure	Editor-teacher, peer, self	Experimental	3 studies
Visalli-Gold, (2005) unpublished dissertation	Middle school students	Structure	Editor-teacher, peer	Experimental	1 study
Broto & Greer, (2014)	Second grade students	Function Structure	Writer	Experimental	1 study
Pellegren, (2015) unpublished dissertation	Third grade students	Function Structure	Editor-peer	Experimental	2 studies
Weber, (2016) unpublished dissertation	Fourth grade students	Function	Writer Editor-peer	Experimental	2 studies

Note: Structure vs. Function refers to the focus of the dependent variable of each study. Editor vs. Writer refers to the focus of the intervention

In two experiments, Reilly-Lawson & Greer (2006) studied the effects of a writer immersion protocol on the structural and functional components of writing for middle school students. In the first experiment, the experimenter gave participants a picture with several components (colors, shapes, letters, words positioned in different places on the paper) and written instructions to write a paragraph describing the picture. After the participants finished writing the instructions, the written response was given to a naïve peer reader. The reader drew a picture based solely on the written instructions. The participants did not see the reader's drawings and were not consequated. In the second phase, the experimenter gave both the writer and the reader a picture and the same written antecedent as in baseline conditions. The writer produced a written response to the antecedent. The reader read the writer's response and drew a picture based on the instructions. The experimenter then provided learn units (Albers & Greer, 1991) for the structural components of the written instructions. The experimenter would discuss the function. The paper was then returned to the writer for a rewrite for both structural and functional components, and this process was repeated until the writer met 100% accuracy in structural components for writer behavior. In the third phase, writer immersion intervention was implemented. The experimenter gave the writer and reader a picture and written directions to describe the picture just as in the baseline phase. The reader then drew a picture based on the written instructions. Learn units were given in written topography for the structural components of the essay and the picture was returned to the writer so the writer could see the effect of his writing. The writer rewrote the essay until criterion was met. Results showed this intervention to be effective.

In the second experiment, all the components were the same except for the writer immersion protocol as the only independent variable. The writer edited his own writing after seeing the drawings completed by the reader. the writer rewrote his essay until the writing met 100% accuracy on both structural and functional components. Results showed an increase in accurate functional and structural components of writing. Results of this study showed an increase in the numbers of sentences written and the percent of accurate structural components after the experimenter editing was completed. The number of correct functional components did not increase until the implementation of the writer immersion procedure. (Reilly-Lawson & Greer, 2006).

Helou, Lai and Sterkin (2007), also tested the effects of writer immersion on the responses emitted by a peer reader for four male middle school participants diagnosed with behavioral disorders. They replicated Reilly-Lawson and Greer (2006) but used a peer yoked contingency due to the lack of social reinforcement. A peer yoked contingency (Davies-Lackey, 2005) is a term coined loosely on animal yokes, where two individuals must work together to achieve an end goal. Teachers use this as part of a tactic in classrooms and create them using poster board. The teacher uses reinforcing stimuli on the board, such as characters from a favorite television show. There are ten steps, marked by Velcro strips going up the board to achieve a goal (i.e. top of a mountain). The teacher has one character, and the students have their chosen character. At a predetermined time or goal, if the students met that goal, their character moves up, if they did not meet the goal, the teacher's game piece moves up. Whoever's piece reaches the end of the game board (i.e. top of the mountain) wins a larger reinforcer. Pre- and post-intervention probes consisted of a picture given to the participants to describe in writing with no consequences. In the treatment phase, four "how-to" tasks were given to each participant where the participants had to write instructions for each task for a reader to accurately complete the task. The tasks included: 1) how to make a peanut butter sandwich, 2) egg hunt I, 3) egg hunt II, and 4) how to make a snowman. Results showed that the writer immersion procedure and the effect of the peer reader's responses to the participant's writing functioned to increase accuracy in both the structural and functional components across all four participants. Research in VBDT continue to investigate not only the function of writing and the effect it has on other readers, but on writers as own readers or self-editors, (Greer & Ross, 2008).

Editor

Writers who read their own work from the perspective of others, which is an observing response of others, and therefore read their own writing as listeners are known as *writer as own readers* or *self-editors* (Greer & Ross, 2008, p.19). This cusp, the joining of the reader and writer repertoires, is essential for students to be successful in school. Editors can listen to what they have written and at the same time take the perspective of the intended audience, (Greer & Speckman, 2009). For a writer to be effective, she needs to be able to not only write with accurate and structural components, but also read her own writing and edit her own work from the perspective of a reader (Greer & Ross, 2008). Research in VBDT on the editor investigated the effects of the self-editor (Marscio, 1998), peer editor and teacher editor (Visalli-Gold, 2005) and a combination of self-editor, teacher editor, and peer editor (Jodlowski, 2000).

Marscio (1998) tested the functional relationship between self-editing math scripts for participants in elementary and middle school students. Participants read to themselves and independently completed math problems. Data were collected on the latency of time between the onset of the task initiation and seeking help or stopping work, and the rate of correct and incorrect responses completed prior to requesting help or stopping work. The experimenter provided scripts on how to complete the math instruction to the participants to use while completing math instruction in a group setting. Participants used the scripts to self-teach the instruction. Results showed all participants had increased intervals of working independently, increased rates of correct responding, and low rates of incorrect responding. In the second experiment, Marscio (1998) tested the effects of the generalization of the self-editing checklist with reading objectives. Results showed increased intervals of time participants worked independently and increased rates of accurate responses (Marscio, 1998).

In three experiments, Jodlowski (2000) tested the effects of peer editing, teacher editing, and serving as a peer editor on self-editing behavior. The experimenter tested the different situations separately and combined on functional and structural components and found that students who functioned as the peer-editor required fewer corrections to rewrite their essay compared to self-editing essays. The first dependent variable was the number of times a participant rewrote the same technical writing assignment during pre- and post-intervention assessments. Technical writing assignments were scripted from four areas in the Common Core State Standards: descriptive, mathematics, science, and how-to. All technical writing assignments included eight functional writing components. Structural components measured in this experiment included complete sentences, subject-verb agreement, spelling, capitalization, punctuation, and word usage. All structural components were measured per sentence and scored as the number of correct components over the total possible components and calculated as a percentage (Jodlowski, 2000). The second dependent variable: self-editing, was defined as when the participant labeled the presence or absence of a functional or structural writing component on a checklist, made the edit in the writing, and then provided a written consequence for each component. Data were collected on both functional and structural writing components for self-editing (Jodlowski, 2000). The independent variable was the mastery of editing intervention. Participants were given an algorithm for functional and structural writing components in the form of a checklist, which was specific to the writing assignment. Participants edited a peer's writing until the peer met criteria of 100% accurate functional components and 90% accurate structural components on the first attempt across two consecutive writing assignments. All feedback communication was provided in writing (Jodlowski, 2000).

Experiment 1 tested the effects of peer editing compared to the effects of teacher editing on the acquisition of self-editing skills. Results demonstrated that the peer editing package resulted in fewer learn units to criterion for essays than in the teacher editor treatment. Self-editing assessments resulted in fewer learn units to criterion after the peer editing treatment when compared to the teacher editing treatment (Jodlowski, 2000).

Experiment 2 tested the relationship between a teacher editor and a peer editor. The writer was not acting as an editor, but only receiving corrections from the peer or the teacher editor. Results did not show a difference in the peer editor treatment when compared to the teacher editor treatment. It did not matter who was delivering the instruction, but the treatment was effective (Jodlowski, 2000).

Experiment 3 tested the effects of a teacher editor and a peer editor while the writer served as a peer editor. Results showed that essays required fewer learn units to criterion per week. There was a limitation in the design of the experiment which resulted in experimenter and peer providing feedback to the writer simultaneously while the target participant was editing another peer's essay (Jodlowski, 2000).

Visalli-Gold (2005) conducted two experiments to test effects of middle school participants receiving corrections and editing from a teacher compared to observing peers receiving corrections and edits on untaught grammatical and structural components of students' writing. Results showed participants who observed peers receiving learn units also improved in their functional writing responses.

In an unpublished doctoral dissertation, Pellegren (2015) sought to control for the simultaneous feedback found in Jodlowski (2000) by only providing a consequence to the participant during intervention. Pellegren (2015) tested the effects of the accuracy of self-editing repertoires on writing for third grade students. The dependent variable was the number of rewrites to criterion for writing assignments as measured by the number of accurate functional writing components. The independent variable was the mastery of an editing intervention. Participants were taught an algorithm for peer editing which was taught to mastery across subject areas (math, science, descriptive writing, how-to writing). A peer editor provided consequences to a writer's functional writing pieces to mastery. Participants edited for functional and structural writing. The results demonstrated that participants increased functional and structural editing of their own writing because of the editing algorithm. Further research in VBDT tested the effects of functional writing algorithms on students' functional writing repertoires (Keohane and Greer 2005; Broto & Greer, 2014; Weber, 2016).

Functional Writing Algorithms

A functional writing algorithm is the production of written steps to solve a problem, such as a math equation or a science experiment (Keohane & Greer, 2005). A few of the writing studies previously mentioned utilized a functional writing algorithm; however, all used the writer immersion to create a motivating operation to have a functional effect and to affect reader behavior. as a verbally governed intervention to teach functional writing, math, and other subjects (Madho, 1997; Reilly-Lawson & Greer, 2006; Helou, Lai and Sterkin, 2007; Broto &

Greer, 2014). There are other studies which focused using a written algorithm to establish functional writing and problem solving (Keohane & Greer, 2005; Broto & Greer, 2014).

Keohane and Greer (2005) tested the effect of instructing teachers to use a verbally governed algorithm to solve learning problems in students and on the number of mastered learning objectives. A multiple baseline design was used to determine effectiveness of the algorithm across three teachers and six students. Results indicated that the teachers' students achieved more learning objectives when using a verbally governed algorithm to solve students' learning problems. Teacher accuracy also improved students who were not part of the study.

In a multiple-probe design, Broto and Greer (2014) tested the effects of a functional writing protocol on the accurate functional and structural responses in mathematical algorithms for six typically developing second grade students. Participants wrote an algorithm on how to solve word problems, and then observed a peer completing the written steps. There were several dependent variables which included the functionality of written algorithms, the number of correct written responses to probe who had questions, and the accuracy of the structural components of the written algorithms. A word problem was classified as functional if an adult reader could solve the problem when given only the written directions. The number of correct responses to word problems was the number of correct solutions to a problem. The structural components included the number of correct and incorrect punctuation marks, spelling of words, and capitalization. A yoked-contingency game board was used where the team of the participant and peer could move up a gameboard if the peer could solve the word problem based on the written algorithm. Results showed an increase in the number of functionally accurate written algorithms. The results showed an increase in the number of functionally accurate written algorithms because of the yoked-contingency intervention.

In an unpublished doctoral dissertation, Weber (2016) tested the effects of an editing treatment package for general education fourth graders to edit their peers' written algorithms so that a naïve reader could solve. Students had previously mastered the math problems. Math problems were derived from practice questions for the *Partnership for Assessment of Readiness for College and Careers* (PARCC, 2015), a standardized test used in the school district. In the first experiment, participants were placed in a dyad where the editor was the target participant and the writer was the peer confederate. The editor used a checklist as a prompt to edit the writer's algorithm and re-edit until a naïve reader could solve the problem. A yoked-contingency game board was also used as a motivating operation. Results showed that the treatment package increased the accuracy of writing math algorithms and the target participants acquired verbally governed responses through editing.

In the second experiment, both the editors and the writers were the target participants. In a multiple probe design across participants, Weber (2016) tested the writing/editing package without the yoked-contingency gameboard or the checklist on 1) the production of previously written math problems, 2) emergence of explanations of "why" (function) from learning "how" to solve a multi-step word problem, 3) production of novel written math algorithms, 4) number of attempted and correct untaught math equations as a measure of reinforcement value. Results demonstrated that the behavior of both the writer and the editor produced word problems that affected the behavior of naïve readers and attempted more untaught math equations. The intervention also resulted in increased reinforcement value for math.

Rationale for Experiment

Skinner argued that problem solving is a behavioral process, and "logic, mathematics, and science are disciplines which are concerned with ways of solving problems," (Skinner, 2014, p. 144). Teachers of Mathematics instruction often are concerned with teaching the process to solve the problem, and not the rationale behind solving the word problem (National Governors Association, 2010). Students can produce the listener responses of solving an equation but explaining the "how" and "why" of the math problem is found lacking in current research. As Vargas (2013) asked, what is the point of word problems? Often word problems are designed with inappropriate antecedent control. The numbers are in Arabic form so one does not necessarily need to read the word problem to determine the procedure or the necessary information. Moreover, there are irrelevant cues with obvious questions such as "How many are left" which automatically indicates subtraction. Students need to read the word problem without relying on obvious clues as to what operation to use so that they can develop problem solving skills, (Vargas, 2013). The rationale for the current experiment is that it is an extension of the research conducted by Weber (2016) and uses word problems without irrelevant cues (Vargas, 2013) to test the effects of a writing/editing package on the functional writing of math algorithms on middle school students with disabilities.

I asked the following research questions in Experiment I:

1. Does the functional writing intervention significantly improve writing the functional writing repertoires of middle school students with disabilities to educational significant levels?

Chapter II

EXPERIMENT I

Method

Participants

There were eight participants, ages 11-14 years old. Seven participants had Individualized Education Plans (IEP's) with diagnoses of Pervasive Development Disorder-Not Otherwise Specified (PDD-NOS), intellectual disability, autism spectrum disorder (ASD) and Participant S was typically developing with a Section 504 plan and diagnosed with an emotional disability. Participant W, Participant L, Participant M, and Participant S functioned at slightly below grade level in math and reading according to the i-ready® school-based assessments. Participant N, Participant R, Participant B, and Participant E functioned at two to three grade levels below for reading and math. The participants' relevant cusps were: BiN, Transformation of Stimulus Function across Saying and Writing, Read-Do Correspondence. The participants from the self-contained classroom received reading and math instruction in a self-contained classroom which operated under the Comprehensive Application of Behavior Analysis to Schooling (CABAS®) model of instruction (Greer, 2002). These participants received all other academic instruction in special education settings and were with general education peers for lunch and physical education. Participant S participated in general education classes across all academic subjects and was part of the CABAS ® class as a grade level peer tutor. (Table 2 includes a detailed description of each participant).

Table 2

Participant Description (Demographic and Verbal Behavior Description)

Participant		W	L	M	S	N	R	B	E
Diagnosis		PDD-NOS (Neuro-developmental Evaluation)	PDD-NOS (Pediatrician diagnosis)	PDD-NOS (Neuro-developmental Evaluation)	Emotional Disability (Pediatrician diagnosis)	ASD (Pediatrician diagnosis)	Intellectual Disability (Pediatrician diagnosis)	ASD (Neurodevelopmental Evaluation)	ASD/ Intellectual Disability (Neurodevelopmental Evaluation)
Gender		Male	Male	Male	Male	Male	Male	Male	Female
Age		12.2	12.4	12.9	13.6	13.8	11.6	13.3	13.1
Grade		6th	6th	7th	8th	8th	6th	7th	7th
Free & Reduced Lunch		No	No	No	No	No	Yes	No	Yes
Grade		6th	6th	7th	8th	8th	6th	7th	7th
i-Ready Math		4th	5th	6th	7th	2nd	2nd	1st	1st
i-Ready Reading		5th	4th	6th	7th	2nd	1st	1st	1st
Woodcock Johnson-Fourth Edition (WJ-IV)	Broad Math	91	n/a	n/a	n/a	58	58	n/a	63
	Broad Writing	101	n/a	n/a	n/a	n/a	89	n/a	76
	Broad Reading	93	n/a	n/a	n/a	n/a	57	n/a	65
Wechsler Intelligence Scale for children-Fifth Edition (WISC-V)	Verbal Comprehension	98	81	n/a	n/a	84	68	n/a	77
	Working Memory	94	86	n/a	n/a	74	82	n/a	83
	Fluid Reasoning	79	100	n/a	n/a	79	74	n/a	n/a
	Processing Speed	86	73	n/a	n/a	95	75	n/a	73
	Visual Spatial	102	n/a	n/a	n/a	81	89	n/a	73
	Full Scale IQ	88	81	n/a	n/a	75	67	n/a	72
BiN		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
OL		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
TSF		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: PDD-NOS= Pervasive Developmental Disorder-Not Otherwise Specified; ASD Autism Spectrum Disorder; OL= Observational Learning (Greer & Ross, 2008); BiN= Bidirectional Naming (Greer & Ross, 2008); TSF = Transformation of Stimulus Function across Saying and Writing (Greer & Ross, 2008); *i-Ready* is an online, adaptive curriculum used as curriculum based assessment for Reading and Math; *WISC-V* scores, 69 and below = Extremely Low, 70-79= Very Low, 80-89 = Low Average, 90-109= Average, 110-119= High Average; *WJ-IV* scores, 69 and below = Very Low, 70-79= Low, 80-89= Low Average, 90-110= Average, 110-120= High Average

Seven participants were selected from a CABAS® multi-grade, self-contained middle school classroom composed of seven students, one teacher, and three teaching assistants. There were three sixth-graders, three seventh-graders, and one eighth grade self-contained student. The middle-school students functioned at the reader and writer levels of verbal behavior. Participant S was a typically developing eighth-grade student who came to class to tutor the other students. The classroom was in a public middle school located outside a major metropolitan city. Participants were selected for this study because they demonstrated the necessary pre-requisite cusps and capabilities but did not demonstrate functional writing for multiple-step word problems.

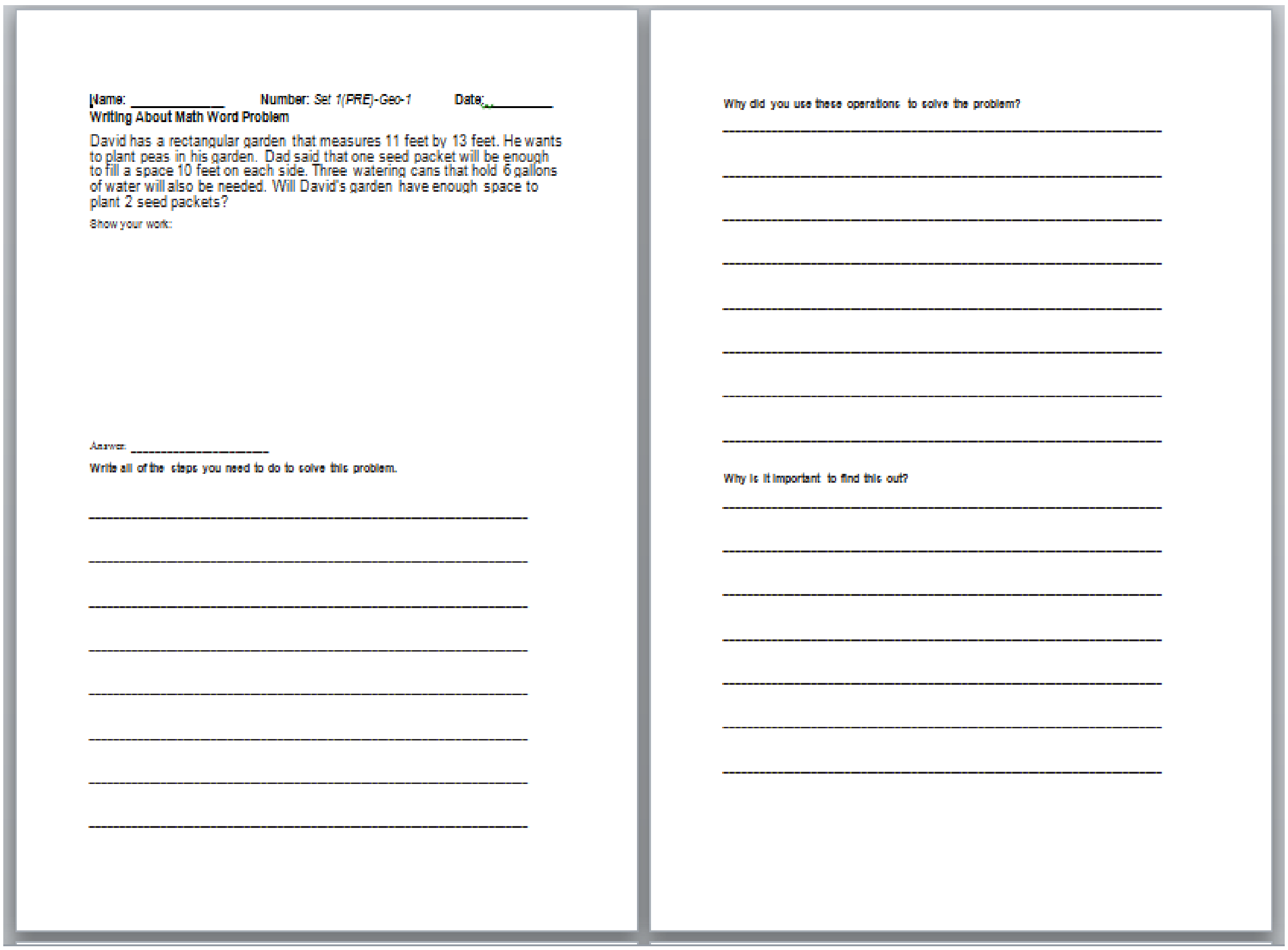
Setting

The pre- and post-intervention assessments took place in the self-contained classroom. Participants sat at a u-shaped table or at their own desks. Participants who were not involved with the study sat at a different u-shaped table, or at other desks and were participating in independent math activities which were a part of their individualized instruction.

Materials

Pre- and post-intervention materials. Materials for pre- and post-intervention probes included math word problems designed from a Grade 1, Grade 2, or Grade 5 Evan-Moor® word problem book which aligned with the Common Core State Standards (CCSS) and was used in the math curriculum. Each probe consisted of a word problem from each domain within the CCSS: Algebra and Operations, Numbers and Operations, Geometry, Measurement and Data. Each dyad was given a word problem that was at an appropriate grade level based on the participants' math grade level. Fifth grade word problems consisted of four steps using all operations (addition, subtraction, multiplication, division). Second grade word problems had four steps and used two operations (addition and subtraction). Each first-grade word problem also had four steps, but only used one operation (addition). The experimenter included Vargas (1978) suggestions for word problem stimuli without obvious clues and used word problems that did not include explicit questions ("How much is 2+2?"), used words instead of Arabic numbers ("three" instead of "3") and included a distractor sentence (e.g. in a word problem about reptiles, a sentence was included about a fish).

The word problem was pasted on a form designed for the experiment (See Figure 1) which also asked the question "Write all of the steps you need to do to solve this problem." The back of the 8 ½ X 11 in sheet of paper, included the question "Why did you use these operations to solve the problem?" with lines provided for writing. Below these lines, the third question was printed: "What is important to find out about this?" Word problem sets were counterbalanced across dyads. For the untaught algebra assessment, multiple-step algebra equations at an upper middle school to early-high school level were used. There were twenty equations on a page with up to 200 possible equations to solve. Other materials included white boards, Expo® markers, pencils.



Name: ____________ Number: *Set 1(PRE)-Geo-1* Date: ________

Writing About Math Word Problem

David has a rectangular garden that measures 11 feet by 13 feet. He wants to plant peas in his garden. Dad said that one seed packet will be enough to fill a space 10 feet on each side. Three watering cans that hold 6 gallons of water will also be needed. Will David's garden have enough space to plant 2 seed packets?

Show your work:

Answer: ________________

Write all of the steps you need to do to solve this problem.

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Why did you use these operations to solve the problem?

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Why is it important to find this out?

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Figure 1. Word problem format used for pre-assessment and post-assessment, and intervention.

Intervention materials. Materials for the intervention included different sets of word problems as the dependent variables in accordance with the participants' math grade level from Evan-Moor® word problem book which is aligned with the Common Core State Standards (CCSS). A different set of word problems was given to the participants to provide multiple opportunities to respond to different stimuli. The participant as writer was provided with the written question of "Write all of the steps you need to do to solve this problem." Rewrite worksheets were provided for the writer if additional rewrites were needed and only consisted of the same written instruction. The word problem was not present on the rewrite worksheet. An editor worksheet was provided with space for the editor to solve the problem, and pre-printed lines for the editor to write questions. See appendix for intervention stimuli and answer key.

Dependent Variables

There were five dependent variables: 1) algorithm components including functional and rationale descriptions; 2) functional accuracy of a written math algorithm; 3) structural components of written responses including grammar, spelling, and punctuation; 4) social validity measure to determine whether the was a significant difference in the means of scores assigned by naïve readers for pre- and post-intervention samples; 5) resistance to extinction measures for solving above grade level algebra problems. All dependent variables used a different set of word problems for pre-intervention and post-intervention measures.

Dependent variable 1: Algorithm Components (functional and rationale components). The functional component of a math algorithm was defined as the written mathematical equations in the algorithm so that a naïve reader could solve. Each word problem had five steps. Each step had a functional and rationale component for a total of five possible written functional components and five possible rationale components per word problem. The written rationale for why each operation was used and why the problem needed to be solved was defined as 1) description of each operation and 2) rationale of practical application of the problem. After the participant wrote the written explanation for the equation, the two antecedents were presented in written topography. The first question was “Why did you use these operations to solve the problem?” and the second, “Why is it important to find out?”. These written instructions were provided to ask the participants respond to how they solved the problem by describing the reason for each mathematical operation used (in either the written explanation for how to solve the problem or following the “Why did you use these operations to solve the problem?” antecedent), and the practical application for the use of the word problem. For every functional component there was an according rationale. See Figure 2 for procedure.

Procedure and Data Collection. The experimenters presented the participants with a word problem to solve and produce a written explanation of previously mastered math equations. The experimenter checked the accuracy of the answer and delivered consequences in the form of the learn unit (reinforcement for a correct response in the form of social praise, and a correction for an incorrect response.) Participants were given the written instruction “Write all of the steps you need to do to solve this problem.”

The written algorithms were scored with the help of five naïve adult readers, who indicated the presence and absence of each component by scoring a plus (+) for the presence or a minus (-) for the absence of each functional component and for each rationale component for each word problem using an answer key which consisted of all necessary steps required to solve the word problems. The scores were totaled and graphed with a total of twenty-five functional components (five possible total correct responses for each reader) and twenty-five rationale components for each word problem (five possible total correct responses for each reader). See appendix for answer key.

Dependent variable 2: Functional accuracy of a math algorithm. The functional accuracy of a math algorithm was defined as the number of algorithms which could be solved by a naïve adult reader during pre- and post-intervention assessment.

Procedure and Data Collection. Two naïve adult readers (different readers than the algorithm component readers) attempted to produce the solution of each written algorithm. If the naïve reader could arrive at the accurate answer according to the answer key, the written algorithm was scored as a plus (+). If the naïve reader could not accurately solve the word problem, then the algorithm was scored as a minus (-). The two naïve readers totaled the number of correctly solved written algorithms out of the total number of algorithms and multiplied by 100 to find the percentage of accurately solved word problems. Each dyad completed a different number of pre-intervention word problems. All dyads completed four post-intervention written algorithms. The first dyad completed four pre-intervention word problems, the second dyad completed eight pre-intervention problems, the third dyad completed 12 pre-intervention written algorithms, and the fourth dyad completed 16 pre-intervention word problems.

Dependent variable 3: Structural elements. The structural components of the written algorithms were the percent of correctly spelled words, the percent of correct punctuation, and the percentage of the correct grammar.

Data Collection. Correctly spelled words were counted based on the number of words spelled correctly out of the total number of words across the written functional components and the written rationale. Punctuation and Grammar were counted as the correct number of sentences out of the total number of sentences. Structural components were not consequated during pre-intervention, post-intervention, or intervention sessions. Data were collected and converted to percentages.

Dependent variable 4: Social validity. The experimenter took two pre-intervention and two post-intervention permanent products collected from the functional components and the written rationale and typed them exactly as written into a Microsoft Word® document. The experimenter sent the samples to seventeen naïve adult readers. The naïve adult readers ranked the permanent products from worst to best four participants. Naïve readers ranked the best response for each participant as 4 and the worst response as a 1. The experimenter expected most pre-intervention permanent products to receive a score of 1 or 2, and the post-intervention scores to receive a 3 or a 4. A total of seventeen naïve readers scored the four samples from four participants. The experimenter then conducted a dependent sample t-test comparing the means of pre- and post-intervention scores across participants as a measure of social validity. See appendix for samples used in this measure. The experimenter wrote the following direction for ranking the permanent products:

> “These are writing samples from 7 students. Each student was given a set of word problems. The student was asked to independently solve each one. Students were then directed to write the steps needed to solve the written algorithm so that someone else could solve it. We implemented a writing/editing tutoring activity to see if their writing would improve. Below are writing samples from before and after the writing/editing intervention; however, they are not in a particular order. They are typed exactly as the students wrote them, including all spelling and other mechanical errors. Rank each word problem from 1 (worst) to 4 (best). Consider if you could solve the problem and if you know why you are solving the problem. Two written algorithms from the same student cannot have the same score.”

Pre-Intervention

All participants completed a set of four pre-intervention word problems, one each day.
Experimenter corrects word problem for accuracy.
Participants complete:

1) Algorithm Components

Dyad 1 completes five sessions of the measure of math reinforcement (one session of 10 m. per day)

All other dyads complete subsequent sets of word problems.
Experimenter corrects word problem for accuracy.
Participants complete:

1) Algorithm Components

All dyads complete five sessions of the measure of math reinforcement prior to entering intervention (one session of 10 m. per day)

Intervention

Experimenter chooses the writer and editor of each dyad.

1. The writer solves a word problem.
2. Experimenter checks for accuracy
3. Writer writes written explanation
4. Editor attempts to solve the problem using the explanation
5. Editor writes a list of questions to help the writer the revise if the editor cannot solve the problem
6. Writer rewrites until editor can solve the problem
7. Intervention concludes when Writer produces written explanation that requires zero rewrites

Post-Intervention

Each participant completed a set of four pre-intervention word problems, one each day.
Experimenter corrects word problem for accuracy.
Participants complete:

1) Algorithm Components

Each completes five sessions of the measure of math reinforcement

(one session of 10 m. per day)

Data Collection:
Naïve adult readers use answer key to score:

1. functional components
2. rationale

Experimenter scores the measure of math reinforcement and structural components

Figure 2. Figure 2 shows the procedure for the dependent and independent variable procedure.

Dependent variable 5: Measure of reinforcement value. The number of untaught math problems attempted was a measure of reinforcement, defined as the number of untaught algebra equations the participant attempted and the number of correct problems in a 10m session without any social reinforcement. This dependent variable was used as a measure of resistance to extinction. See Figure 2 for procedure.

Procedure and Data Collection. Participants were seated at the table and given graph paper and a packet of algebra equations. Participants were told to do the best they could, and they would be told when to stop. The experimenter set the timer for 10m and did not offer any reinforcement or attention to the participants. Data were collected on correct and attempted responses to equations. Responses were defined and recorded as 1) number of problems attempted each session, 2) number of correct problems.

Independent Variable

The independent variable was an editing and writing package for producing a written explanation for specific steps to solve a multi-step math problem. The experimenter chose the writer and the editor of the dyad and presented the writer with a word problem. The writer solved the word problem and the experimenter checked for accuracy. The writer then wrote the written explanation for the word problem. The rationale was not part of the intervention. The writer then gave the editor the written explanation. The editor attempted to solve the problem using only the written explanation. If the editor could not solve the problem, s/he wrote a list of questions and passed the list to the writer. The writer rewrote the explanation. Criterion for the intervention was achieved when the writer produced a written explanation with all four necessary functional components and required no additional rewrites. See Figure 2 for procedure. Structural elements were not consequated.

Design and Sequence

The experimental design was a multiple probe design across dyads (Horner & Baer, 1978). Each dyad consisted of an editor and a writer. Initial pre-intervention assessment data were collected for all participants. Following the initial pre-intervention assessments, the first dyad entered the intervention. Once the first dyad achieved criterion on the intervention and entered post-assessment probes, the second dyad was re-assessed and began intervention. Probes were repeated for each dyad until they entered intervention. See Figure 3 for experimental design and sequence.

Dyad 1, Dyad 2, Dyad 3, and Dyad 4 completed the first set of pre-intervention probes (four word problems). Dyad 1 entered intervention. Dyad 2, Dyad 3, and Dyad 4 completed a second round of pre-intervention probes (four word problems). Dyad 1 completed intervention and entered post-intervention probes. Dyad 2 completed Measure of Reinforcement Value pre-probes (set of 5 sessions of algebra problems). Dyad 2 entered intervention. When Dyad 2 completed intervention, Dyad 2 completed post-intervention probes (set of four word problems) and Measure of Reinforcement Value probes (set of 5 sessions of algebra problems). Dyad 3 and Dyad 4 completed a third round of pre-intervention probes (four word problems). Dyad 3 completed Measure of Reinforcement Value pre-intervention probes (set of 5 sessions of algebra problems). Dyad 3 entered intervention. When Dyad 3 completed intervention, Dyad 3 completed post-intervention probes (set of four word problems) and Measure of Reinforcement Value probes (set of 5 sessions of algebra problems). Dyad 4 completed fourth round of pre-intervention probes (four word problems) and Measure of Reinforcement Value pre-intervention probes (set of 5 sessions of algebra problems). Dyad 4 entered intervention. When Dyad 4 finished intervention, Dyad 4 completed post-intervention probes (set of four word problems) and Measure of Reinforcement Value probes (set of 5 sessions of algebra problems). The naïve adult readers scored the written algorithms for Algorithm Components and Functional Accuracy, at the completion of the experiment. The experimenter scored the Structural Components and Measure of Reinforcement Value at the conclusion of the experiment.

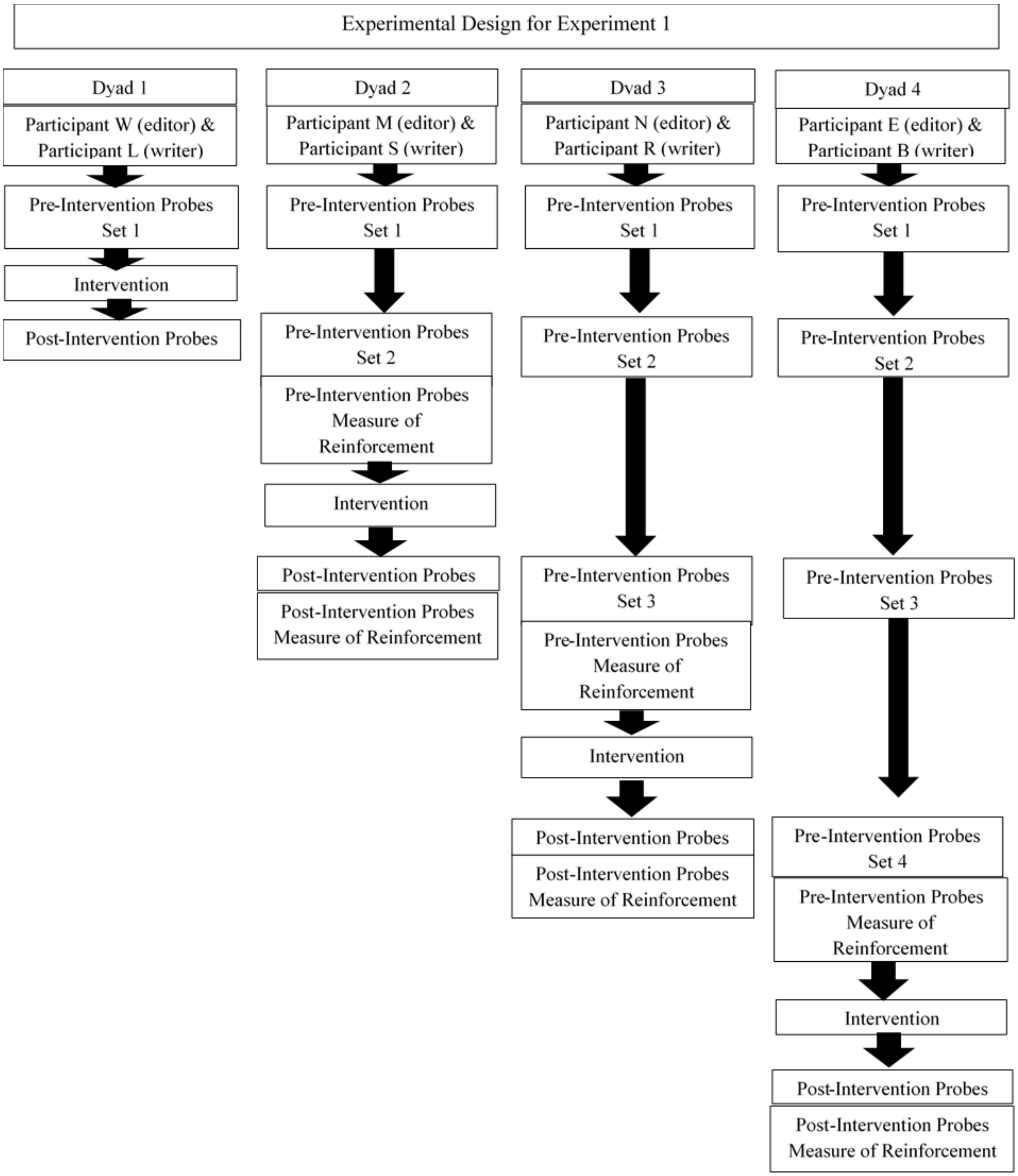

Figure 3. Sequence of experimental design for Experiment I. Measure of Reinforcement probes were not conducted for Participant L (writer) & Participant W (editor)

Interscorer Agreement (ISA)

Algorithm Components. Five middle school Language Arts teachers scored the written algorithms and were naïve to the study (separate naïve readers from Functional Accuracy). The naïve adult readers provided interscorer agreement for the functional components and rationale components of a math algorithm using an answer key for point to point correspondence for the functional steps of the algorithm. ISA was calculated by taking the average score of the naïve readers and comparing it to the scores of the experimenter. Agreement was computed as the total number of agreement divided by the total number of agreements plus disagreement opportunities between the average of the five naïve adult readers and the experimenter. The percentage of agreement was calculated by multiplying the answer by 100%. ISA was conducted across 100% of pre-intervention and post-intervention sessions. See Table 3 for ISA scores for Algorithm Components.

Functional Components. Participant L had a mean agreement of 91% (range 90%-100%) for pre-intervention sessions. Post-intervention ISA was 80% (range 80%-100%) for Participant L. Participant W had 93% (range 81%-100%) for pre-intervention scores and 85% (range 80%-100%) for post-intervention scores. Participant S had 87% (range 84%-100%) for pre-intervention and 84% (range 81%-100%) for post-intervention. Participant M had 88% (range 82%-100%) for pre-intervention and 85% (range 80%-100%) for post-intervention. Participant R had 98% (range 94%-100%) for pre-intervention agreement and 87% (range 84%-100%) for post-intervention agreement. Participant N had 90% (range 88%-100%) for pre-intervention agreement and 85% (range 82%-100%) for post-intervention agreement. Participant B had 100% for pre-intervention scores and 90% (range 82%-100%) for post-intervention scores. Participant

E had 82% (range 80%-100%) for pre-intervention scores and 85% (range 83%-100%) for post-intervention scores.

*Rationale Components***.** Participant L had a mean agreement of 91% (range 83%-100%) for pre-intervention scores. Post-intervention ISA was 86% (range 85%-100%) for Participant L. Participant W had 88% (range 82%-100%) for pre-intervention scores and 83% (range 81%-100%) for post-intervention scores. Participant S had 83% (range 83%-100%) for pre-intervention and 84% (range 83%-100%) for post-intervention. Participant M had 96% (range 92%-100%) for pre-intervention and 87% (range 83%-100%) for post-intervention. Participant R had 100% pre-intervention agreement and 85% (range 82%-100%) for post-intervention agreement. Participant N had 100% pre-intervention agreement and 99% (range 99%-100%) for post-intervention agreement. Participant B had 100% for pre-intervention scores and 95% (range 95%-100%) for post-intervention scores. Participant E had 100% agreement for pre-intervention scores and 90% (range 88%-100%) for post-intervention scores.

Table 3

ISA for Five Naïve Adult Readers for Dependent Variable 1

	Functional Components		Rationale Components	
Participant	Pre-intervention Agreement (Range of Agreement)	Post-intervention Agreement (Range of Agreement)	Pre-intervention Agreement (Range of Agreement)	Post-intervention Agreement (Range of Agreement)
L	91% (90%-100%)	80% (80%-100%)	91% (83%-100%)	86% (85%-100%)
W	93% (81%-100%)	85% (80%-100%)	88% (82%-100%)	83% (81%-100%)
S	87% (84%-100%)	84% (81%-100%)	83% (83%-100%)	84% (82%-100%)
M	88% (82%-100%)	85% (80%-100%)	96% (92%-100%)	87% (83%-100%)
R	98% (94%-100%)	87% (84%-100%)	100%	85% (82%-100%)
N	90% (88%-100%)	85% (82%-100%)	100%	99% (99%-100%)
B	100%	90% (82%-100%)	100%	95% (95%-100%)
E	82% (80%-100%)	85% (83%-100%)	100%	90% (88%-100%)

Functional accuracy. Two naïve adult readers, who were Speech and Language Pathologists, solved the written algorithms to determine their functionality. ISA was conducted by a second observer without an answer key. The naïve adult readers only had access to the written algorithms produced by the participants. ISA was conducted across 100% of pre-intervention assessments with a mean agreement of 88% (range 87%-100%). Post-intervention ISA was collected for 100% of post-intervention sessions with 100% agreement.

Measure of reinforcement. A second observer independently scored correct and incorrect responses for the untaught algebra math problems. ISA was collected for 100% of pre-intervention sessions with 100% agreement, and 100% of post-intervention sessions with 100% agreement.

Structural elements. A second observer independently scored correct and incorrect structural elements including grammar, spelling, and punctuation. ISA was collected for 100% of pre-intervention sessions with 90% agreement (range 90%-100%), ISA was collected for 100% of post-intervention sessions with 99% agreement (range 94%-100%).

Measure of reinforcement. A second observer independently scored correct and incorrect responses for the untaught algebra math problems. ISA was collected for 100% of pre-intervention sessions with 99% agreement (range 95%-100%), ISA was collected for 100% of post-intervention sessions with 99% agreement (range 96%-100%).

Intervention. Interscorer agreement was collected for 100% of intervention sessions using the permanent products of written math algorithms with a mean agreement of 95% (range 92%-100%) of the functional components and a mean of 100% agreement for number of questions the editor asked, and 100% agreement for number of rewrites required by the writer.

Results

Algorithm Components

Figure 4 shows the number of correct functional components and correct rationale components scored by five naïve readers for Participant L (writer) and Participant W (editor), Participant M (writer), Participant S (editor), Participant N (editor), Participant R (writer), Participant B, (writer) and Participant E (editor).

Participant L (writer), Participant W (editor), Participant S (editor), and Participant E (editor) showed few improvements in functional components and few improvements in rationale components following intervention. Participant M (editor) had few improvements in functional component scores following intervention and some increase in scores for rationales following intervention. Participant R (writer), Participant N (editor), Participant B (writer) showed the strongest improvements in functional components following intervention and displayed minimal increases in rationale scores following intervention.

Functional Accuracy of Math Algorithm

Figure 5 shows the percentage of algorithms written with functional accuracy as solved by the two naïve readers for Participant L (writer) and Participant W (editor), Participant M (writer), Participant S (editor), Participant N (editor), Participant R (writer), Participant B, (writer) and Participant E (editor).

Participant W (editor), Participant L (writer), Participant M (writer) showed some increase in the percentage of problems solved by naïve readers following intervention. Participant S (editor) and Participant E (editor) had no change in the percentage of algorithms solved by naïve readers following intervention. Participant R (writer), Participant N (editor) and

Participant B (writer) showed the strongest improvement in the percentage of problems solved accurately by naïve readers.

Structural elements

Figure 6 shows the findings for structural elements (grammar, spelling, punctuation) for Participant L (writer) and Participant W (editor), Participant M (writer), Participant S (editor), Participant N (editor), Participant R (writer), Participant B, (writer) and Participant E (editor).

Participant L (writer), Participant W (editor), Participant M (editor), Participant S (editor), and Participant B (editor) showed few to no improvements in structural elements (grammar, spelling, punctuation) following intervention. Participant R (writer), Participant N (editor), Participant E (writer) showed the little improvement in structural elements (grammar, spelling, punctuation) following intervention.

Measure of reinforcement

Figure 7 shows the results for the number of attempted problems and number of correct problems for Participant L (writer) and Participant W (editor), Participant M (writer), Participant S (editor), Participant N (editor), Participant R (writer), Participant B, (writer) and Participant E (editor). There were no effects in this measure.

Social Validity

The experimenter conducted a dependent samples t-test comparing the means of naïve readers' scores for pre-intervention and post-intervention permanent products as a measure of social validity. The dependent samples t-test revealed a statistically significant difference between the means of pre-intervention scores (M=1.57, SD=.057) and post-intervention scores (M=3.43, SD=.057); $t(2) = -28$, $p<.001$.

Intervention

Figure 8 shows the number of correct functional components for the writer and the number of rewrites per intervention session and the number of questions asked by the editor in for Dyad 1. The number of functional components for Participant L (writer) increased to a score of four components across the last two intervention sessions. Participant L (writer) required four rewrites for the first session and decreased to zero rewrites at the fourth session. Participant W (editor) asked 19 questions in the first and second session, 2 questions in the third session, and 0 questions in the fourth session.

Participant M (writer) required two intervention sessions with a total of three rewrites for the first session and zero rewrites for the second session. Participant S (editor), asked six questions in the first session and zero questions in the second session.

Participant R (writer) increased to 5 functional components after five sessions and needed 2-4 rewrites in each session until requiring 0 rewrites after the fifth session. Participant N (editor) asked 13 questions in the first session and decreased to 0 questions in the fifth session.

Participant B (writer) required seven intervention sessions to meet criterion and required 1-2 rewrites per session until the seventh intervention session. Participant E (editor) asked 5 questions in the first session and decreased to 0 questions by the seventh session.

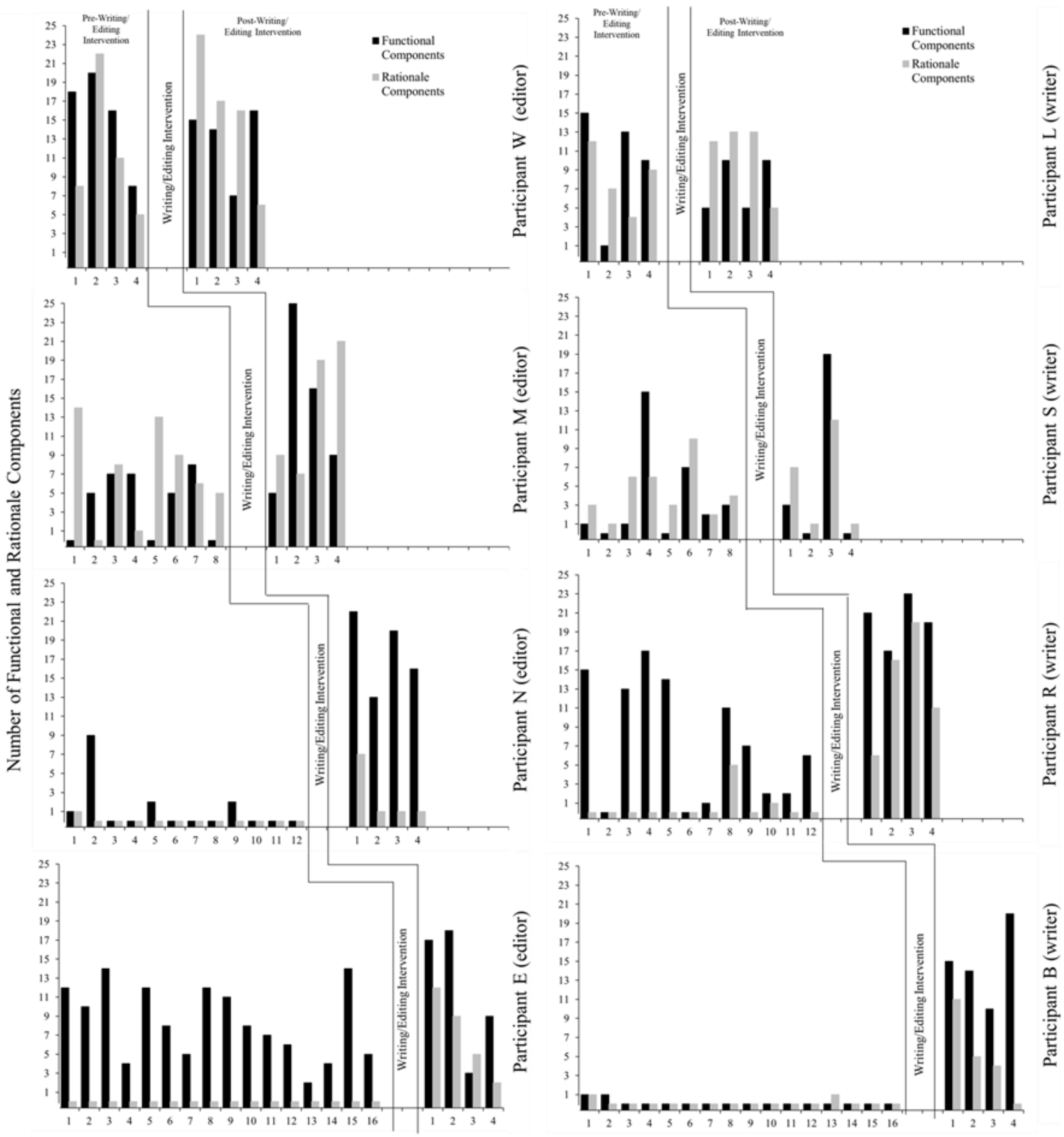

Figure 4. Dependent Variable 1: Number of correct functional components and number of correct rationale components for Participant L (writer) and Participant W (editor), Participant M (writer), Participant S (editor), Participant N (editor), Participant R (writer), Participant B, (writer) and Participant E (editor) before and after the writing/editing intervention.

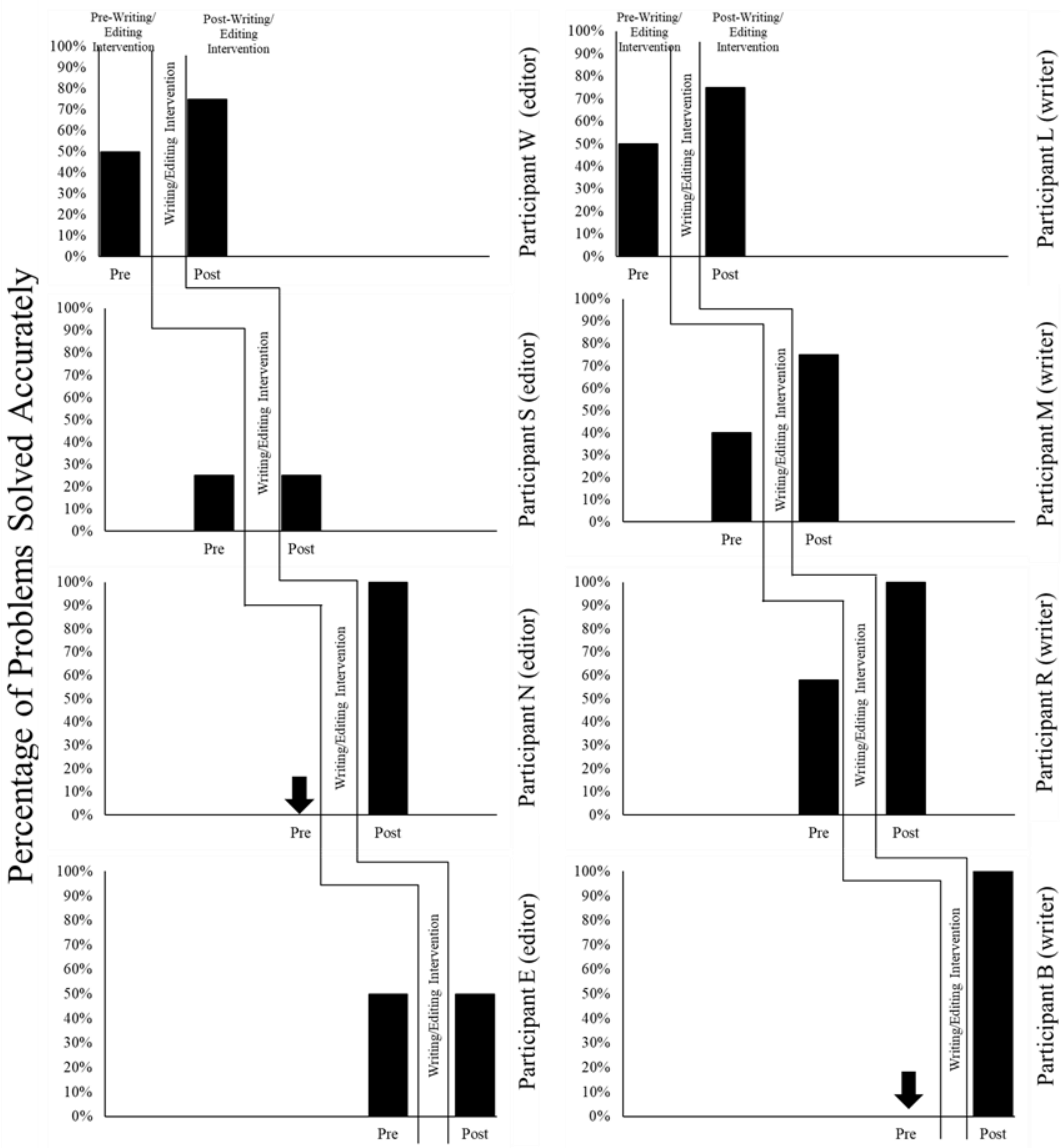

Figure 5. Dependent Variable 2: Functional Accuracy for Participant L (writer) and Participant W (editor), Participant M (writer), Participant S (editor), Participant N (editor), Participant R (writer), Participant B, (writer) and Participant E (editor) before and after the writing/editing intervention. This figure shows the percentage of the word problems that could be solved by a naïve adult reader prior to and following the intervention calculated from the sum of pre-intervention and post-intervention solutions.

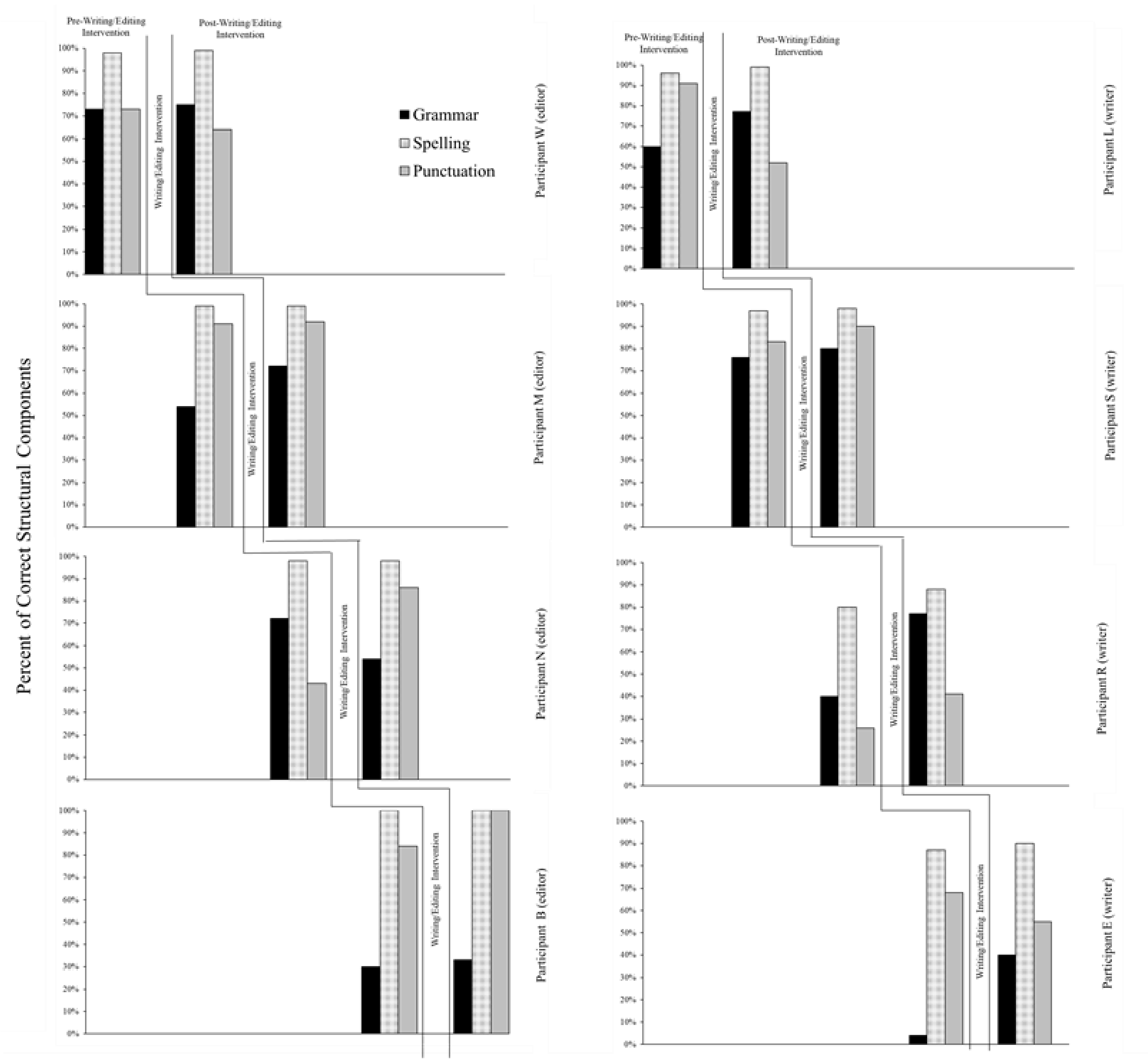

Figure 6. Dependent Variable 3: Structural Components. Percent of correct structural components for grammar, spelling, and punctuation for Participant L (writer) and Participant W (editor), Participant M (writer), Participant S (editor), Participant N (editor), Participant R (writer), Participant B, (writer) and Participant E (editor)before and after writing/editing intervention.

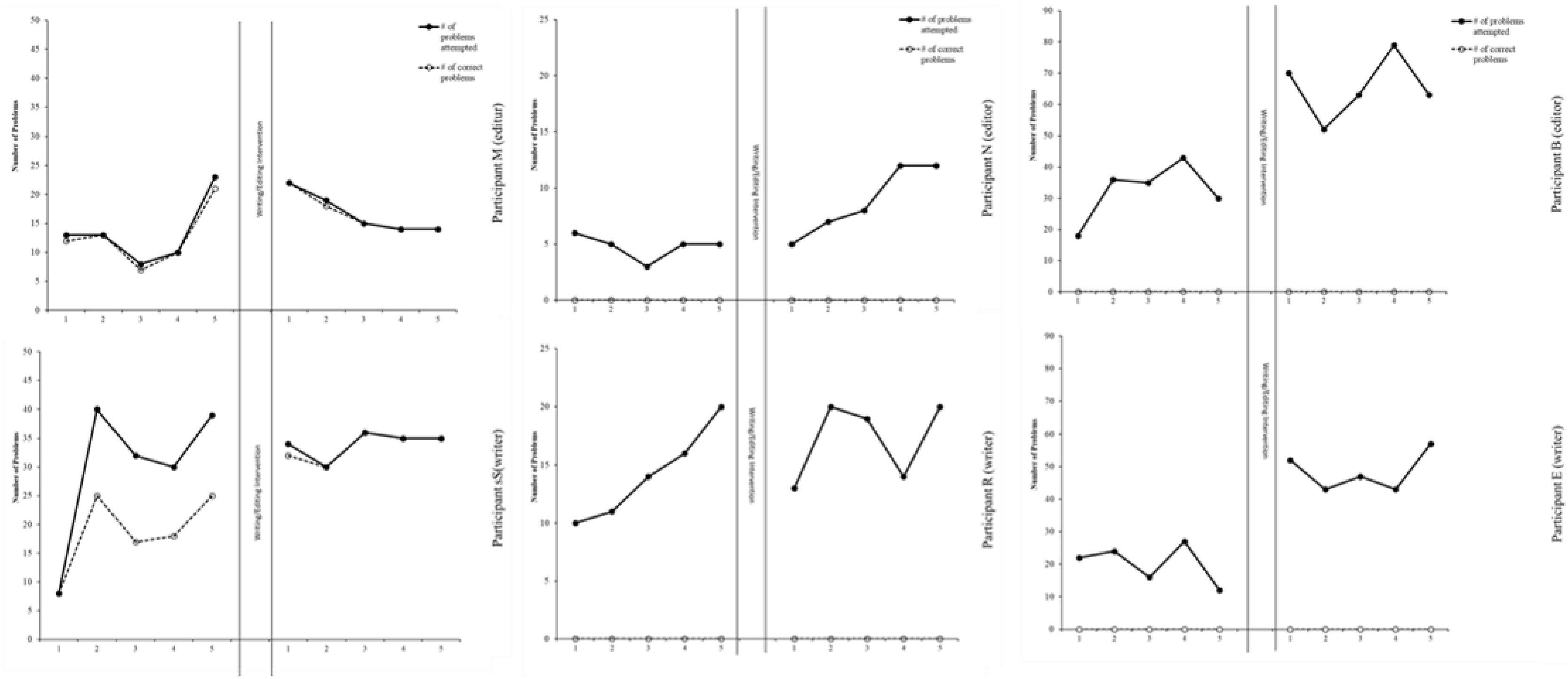

Figure 7. Dependent Variable 5: Resistance to Extinction. Cumulative number of untaught algebra equations for Participant M (writer), Participant S (editor), Participant N (editor), Participant R (writer), Participant B, (writer) and Participant E (editor)before and after the writing/editing intervention.

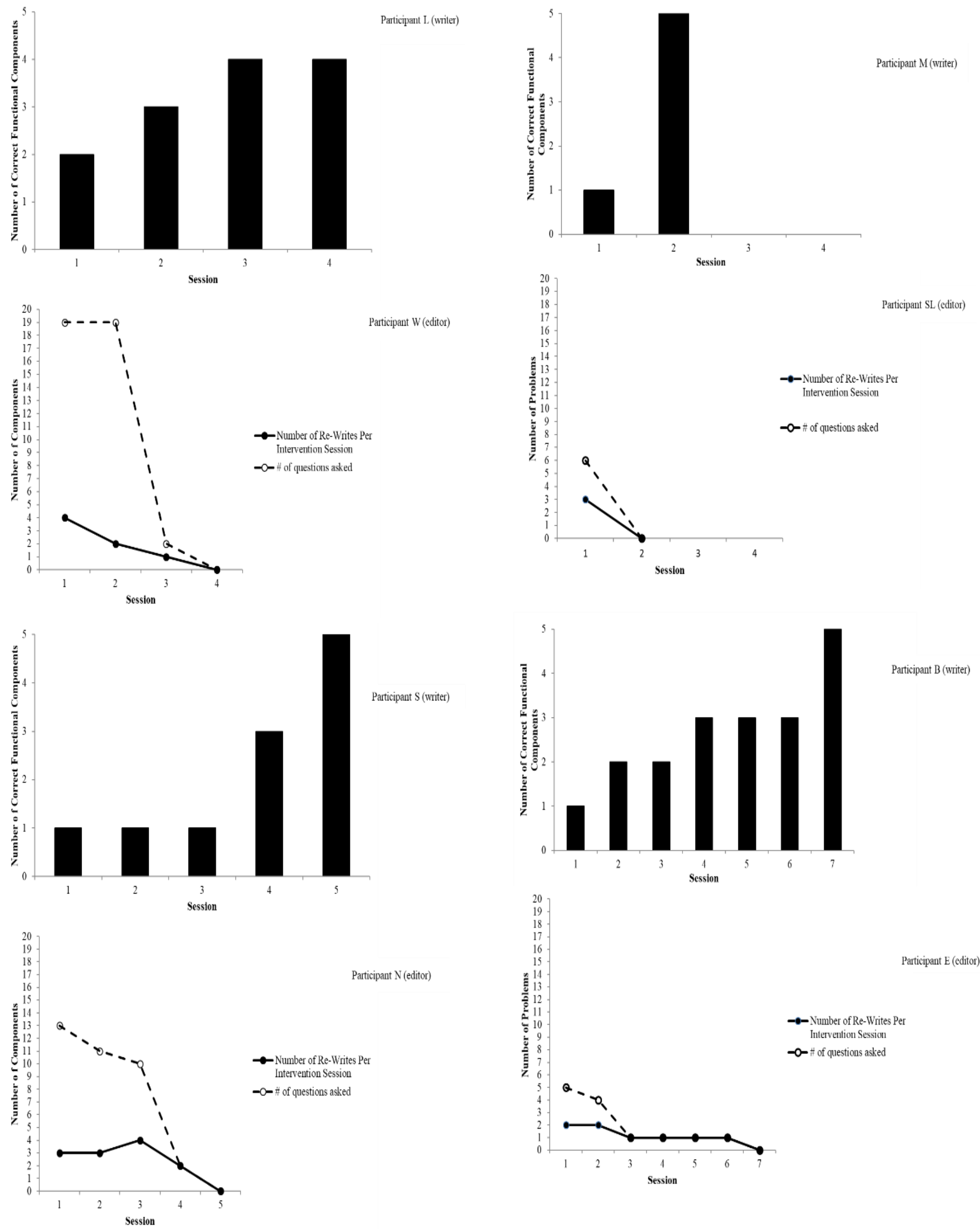

Figure 8. Intervention data for Participant L (writer) and Participant W (editor), Participant M (writer), Participant S (editor), Participant N (editor), Participant R (writer), Participant B, (writer) and Participant E (editor).

Discussion

The purpose of this experiment was to test the effectiveness of the Functional Writer Immersion Package on the writing repertoires of middle school students with disabilities. There were some effects demonstrated in the of results of Participant M (editor), Participant N (editor), Participant R (writer), and Participant B (writer). The participants, whether their role was an editor or a writer, acquired writing skills to affect the naïve adult reader so that the naïve adult writer could produce steps to solve a word problem when they did not receive the original word problem.

Some participants had never experienced this kind of writing prior to the intervention. Participant R had never experienced writing about a word problem before. He stated multiple times that he "couldn't do it," and, "I don't know how." The participants lacked prior experience in functional algorithm writing, although the participants had experience in the writer immersion protocol. As Dewey (1933) said, *"*But unless there has been experience in some degree analogous, which may now be represented in imagination, confusion remains mere confusion," Dewey (1933, p.4), Participant R's explanations often consisted of statements such as "You need to do 7 minus 3 and you get 4." Following the intervention, Participant R wrote two pages of detailed functional components to solving the word problem when compared to his two incomplete sentences in the pre-intervention sessions.

Algorithm Components

Functional components. Participant B explained the word problems with sentences such as "I solved the problem." Participant E wrote the procedure for the equation, (e.g. "First I put eight plus two. Then I put two plus four. Then I put four plus six equals twenty."). Following intervention, Participant B's functional component responses increased, with step by step instructions and mathematical terms such as "I added them together." Participant E's functional components also increased slightly, and she added more mathematical terms in her writing as well. These findings are not consistent with the results in Weber (2016) who found an increase in functional components for all her typical fourth grade participants.

Rationale components. The intervention did not have an effect on the production of rationale components for solving the word problem. Participant M was the only student who demonstrated accurate responses to "why" questions following the intervention. This is different than Weber (2016) where the participants were typically developing fourth grade students who functioned on or above grade level. The participants' responses to "why" questions emerged following the writing/editing intervention. The participants in the current study are middle school students in a self-contained classroom, and therefore have challenges learning in a larger environment. The participants require more learn units to acquire skills and often need to be explicitly taught a skill.

Functional Accuracy

The functional accuracy increased in the same participants who had an increase in functional components. Participant W (editor), Participant L (writer), Participant M (writer) showed improvements in the percentage of problems solved by naïve readers following intervention and Participant R (writer), Participant N (editor) and Participant B (writer) showed the strongest increase in the percentage of problems solved accurately by naïve readers. This is different than Broto & Greer (2014) where all six participants showed improvement in the functional accuracy of word problems.

Structural Elements

There were few if any improvements in structural elements for participants following intervention. This may be due to no direct intervention to the structural elements in the intervention. In Broto & Greer (2014) the experimenter corrected the participants' written algorithms which resulted in an improvement in structural elements for participants.

Measure of Reinforcement

Figure 7 shows the results for the number of attempted problems and number of correct problems for Participant L (writer) and Participant W (editor), Participant M (writer), Participant S (editor), Participant N (editor), Participant R (writer), Participant B, (writer) and Participant E (editor). There were no effects in this measure. This is contrary to the results from Weber (2016), who found that there was an increase in the resistance to extinction for her participants.

Limitations

There were limitations to this experiment. Participant W and Participant L did not participate in the assessment for resistance to extinction with the number of untaught algebra equations. This was of no consequence because there were no effects on the measure of reinforcement. The participants solved a similar number of algebra problems prior to the intervention as following the intervention.

Structural elements were not consequated in this study. There were no effects after the intervention. This could be due to no direct consequences to any structural elements during intervention.

Conclusion

In previous studies, the function of writing is taught through writer immersion where the writer learns to affect the behavior of the reader (Broto & Greer, 2014; Helou, et. al, 2007; Jodlowski, 2000; Madho, 1997; Pellegren, 2015; Reilly-Lawson & Greer, 2006). Writer immersion creates an establishing operation in order for students to learn the function of writing. In this experiment, the results are promising in that the intervention may help create a similar motivating operation for students to learn the function of math writing. Weber (2016) demonstrated the effects of the writing/editing intervention package on producing a math algorithm with general education students in the fourth grade. This current study attempted to replicate these effects with students with disabilities in a self-contained classroom. While there were clear effects for dependent variable 1, there were little to no effects for dependent variable 2, and no effects on dependent variable 3. The second experiment will focus on refining the intervention package to attempt to establish the “why” response and extend the effects for the functional components.

CHAPTER III

EXPERIMENT II

Method

All procedures and dependent variables were the same. The intervention included a change to address the rationale and structural elements.

Participants

There were six participants, ages 11-14 years old. One participant had a diagnosis of autism spectrum disorder and the other five participants had Individualized Education Plans (IEP's) with diagnoses of a learning disability. The participants from Experiment II were Participant C, Participant D, Participant K, Participant O, Participant P, and Participant V.

Participant C and Participant D both functioned at two to five grade levels below for math and two to three grade levels below for reading. Relevant Verbal Behavior Development cusps that were present in the new participants' repertoires included: BiN, Transformation of Stimulus Function across Saying and Writing, Read-Do Correspondence. Participant C and Participant D received reading and math instruction in a self-contained classroom which operated under the Comprehensive Application of Behavior Analysis to Schooling (CABAS®) model of instruction (Greer, 2002). These participants received all other academic instruction in special education settings and were with general education peers for lunch and physical education.

Participant K, Participant O, Participant P, and Participant V functioned at two to six grade levels below for math and reading. Relevant cusps that were present in the new participants' repertoires included: BiN, Transformation of Stimulus Function across Saying and Writing, Read-Do Correspondence. Participant K, Participant O, Participant P, and Participant V received reading and math instruction in a resource room setting which did not operate under the

CABAS® model of instruction (Greer, 2002). These participants were selected for this study because they demonstrated the necessary pre-requisite cusps and capabilities but did not demonstrate functional writing for multiple-step word problems. (Table 4 includes a detailed description of participants).

Independent Variable

The independent variable followed the same procedure to Experiment I with the addition of two additional steps. After the writer wrote the initial written explanation, the experimenter edited for structural elements. When the writer completed his rewrites based off the editor's questions, the editor wrote the word problem based off the writer's explanation in attempt to match the original word problem. This extra step provides the editor with the opportunity to see the effect of his questions on the writer by using the final written explanation to write his own word problem. The editor's word problem was unconsequated.

Table 4

Participant Description (Demographic and Verbal Behavior Description)

Participant		Participant C	Participant D	Participant K	Participant O	Participant P	Participant V
Diagnosis		ASD (Pediatrician diagnosis)	Intellectual Disability (Pediatrician diagnosis)	Intellectual Disability (Pediatrician diagnosis)	ADD (Pediatrician diagnosis)	Intellectual Disability (Pediatrician diagnosis)	Intellectual Disability/ADD (Pediatrician diagnosis)
Gender		Male	Male	Female	Male	Male	Male
Age		12.2	12.4	12.8	12.9	12.9	14.0
Grade		6th	6th	7th	7th	7th	7th
Free & Reduced Lunch		No	No	Yes	Yes	No	Yes
i-Ready Math		4th	1st	4th	4th	5th	1st
i-Ready Reading		3rd	4th	4th	1st	3rd	1st
Woodcock Johnson-Fourth Edition (WJ-IV)	Broad Math	99	54	79	78	n/a	n/a
	Broad Writing	15	85	89	79	n/a	n/a
	Broad Reading	77	77	87	69	n/a	n/a
Wechsler Intelligence Scale for children-Fifth Edition (WISC-V)	Verbal Comprehension	98	92	n/a	104	n/a	81
	Working Memory	79	94	n/a	80	n/a	62
	Fluid Reasoning	100	91	n/a	n/a	n/a	n/a
	Processing Speed	103	72	n/a	97	n/a	88
	Visual Spatial	100	94	n/a	n/a	n/a	n/a
	Full Scale IQ	94	82	n/a	95	n/a	69
Bi-Directional Naming		Yes	Yes	Yes	Yes	Yes	Yes
OL		Yes	Yes	Yes	Yes	Yes	Yes
TSF		Yes	Yes	Yes	Yes	Yes	Yes

Note: ASD= Autism Spectrum Disorder; ADD= Attention Deficit Disorder; OL= Observational Learning (Greer & Ross, 2008); Bi-Directional Naming (BIM) (Greer & Ross, 2008); TSF = Transformation of Stimulus Function across Saying and Writing (Greer & Ross, 2008); *i-Ready* is an online, adaptive curriculum used as curriculum based assessment for Reading and Math; *WISC-V* scores 69 and below = Extremely Low, 70-79= Very Low, 80-89 = Low Average, 90-109= Average, 110-119= High Average*; WJ-IV* scores, 69 and below = Very Low, 70-79= Low, 80-89= Low Average, 90-110= Average, 110-120= High Average

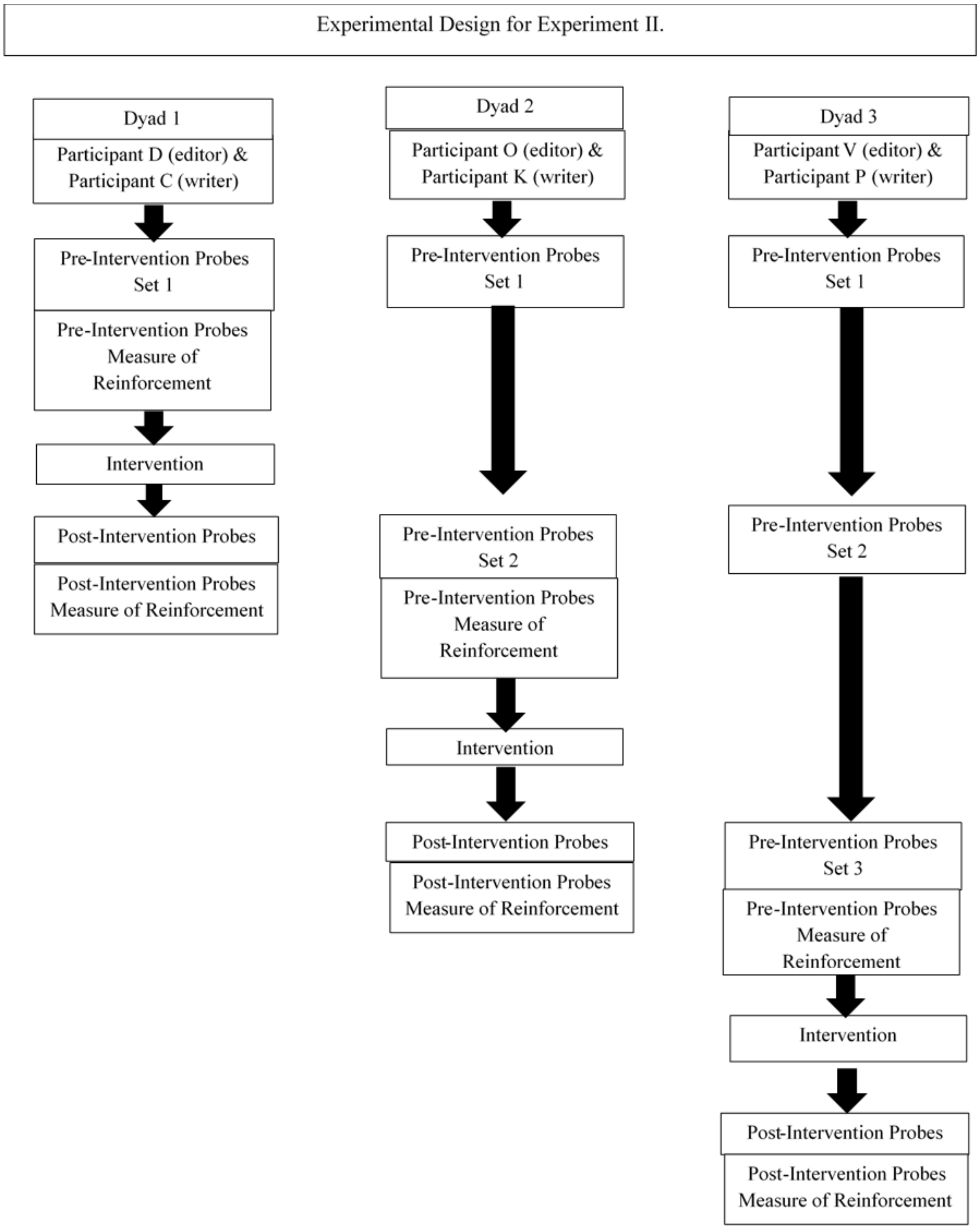

Figure 9. Sequence of experimental design for Experiment II.

Interscorer Agreement (ISA)

Algorithm Components. Five middle school Language Arts teachers scored the written algorithms and were naïve to the study (separate naïve readers from Dependent Variable 1). The naïve adult readers provided interscorer agreement for the functional components and the rationale components of a math algorithm using an answer key for point to point correspondence for the functional steps of the algorithm. ISA was calculated by taking the average score of the naïve readers and comparing it to the scores of the experimenter. Agreement was computed as the total number of agreement divided by the total number of agreements plus disagreement opportunities between the average of the five naïve adult readers and the experimenter. The percentage of agreement was calculated by multiplying the answer by 100%. See Table 5 for ISA for Algorithm Components.

Functional Components. Pre-intervention scores for Participant C was 85% agreement with a range of 80%-100% agreement. Post-intervention scores for Participant C was 87% with a range of 83%-100% agreement. Pre-intervention scores for Participant D was 91% agreement (range 88%-100%) and post-intervention was 91% (range 88%-100%). Participant K had 92% agreement for pre-intervention (range 85%-100%) and post intervention agreement was at 91% (range 84%-100%). Participant O had 90% agreement (range 87%-100%) for pre-intervention and 82% agreement range (82%-100%) for post-intervention. Participant P had 100% agreement for pre-intervention scores and 90% agreement for post-intervention scores (range 85%-100%). Participant V had 85% agreement for pre-intervention scores (range 82%-100%) and 89% for post-intervention (range 84%-100%).

*Rationale Components***.** Pre-intervention scores for Participant C was 85% agreement with a range of 80%-100% agreement. Post-intervention scores for Participant C was 80% with a range of 80%-100% agreement. Pre-intervention scores for Participant D was 91% agreement (range 82%-100%) and post-intervention was 87% (range 83%-100%). Participant K had 100% agreement for pre-intervention and post intervention agreement was at 82% (range 80%-100%). Participant O had 93% agreement (range 89%-100%) for pre-intervention and 89% agreement (range 85%-100%) for post-intervention. Participant P had 100% agreement for pre-intervention scores and 82% agreement for post-intervention scores (range 81%-100%). Participant V had 80% agreement for pre-intervention scores (range 80%-100%) and 90% for post-intervention (range 86%-100%).

Functional accuracy. Two naïve adult readers solved the written algorithms to determine their functionality. ISA was conducted by a second observer without an answer key. The naïve adult readers only had access to the written algorithms produced by the participants. ISA was conducted by a second observer without an answer key. The naïve adult readers only had access to the written algorithms produced by the participants. ISA was conducted across 100% of pre-intervention assessments with a mean agreement of 99% (range 95%-100%). Post-intervention ISA was collected for 100% of sessions with a mean agreement of 99% (range 93%-100%).

Table 5

ISA for Five Naïve Adult Readers for Dependent Variable 1

	Functional Components		Rationale Components	
Participant	Pre-intervention Agreement (Range of Agreement)	Post-intervention Agreement (Range of Agreement)	Pre-intervention Agreement (Range of Agreement)	Post-intervention Agreement (Range of Agreement)
C	85% (80%-100%)	86% (83%-100%)	85% (80%-100%)	80% (80%-100%)
D	91% (88%-100%)	90% (88%-100%)	91% (82%-100%)	87% (83%-100%)
K	92% (85%-100%)	91% (84%-100%)	100%	82% (80%-100%)
O	90% (87%-100%)	93% (82%-100%)	93% (89%-100%)	89% (85%-100%)
P	100%	90% (85%-100%)	100%	82% (81%-100%)
V	85% (82%-100%)	89% (83%-100%)	80% (80%-100%	86% (86%-100%)

Structural elements. A second observer independently scored correct and incorrect structural elements including grammar, spelling, and punctuation. ISA was collected for 100% of pre-intervention sessions with 99% agreement (range 90%-100%), ISA was collected for 100% of post-intervention sessions with 99% agreement (range 94%-100%).

Measure of reinforcement. A second observer independently scored correct and incorrect responses for the untaught algebra math problems. ISA was collected for 100% of pre-intervention sessions with 99% agreement (range 95%-100%), ISA was collected for 100% of post-intervention sessions with 98% agreement (range 96%-100%).

Intervention. Interscorer agreement was collected for 100% of intervention sessions using the permanent products of written math algorithms with a mean agreement of 99% (range 97%-100%) of the functional components and 100% of agreement for number of questions the editor asked, and 100% agreement of number of rewrites required by the writer.

Results

Algorithm Components

Figure 10 shows the number of correct functional components and correct rationale components scored by five naïve readers for Participant C (writer) and Participant D (editor), Participant K (writer), Participant O (editor), Participant V (editor), Participant P (writer).

All participants showed strong improvements in both functional and rationale components following intervention. Participant P (writer) had the strongest improvement in both functional and rationale components following intervention.

Functional Accuracy of Math Algorithm

Figure 11 shows the percentage of algorithms (calculated from all pre-intervention algorithms and post-intervention algorithms) written with functional accuracy as solved by the two naïve readers. For Participant C (writer) and Participant D (editor), Participant K (writer), Participant O (editor), Participant V (editor), Participant P (writer). All participants increased to 100% accuracy following intervention with Participant D (editor) and Participant P (writer) showing the strongest improvements.

Structural elements

Figure 12 shows the percentage of correct structural components for grammar, spelling, and punctuation during pre-intervention and post-intervention conditions for Participant C (writer) and Participant D (editor), Participant K (writer), Participant O (editor), Participant V (editor), Participant P (writer). Participants showed the strongest improvement in grammar, and some improvement in punctuation. Participant C (writer), Participant O (editor), Participant V (editor).

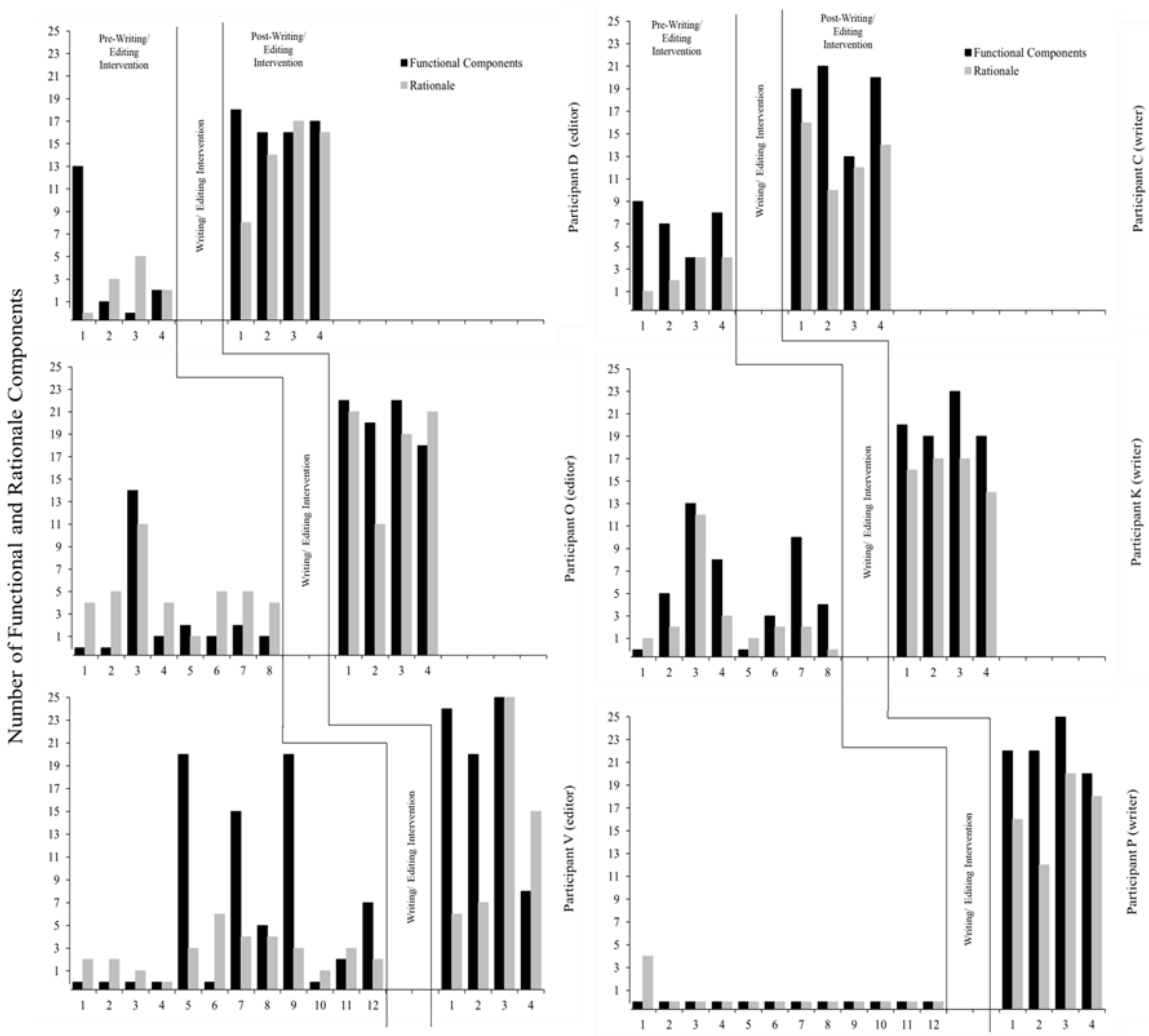

Figure 10. Dependent Variable 1: Number of correct functional components and number of correct rationale components Participant D (editor), Participant C (writer), Participant O (editor), Participant K (writer), Participant V (editor), and Participant P (writer)before and after the writing/editing intervention.

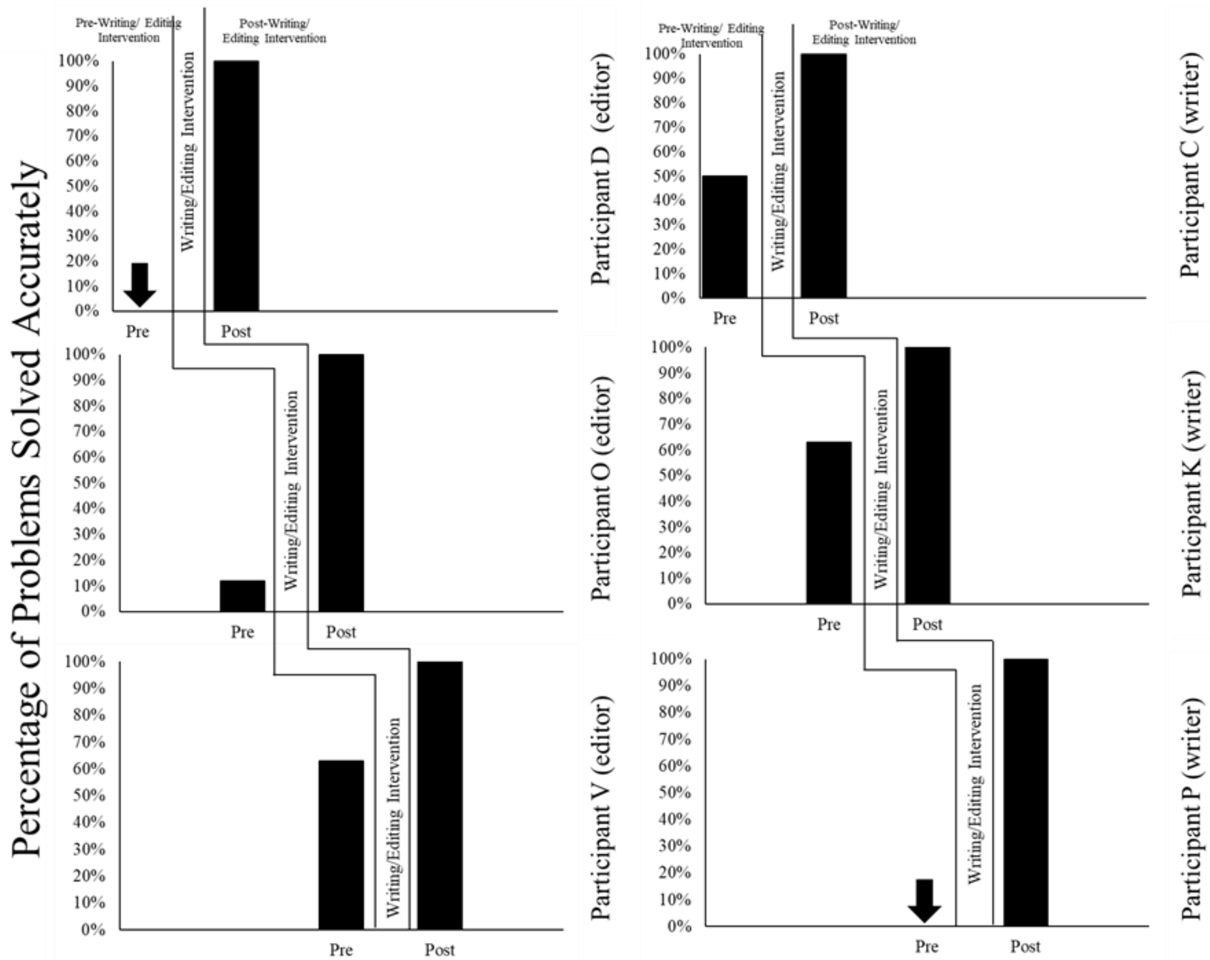

Figure 11. Dependent Variable 2: Functional Accuracy for Participant D (editor), Participant C (writer), Participant O (editor), Participant K (writer), Participant V (editor), and Participant P (writer) before and after the writing/editing intervention. This figure shows the percentage of the word problems that could be solved by a naïve adult reader prior to and following the intervention calculated from the sum of pre-intervention and post-intervention solutions.

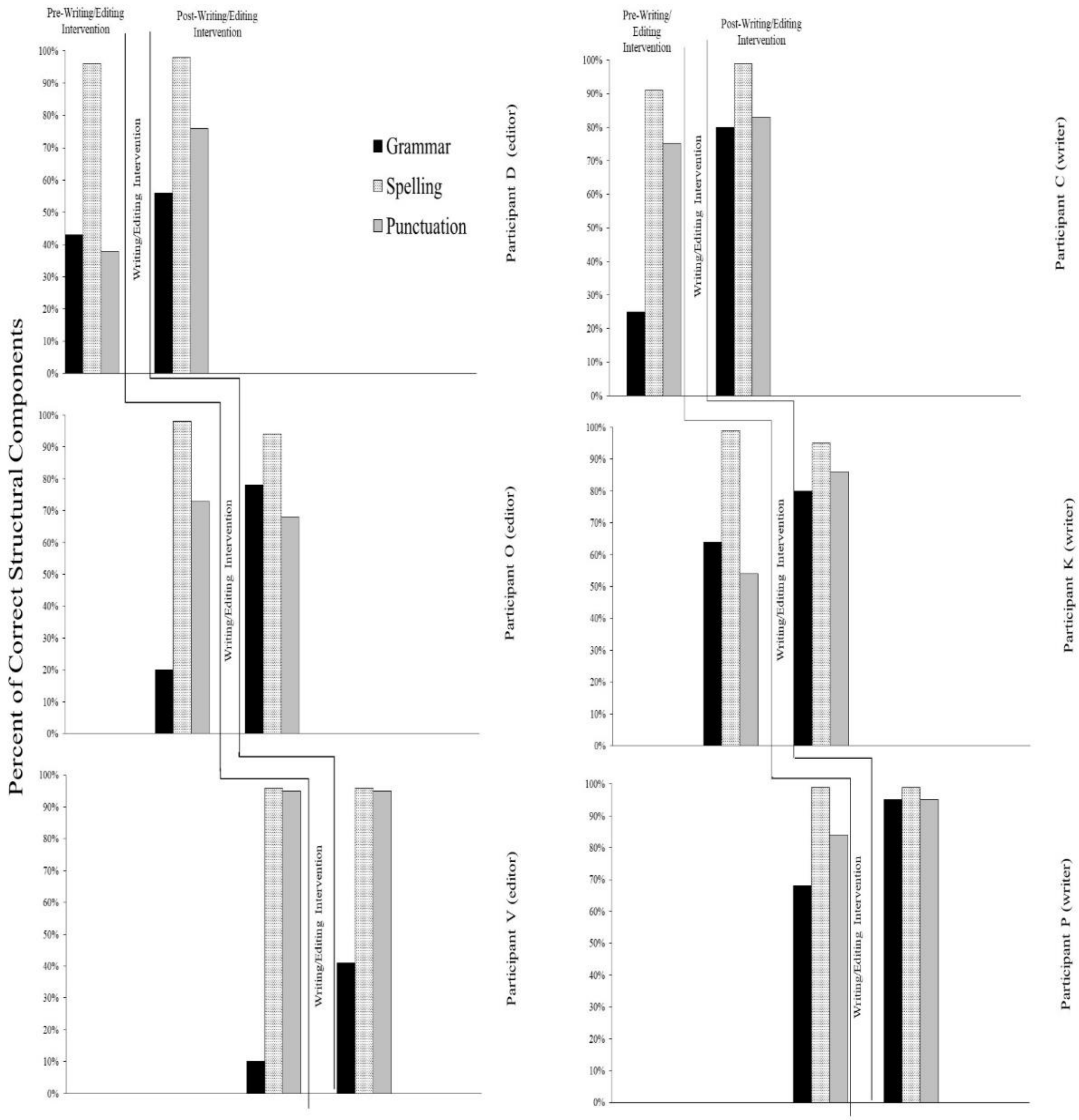

Figure 12. Dependent Variable 3: Structural Elements. Percent of correct structural components for grammar, spelling, and punctuation for components for Participant D (editor), Participant C (writer), Participant O (editor), Participant K (writer), Participant V (editor), and Participant P (writer) before and after writing/editing intervention.

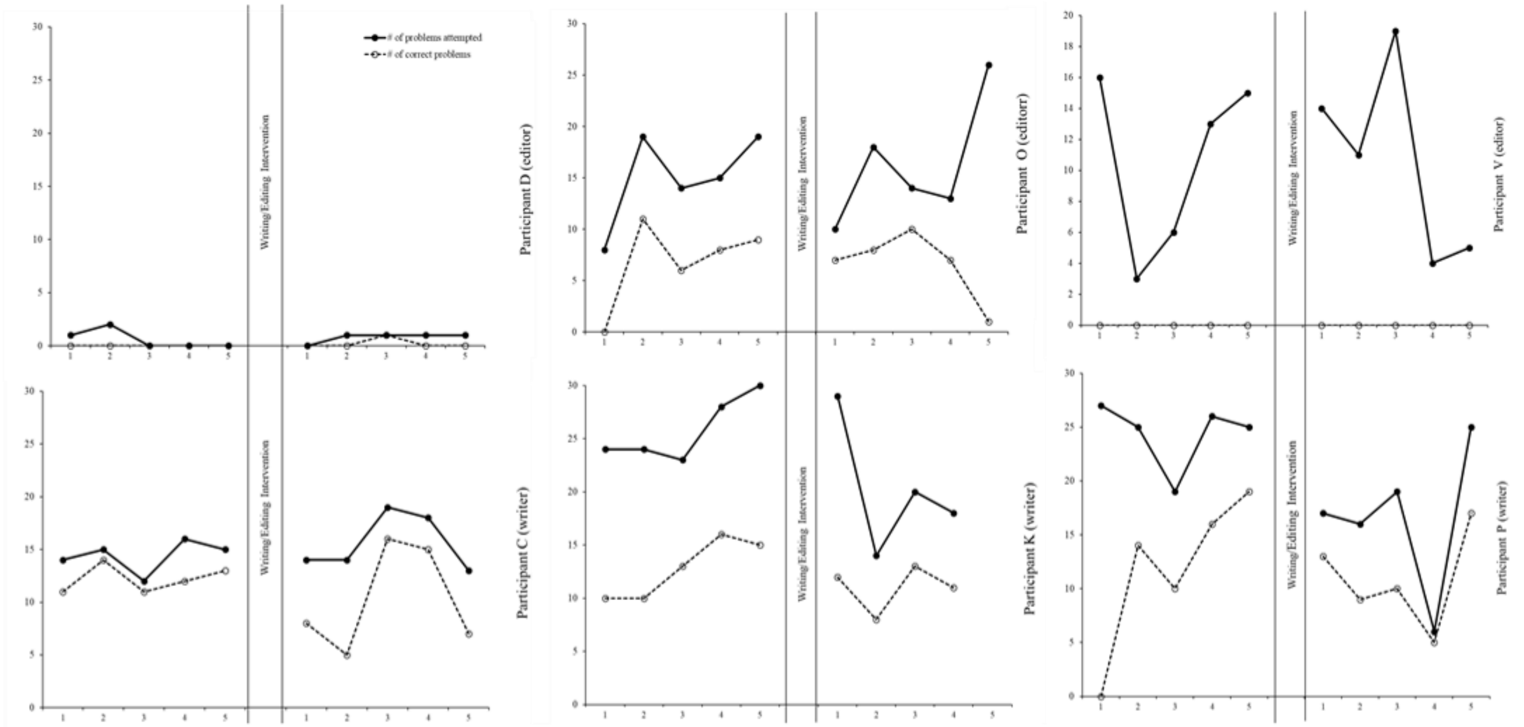

Figure 13. Dependent Variable 5: Resistance to Extinction. Cumulative number of untaught algebra equations for Participant D (editor), Participant C (writer), Participant O (editor), Participant K (writer), Participant V (editor), and Participant P (writer) before and after writing/editing intervention.

Measure of Reinforcement

Figure 13 shows the results for the number of attempted problems and number of correct problems for Participant C (writer) and Participant D (editor), Participant K (writer), Participant O (editor), Participant P (writer), and Participant V (editor). There were no effects in this measure.

Social Validity

A total of seventeen naïve readers scored the four samples from three participants. The experimenter then conducted a dependent sample t-test comparing the means of pre- and post-intervention scores across participants as a measure of social validity. The experimenter conducted a dependent samples t-test comparing the means of naïve readers' scores for pre-intervention and post-intervention permanent products as a measure of social validity. The dependent samples t-test revealed a statistically significant difference between the means of pre-intervention scores (M=1.62, SD=.095) and post-intervention scores (M=3.35, SD=.129); $t(3) = -15.559$, $p < .001$.

Intervention

Figure 14 shows the number of correct functional components for the writer and the number of rewrites per intervention session and the number of questions asked by the editor in for Participant C (writer) and Participant D (editor), Participant K (writer), Participant O (editor), Participant V (editor), Participant P (writer).

The number of functional components for Participant C (writer) increased to a score of five components across three intervention sessions. Participant C (writer) required five rewrites for the first session and decreased to zero rewrites in the third session. Participant D (editor) asked 18 questions in the first and second session, 3 questions in the third session, and 0 questions in the third session.

Participant K (writer) required four intervention sessions with a total of three rewrites for the first session, two rewrites in the second session, one rewrite in the third session, and zero rewrites for the second session. The number of functional components for Participant K (writer) increased to a score of five components across four intervention sessions. Participant O (editor), asked six questions in the first session five questions in the second session, one question in the third, and zero questions in the fourth session.

Participant P (writer) increased to five functional components after four sessions and needed two or three rewrites in each session until requiring zero rewrites in the fourth session. Participant V (editor) asked 16 questions in the first session and decreased to zero questions in the fourth session.

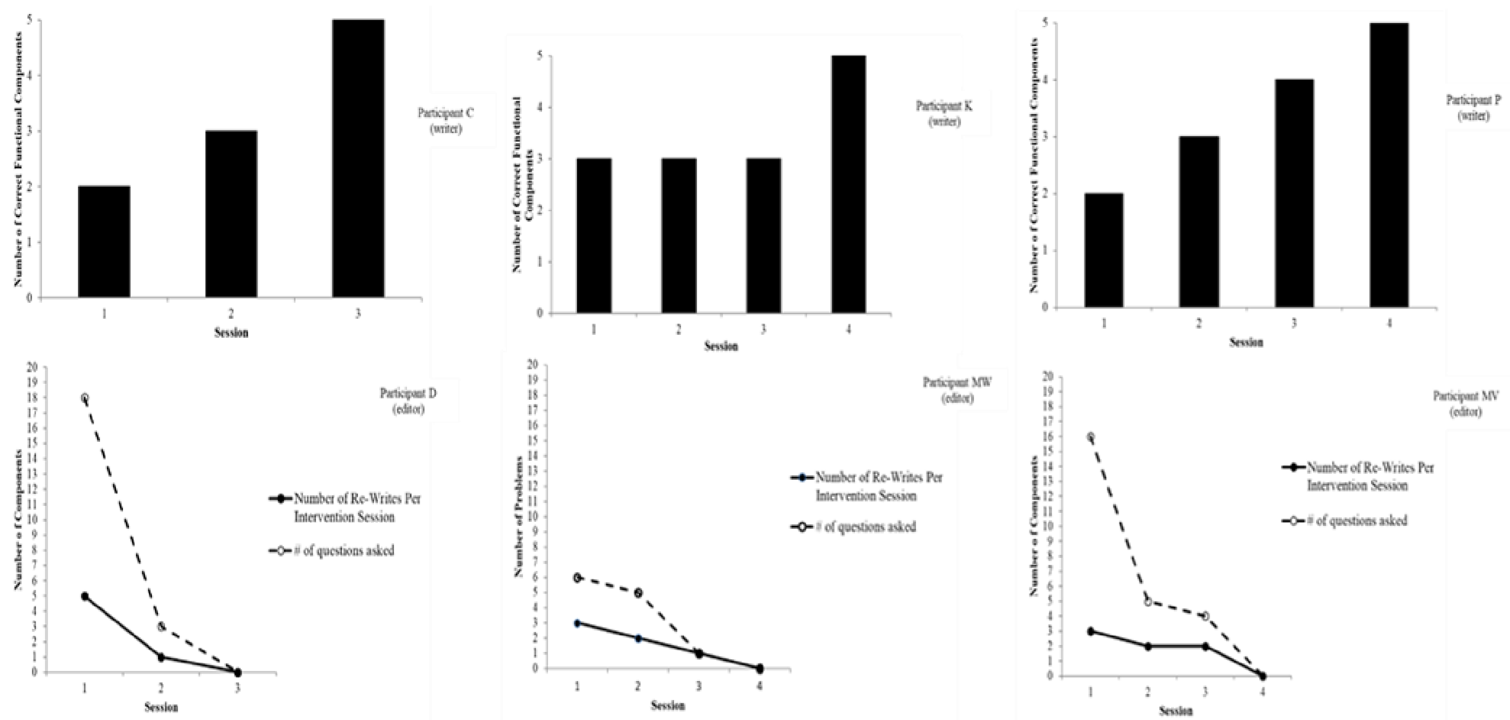

Figure 14. Intervention data for Participant C (writer) and Participant D (editor), Participant K (writer), Participant O (editor), Participant V (editor), Participant P (writer).

Discussion

The results of Experiment 2 showed that the participants acquired both the functional components and the rationale components as a result of the intervention. A functional relation was shown between the writing/editing package and the number of functional and the number of rationale components. The necessary change was the addition to the intervention, where the editor had to write the word problem based off of the writer's algorithm. The editor was motivated to ask questions to prompt the writer to supply the necessary information to write a complete word problem. The effects of this were carried to the post-intervention sessions, where some of the written algorithms were formatted similar to a word problem.

The participants in Experiment II were from a mix of two classrooms and had varying levels of grade level functions for math and reading, however their higher grade levels in math and reading made the Experiment II participants more suited to the intervention, as evidenced by the results. Participant C (writer) was the only participant with a diagnosis of ASD and functioned at a fourth-grade math level and third grade reading level. Participant D (editor) had an intellectual disability diagnosis and functioned at a first-grade math level and fourth grade reading level. Participant C (writer) was given a second-grade word problem set and Participant D (editor) was given first grade word problems. Both participants' algorithm components and functional accuracy scores increased following intervention. Although each participant had a differentiated word problem, functional writing was established.

Participant K (writer), Participant O (editor), Participant P (writer), and Participant V (editor) were closer in math and reading grade level to each other and were given first grade word problems. Participant K (writer) and Participant P (writer) functioned at higher reading and math grade levels; however due to disability needs were given the lower grade level word problems. It can be seen in the results that even though these participants were given word problems at a lower grade level, the baseline results were very low for algorithm components.

The populations of participants in Experiment II were different than in Experiment I. Four out of six participants in Experiment II were in a lesser restrictive environment than the remaining participants in Experiment II and all the participants in Experiment I. Six participants in Experiment I had a diagnosis of PDD-NOS or ASD, and there was one participant with an Intellectual Disability diagnosis. In Experiment II there were four participants with Intellectual Disability diagnosis, one student with Attention Deficit Disorder, and one student with ASD. Although all participants across Experiment I and Experiment II had appeared to be the necessary prerequisite cusps and capabilities in repertoire, their grade levels and other test scores were vastly different. Additionally, there were only two females across both experiments. Participant K (writer) in Experiment II was not in the self-contained classroom, and she functioned at a higher-grade level for both math and reading. Both Participant K (writer) and Participant E (editor) were given the same word problems (in different orders) and Participant K (writer) showed more significant improvements in Algorithm Components and Functional Accuracy results following intervention.

Algorithm Components

All participants improved in functional components. Participant P (writer) showed the most improvements following intervention. Overall an improvement could be seen in both functional and rationale components for all participants. This was comparable to the results found in Weber (2016) where the functional and rationale components increased following intervention; however, this current study required intervention to increase the rationale components.

Functional Accuracy

All participants increased their functional accuracy, which means that a naïve reader could solve the post-intervention algorithms. Participant D (editor), Participant O (editor), and Participant P (writer) started at zero percent in baseline and increased to 100% as result of the intervention. These participants' results matched their result from the Algorithm components dependent variable as well. This also was comparable to Broto & Greer (2014) results where the number of algorithms solved increased for all participants following intervention.

Structural Elements

The experimenter consequated the structural elements in the intervention. Grammar, and punctuation increased the most in post-intervention assessments as a result of the writing/editing intervention package. This could result from the participants producing an increase in sentences following intervention. The results were similar to that of Broto & Greer (2014) where structural elements increased following intervention where the experimenter intervened on structural elements.

Measure of Reinforcement

There were no effects on the measure of reinforcement. This was different to what was found in Weber (2016) although similar to the results found in Experiment 1 of the current study.

Limitations

One of the limitations in this study was that one participant in this study had the medical diagnosis of autism spectrum disorder, while the other five participants had and educational diagnosis of a learning disability. This was different than the first study, where six participants had a diagnosis of autism spectrum disorder or pervasive developmental disorder-not otherwise specified (PDD-NOS). This study was replicated with students who did not share the same diagnosis due to the limited availability of students with autism.

The next chapter will connect the results to relevant studies and discuss their significance.

CHAPTER IV

GENERAL DISCUSSION

The purpose of this study was to determine if the functional writing intervention significantly improved the functional writing repertoires of middle school students with disabilities. This study was an extension of an unpublished dissertation by Weber (2016) and a systematic replication of her study with middle school students with disabilities.

Experiment I found that the functional writing intervention showed some improvements in four out of the eight participants functional components and some improvements in two out of the eight participants' rationale components. Participants were students in a self-contained classroom who each functioned at a different math and reading level and had varying disabilities which may account for the variable results. This is different than Weber (2016) whose participants were typically developing fourth graders who were at the same level. Experiment II sought to account for instructional histories and varied grade levels of students by asking the editor to write the word problem based off of the writer's algorithm.

Experiment II found that the functional writing intervention showed a functional relationship in all the participants' functional components and rationale components'. Two participants were students in the self-contained class, and four participants were students from a resource room class. The change to the intervention, where the editor had to write a word problem based on the writer's algorithm at the completion of the intervention session, resulted in increases in functional writing skills for all participants.

Major Findings

Experiment I

Experiment I was a replication of an unpublished dissertation by Weber (2016) and conducted to test the effectiveness of the Functional Writer Immersion Package on the writing repertoires of middle school students with disabilities. There were some effects demonstrated in the of results of Participant M (editor), Participant N (editor), Participant R (writer), and Participant B (writer). These participants, whether their role was an editor or a writer, acquired writing skills to affect the naïve adult reader so that the naïve adult writer could produce steps to solve a word problem when they did not receive the original word problem. There were some additional aspects of the study which contributed to these findings.

Writer immersion. Some of the participants learned to affect the behavior of the writer for math, which was similar to previous studies using the same protocol (Helou, Lai, & Sterkin, 2007; Jodlowski, 2000; Madho, 1997; Reilly-Lawson & Greer, 2006; Visalli-Gold, 2005). The four participants who had acquired the functional writing for math had no instructional history with Writer Immersion protocol. Moreover, this was the first instance that they were taught to write for function. For participants with necessary prerequisites, they had acquired the function of writing. This may explain why they had greater results then other participants, who after multiple years of experience with the procedure similar to Writer Immersion, may have found the writing conditions aversive.

Participants that had some components of functional writing, as demonstrated by their pre-intervention probes, suggesting that these participants had an instructional history with the Writer Immersion protocol. Participant R (writer) explicitly stated that he had never done this before, and he was new to the self-contained classroom. Participant R (writer) was one of the four participants whose post-intervention algorithms were significantly improved following intervention. The rationale components are not a part of the Writer Immersion protocol, and therefore none of the participants had much prior history with including explanations for the rationale for the math algorithms. Additionally, this is a skill that is difficult for participants with diagnoses and profiles in both experiments (albeit different populations, they held this in common). Participants were in an intervention reading curriculum to work on making inferences, and as explaining a rationale requires inferencing skills, this may account for the lower rationale when compared to the functional components.

Social reinforcement. A lack of social reinforcement in Experiment I was identified as a prerequisite skill. Within the Verbal Behavior Development Theory, there are cusps and capabilities (Rosales-Ruiz & Baer, 1996) which allow an individual to become truly verbal (Greer & Ross, 2008). The acquisition of cusps and capabilities brings about new social reinforcers (Greer & Du, 2014). While the participants had other necessary cusps and capabilities in repertoire to complete the components of the experiment, anecdotally it was noted that the participants were not motivated by their peer in the dyad in Experiment I. The process of editing and writing requires the individual to be motivated by their peer in the dyad to affect the behavior of the reader (Greer & Du, 2014). As individuals acquire more cusps and capabilities, their repertoire grows to extend theses skills to other topographies. The writer is an extension of the speaker, and therefore an individual has to respond as a speaker in written topographies. Similarly, a reader is an extension of the listener, however the topography is textual (Greer, 2008). The participants' motivation to affect the writer came from rule-governed behavior to complete the directions given by the experimenter. Since writing is a form of verbal behavior and social reinforcement is necessary in order to write to affect the behavior of a reader, the reader/editor is reinforced by effectively writing questions so the writer could include all components of his/her writing without additional re-writes.

Rule-governed behavior. Rule governed behavior or verbally governed behaviors are behaviors controlled by verbal stimuli (prompts, language, gestures) (Greer, 2002). The suggestion that the majority of the participants' lack of improvements in functional writing was due to rule-governed behavior can be seen in not only the algorithm components and functional accuracy measures, but in the measure of reinforcement. There were very little changes in the number of problems attempted during post-intervention sessions, which means that the measure of reinforcement was not affected. These responses show that the reinforcement lies in teacher (experimenter) contingencies, and not in solving math equations.

Experiment II

The results of Experiment II revealed that the participants acquired functional writing as a result of the intervention. A functional relation was demonstrated between the writing/editing package and the number of functional and the number of rationale components and the functional accuracy. The addition to the intervention, where the editor had to write the word problem based off of the writer's algorithm, was necessary to these effects. The editor was motivated to interact with his peer through writing to ask questions (in written topography) to prompt the writer to supply the necessary information to write a complete word problem.

Writer immersion. The participants learned to affect the behavior of the reader through the writing/editing intervention package, an extension of Writer Immersion protocol. These are similar results as found in other literature which utilized the same procedure, (Helou, Lai, & Sterkin, 2007; Jodlowski, 2000; Madho, 1997; Reilly-Lawson & Greer, 2006; Visalli-Gold, 2005). The participants in Experiment II had no instructional history with the procedure and therefore made significant improvements with their functional writing. This is consistent with prior studies which introduced the procedure to the participants (Helou, Lai, & Sterkin, 2007; Jodlowski, 2000; Madho, 1997; Reilly-Lawson & Greer, 2006; Visalli-Gold, 2005). The Writer Immersion protocol establishes an environment which facilitates a motivating operation conducive to producing writing that affects the behavior of a reader.

Role of the listener. Writing is an extension of speaker behavior and editing is an extension of listener behavior (Greer & Keohane, 2005). Individuals with "read-do" cusp, where individuals read and respond to the text is the same role as a self-editor (Greer & Speckman, 2009). The role of the listener is to provide consequences to the speaker, which in turn either reinforces or punishes future occurrences of that speaker behavior (Skinner, 1957). The listener always responds to the speaker behavior (Skinner, 1957). As writing is an extension of listening behavior, the function of writing allows the reader to understand the writer's experience, which means that the writer must write with enough detail so that the reader can respond (Vargas, 1978). The participants in this study only had one defined role in the intervention-either the editor or the writer, however all participants had to act as writers or editors in the pre-intervention and post-intervention assessment conditions. The results showed that functional writing emerged as a result of the participants functioning as both editors and writers ("writer as editor") within the skin.

Math as a verbal repertoire. The findings of Experiment II are consistent with prior research (Greer & Keohane, 2005; Broto & Greer, 2014; Pellegren, 2015; Weber, 2016) when considering math as a verbal repertoire. The Verbal Behavior Development Theory (VBDT) (Greer & Ross, 2008; Greer & Keohane, 2005; Greer & Speckman, 2009) has protocols to induce functional repertoires. Functional writing is taught through the Writer Immersion protocol

(Helou, Lai, & Sterkin, 2007; Jodlowski, 2000; Madho, 1997; Reilly-Lawson & Greer, 2006; Visalli-Gold, 2005). Furthermore, teaching the function of math where we use math as a language, means that math can be considered a verbal repertoire. If teachers think of teaching math as a language, then math education can be implemented to affect the behavior of the listener or a reader when introducing new math repertoires.

Social reinforcement. The participants in Experiment II were from a combination of two classes, a self-contained CABAS® class and a resource room class. The CABAS® class is the more restrictive of the two settings and the participants from the resource class have more social reinforcement. The participants from Experiment II were motivated by their peers, as evidenced by anecdotal data of the experimenter having to remind the participants to not talk to each other more frequently than the participants from Experiment I. The participants in Experiment II were motivated by their peers, and this translated into their writing. The editors were motivated to have their peers avoid doing rewrites, and the writers were motivated to produce functional writing, so the editors would not produce questions. The idea that social reinforcement is necessary to improvement in functional writing with Broto and Greer (2014), who used a yoked contingency gameboard to motivate the peers to work together to write algorithms in order to use the social reinforcement to improve written algorithms.

Rule- Governed Behavior. In Experiment II, the measure of reinforcement proved to not show that the reinforcement value of math was affected by the intervention. The participants in Experiment II may have more social reinforcement for their peers than the participants in Experiment I, however the reinforcement value of their teachers is still valued more, as well as the reinforcement of verbally governed behavior. When the experimenter/ teacher gives a direction to complete an assignment, the participants do not protest no matter how aversive or reinforcing the assignment is perceived. Greer and Keohane (2005) examined the use of a verbally governed algorithm to solve learning problems. Broto and Greer (2014) tested a functional writing protocol, and participants acquired writing math algorithms as a result. Pellegren (2015) found that when the participants only functioned as an editor and used an editing checklist, verbally governed behaviors were acquired. Although half of the participants in Experiment II were identified as editors in the intervention, the participants functioned as self-editors. In the current study, the participants acted both as writer and as editor when given the algorithms. When participants wrote the algorithm, they had to consider their writing from the perception of the reader, and learned to write to affect the reader. The assigned role in the intervention did not affect the outcomes in the post-intervention. This is different than Pellegren (2015) who found that participants who were given the role of editor had more improved results.

Findings Across Experiment I and Experiment II

Thinking in Problem Solving

Thinking is covert behavior (Skinner, 1957) where the role of the speaker and listener are rotated under the skin. When one writes, the individual acts as the speaker, and in the same skin, that individual reads what he wrote, and acts as the listener. Editing acts as both avoiding punishment and attain reinforcement from the reader, (Skinner, 1957). The participants who had prior experience in Writer Immersion in Experiment I emitted the same behavior as an editor would but lacked social reinforcement. The participants in Experiment I who had significant results and the participants in Experiment II had both the social reinforcement in repertoire and novel exposure to the Writer Immersion protocol. Therefore those participants were able to follow the components of problem solving (Skinner, 1957): 1)identify the problem (the editor asked a question seeking information for rationale, or the writer produced an algorithm with complete components) and were motivated to do so (Writer Immersion contingencies and social reinforcement) in order to 2) seek out the solution to the problem (writer learned from previous corrections, editor asked more specific questions).

Limitations

The limitations in Experiment I included the measure of reinforcement not run with Participant L (writer) and Participant W (editor). The materials for both experiments could be condensed to one page where the participant can solve the word problem on a separate piece of paper, and then use the one page to write the written algorithm with no additional questions. More word problems need to be sure to include more real-world applications as opposed to using word problems with zebras so that participants can make better connections to the word problems using familiar tacts. There was also a limited sample size to the number of participants who completed each grade level of word problems. In Experiment I, four participants completed fifth-grade level word problems, two participants completed second-grade word problems, and two participants completed first-grade word problems.

Implications

The definition of functional is evolving. Broto and Greer (2014) defined a functional word problem if an adult reader could solve the problem when given the written directions. As an extension of Weber (2016) unpublished dissertation, this study included the use of functional and rationale components as necessary algorithm components in order for a word problem to be truly functional. This is educationally significant for teachers in their classroom because it is an interdisciplinary approach to teaching which can be applied to all students, regardless of disability. Math instruction should incorporate writing, so that students can learn to use verbal behavior about their math objective to explain to others how to solve a problem and why it is necessary to solve the problem in order to effectively achieve mastery (Greer & Ross, 2008).

Educational Significance

The United States is ranked 36th in the world in mathematics (PISA, 2015). In order to solve this problem, we need to 1) identify the problem and 2) identify the behavior necessary to change the problem (Skinner, 1957). A deficit in today's mathematical curricula is that there is a lack of teaching math as a verbal repertoire. If teachers think of math as a language, and teach the function of math, then math instruction can be implemented to affect the behavior of the listener or a reader when introducing new math repertoires. The participants in the current study are below grade level in math the results showed an increase in their overall math writing functional skills. The Writer Immersion protocol established a "need to know" and is something that can be modified to replicate in today's classrooms as we have seen in other applied studies (Helou, Lai, & Sterkin, 2007; Jodlowski, 2000; Madho, 1997; Reilly-Lawson & Greer, 2006; Visalli-Gold, 2005).

Future Research

In future studies, the conditions need to be set up where they discover the map to learn the "why". Students with the varying disabilities and functioning at the varying grade levels often lack inferencing skills (Chevallier, Wilson, Happé, & Noveck, 2010). As Skinner (1957) says, "Learning then seems to be the discovery of maps," (Skinner, 1957, p 157). Future research should address this deficit and attempt other ways to induce inferencing. While maps include rule-governed behavior (Skinner, 1957), this is a step towards problem solving and is the first step towards inducing contingency-shaped behavior (Skinner, 1957). Additionally, when working with students who have disabilities, future research should look at reinforcement value of writing and social listener reinforcement. Future studies should also consider a component analysis to compare the results of the components more in depth.

Conclusion

As Skinner (1957) said "a child must learn to *use* writing as well as learn to write," (Skinner, 1957, p. 193). Writing is an extension of speaker behavior and a necessary topography to navigate the world we live in today. The reinforcement effect of a person's writing makes that writing functional. If a student writes a note to another student asking for a piece of gum, and that reader hands the writer a piece of gum, the writer has received reinforcement for writing. Not all writing produces reinforcement such as gum, writing instruction must incorporate the functional instruction so that students may write to the same effect. The function of the stimulus control of writing is a learned reinforcement, and for students who write about math, they must be curious about the solution of a problem in order to receive that same reinforcement (Skinner, 1957).

Vargas (1978) included suggestions on how to teach functional writing by having the writer observe the reader actively reading the writing, thus establishing the "need to write" (Greer & Ross, 2008) or the motivating operation (Michael, 2004) for the student to reach a goal. In Experiment II, the editor knew they had to write a word problem at the end of the intervention, and therefore this facilitated a motivating operation for the editor to ask the writer questions in order to receive the needed information. These questions served as learn units for the writer, and the combination of these interlocking operants produced the functional writing seen in post-intervention. Functional writing needs to include the rationale components in addition to the functional components and functional accuracy to provide context for the reader as part of problem solving. The structure of writing (Dewey, 1933) needs to be driven by function, therefore function should be the foundation of instructional practices.

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SET 2 (5th grade)

GROUP A (all operations)

	Word Problem	Rationale for problem	Step 1	Step 2	Step 3	Step 4	Answer
GEOMETRY	Allison needs 432 feet of rope to put a border around her backyard. She will plant 6 trees. She can buy the rope in lengths of 36 feet. Each length of rope costs $8.00. How much will it cost to purchase enough lengths of rope for 4 backyards?	Cost of rope	432/36=12	4*12=48	$48 * 4= $192	$198 * 2= $384	$384
		Rationale for Operations	How many lengths of rope needed for 1 yard	How many lengths of rope for four backyards	Cost of 4 yards	Cost of four backyards (8 lengths of rope)	
N&O	People all around the world eat steaks and fish. Steaks can cost as much as $15 a pound. Fish cost as much as $12 a pound. How much a 3 ¼ pound steak would cost?	Calculate cost of steak based on lbs.	$15/75lb	3*15=45	¼ *15/1= 15/4	45+3.75	$45.75
		Rationale for Operations	Gather info on 1 steak	Calculate cost of steak	Calculate how much ¼ lb. steak cost	Add two calculations for total cost	
ALGEBRA	A group of 5 friends put their money together, hoping that they could all go to the movies as a group. Popcorn cost $3.00, and candy cost $4.50. This is how much the friends gave: $7.25, $5.50, $8.10, $3.25, and $6.90. If a movie ticket costs $6.00, will they have enough money?	Will the friends have enough money?	6*5=30	30+3= 33	33+4.5=37.5	7.25 + 5.5 + 8.10 + 3.25 + 16.9 =31.00	No, $37.5
		Rationale for Operations	Cost of tickets	Cost of popcorn	Total cost	Friends total money	
MEASUREMENT	The hammerhead shark can swim at a speed of 50 miles per hour. The blue shark can swim at a speed of 40 miles per hour. If the blue shark swam at this speed for 15 minutes, how far would it swim? How long would it take the blue shark to travel 90 miles?	How long will it take the blue shark?	40/4=10 mi in 15 min	40mi/1 hr. = 90 mi/ X	40X/40 = 90/40	40X/40 = 90/40	X= 2.025
		Rationale for Operations	How far in 15 min	Set up proportion	Cross multiply	Divide by 40 to solve for x	

SET 2 (SET A) (5th Grade)

GROUP A (all operations)							
	Word Problem	**Rationale for problem**	**Step 1**	**Step 2**	**Step 3**	**Step 4**	**Answer**
GEOMETRY	Mr. Smith is putting a title on a bulletin board: "Jump Right into Learning About Frogs". Each capital letter is 1 ½ inches wide, lowercase letters are 1 inch wide, and there is a 1-inch space between words with 6 words total. How long will the title be?	Total distance of board	5 * 1.5= 7.5	26*1= 26	5*1=5	7.5+26 +5= 38.5	38 ½ in
		Rationale for Operations	Length of capital letters	Length of lower case letters	Length of space between words	Sum	
N&O	The city of Fort Wane, Indiana had a population of 4,282 in 1850 and 45,115 in 1900. The city of Montgomery, Alabama had a population of 8,728 in 1850 and 30,346 in 1900. The city of Tallahassee, Florida had a population of 5,760 in 1850 and 10,564 in 1900 and 678 orange trees. What is the difference between the city with the biggest population growth and the city with the smallest population growth?	Which city's population increased more?	45115-4282 = 40833	30346 - 8728 = 21618	10564-5760= 4804	40833-4804= 36029	36029 people
		Rationale for Operations	Difference in Indiana	Difference in Alabama	Difference in Florida	Difference between IN and FL	
ALGEBRA	Sarah ate breakfast at a restaurant. Sarah ordered a muffin and egg sandwich for $2.50, hash brown potatoes for $1.25, and orange juice for $0.75. Her mother told her that she could spend $5.00. Did she have enough money to buy milk for $0.50?	Could Sarah buy milk?	2.5+1.25= 3.75	3.75+.75= 4.5	5.00-4.5= .5	4.5+ .5 = 5.00	Yes, $4.50
		Rationale for Operations	Add muffin, sandwich	Add OJ	Find difference	Add milk	
MEASUREMENT	Mr. Jones has planned 4 different activities for the day. There will be one clown at each activity. Each one takes 25 minutes. If the party starts at 1:00 pm, at what time will the party be over?	Determine the length of the party	25*4=100 minutes	100/60=1.67	1.67= 1 2/3= 1 hour, 40 min	1:00+ 1 hour 40 minutes = 2:40	2:40
		Rationale for Operations	Total time of activities	Convert to hours	Convert to time	Add to 1:00	

INTERVENTION (5th Grade)

GROUP A (all operations)							
	Word Problem	**Rationale for problem**	**Step 1**	**Step 2**	**Step 3**	**Step 4**	**Answer**
GEOMETRY	Steve wants to buy carpet for the bedroom floor which is 12 feet by 15 feet. The carpet comes on a roll that is 6 feet wide. The carpet salesperson unrolls the carpet to the length you want in yards and cuts off the piece of carpet. What length of carpet will you need to cover the bedroom floor?	Determine length of carpet to cut	12/3= 4	15/3=5	6/3=2	5*2=10	10 yds.
		Rationale for Operations	Convert width to yards	Convert length to yards	Convert to yards	Multiply the length times 2 to cover the area of the floor	
N&O	Isaac would like to practice the violin 7 ½ hours this week. So far, he has practiced 5 ¾ hours and slept for 2 ½ hours. How many more hours does he need to practice this week?	Determine hours left to practice	7 2/4 = 30/4	5 ¾ = 23/4	(30/4) – (23/4) = 7/4	7/4 = 1 ¾	1 ¾ hours
		Rationale for Operations	Convert to improper fraction	Convert to improper fraction	Subtract to determine difference	Convert to mixed fraction	
ALGEBRA	Jamar buys juice for the family. He buys eight 6-packs of juice boxes. His grandmother buys three more 6-packs and 2 ice creams. How many juice boxes were purchased all together?	How many juice boxes purchased in total?	1 pack = 6 boxes	6*8= 48 juice boxes	3*6=18	18+48=66 juice boxes	66 juice boxes
		Rationale for Operations	Pack= juice boxes	Total of Jamar's juice boxes	Total of grandmother boxes	Sum of all juice boxes	
MEASUREMENT	Alaska has more miles of rivers and streams than any other state. The next four highest ranked states are California with 211,513 miles; Texas with 191,228 miles; Montana with 176,750 miles; and Nevada with 143,750 miles. The top five states have 1,088,241 miles of rivers and streams and 546,068 miles of forest. How many miles of rivers and streams does Alaska have?	Find out how many miles of rivers in Alaska	211,513 + 191,228= 402,741	402,741+ 176,750= 579,491	579,491 +143,750=723,241	1088241-723241= 365000 mi	365,000 miles
		Rationale for Operations	Add CA + TX	Total + MT	Total four ranked states	Find total miles of rivers and streams in Alaska	

INTERVENTION (5th Grade)

			GROUP A (all operations)				
	Word Problem	**Rationale for problem**	**Step 1**	**Step 2**	**Step 3**	**Step 4**	**Answer**
GEOMETRY	Mr. Smith built a garden in his backyard. He wants to put chicken wire fence around the garden. The garden is 12 feet long and 4 feet wide. A tomato plant grows up to 6 feet tall. What is the total length of the chicken wire fence?	Determine length of chicken wire	L=12 ft. W = 6ft	12+4=16	12+4=16	$16+16=32ft^2$	$32 ft^2$
		Rationale for Operations	Length and width	Add L+W	Add L+W	Add/Total sides	
N&O	Sam wants to buy a guinea pig, food, and a wheel at the pet store. The guinea pig costs $5.00, the food costs $3.00, and the wheel costs $ 4.00. The parrot costs $3.00. Sam has $15.00 in his pocket. Can Sam buy the guinea pig, the food, and the wheel? How much money will he have left over?	Enough $?	Supplies: $5, $3, $4	5+3=8	8+4=12	15-12=3	$3.00
		Rationale for Operations	Supplies cost	Gp+food	Gp+ food+ wheel	Money left over	
ALGEBRA	Dave trapped two mice every day. He trapped twenty ants every day. How many mice did he trap in two weeks?	# of mice left over	7+7=14	2+2+2+2+2+2+2= 14	2+2+2+2+2+2+2= 14	14*2=28 or 14+14=28	28 mice
		Rationale for Operations	Weeks into days	How many mice caught in one week	How many mice caught in one week	Double/total the mice for 2 wks.	
MEASUREMENT	The male chimpanzee weighs 150 pounds. The female chimpanzee weighs 120 pounds. A baby chimpanzee weighs 40 pounds. A baby elephant weighs 90 pounds. How much more would two male chimpanzees than two baby chimpanzees?	Difference between weights of 2 male and 2 baby chimps	Male = 150lbs, baby = 40lbs.	150+150=300 lbs.	40+40 =80lbs	300-80=220lbs	220 lbs.
		Rationale for Operations	Chimp weight	Total of 2 male chimp weights	Total of 2 baby chimp weights	Difference between male chimp and baby	

SET 2 (2nd Grade)

GROUP B (addition and subtraction)

	Word Problem	Rationale for problem	Step 1	Step 2	Step 3	Step 4	Answer
GEOMETRY	Sam is building a wooden fence around his house. The house is 10 feet long by 6 feet wide. His car is 6 feet long. What is the total length of the fence needed to go around the house?	Determine length of fence needed	L= 10 W = 6	10+10 =20	6+6=12	12+10 =22 ft^2	22 ft^2
		Rationale for Operations	L and W	Add L + W	Add L + W	Total length of sides	
N&O	The lion found ten antelope and then five more antelope and six trees. If the lion eats three antelope then eats two more antelope, how many antelope will be left?	How many antelope left	10, 5, antelope found 3, 2 eaten	10 + 5= 15	15-3=13	12-2=11	11 antelope
		Rationale for Operations	Antelope info	Total antelope found	Antelope eaten	Antelope eaten	
ALGEBRA	The truck traveled 100 miles in one day. The car travels 50 miles each week. How many miles will the truck travel in one week?	Total miles	100 + 100= 200 miles	200 mi + 200 mi = 400 mi	400 + 200= 600 mi	600 + 100 mi = 700	700 mi
		Rationale for Operations	2 days	4 days	6 days	7 days	
MEASUREMENT	A baby panda weighs 50 pounds. A baby kangaroo weighs 30 pounds. A mother panda weighs 100 pounds. A father panda weighs 150 pounds. If the father panda loses 10 pounds, how much do all the pandas weigh all together after weight loss?	Sum Panda lbs.	B = 50 lbs. M = 100 lbs. F = 150 lbs.	150-10= 140lbs	50 + 100= 150	150 + 140= 290	290 lbs.
		Rationale for Operations	Bear weight	Father lbs.	Mother + baby	Sum of panda lbs.	

SET 3 (2nd Grade)		Word Problem	Rationale for problem	Step 1	Step 2	Step 3	Step 4	Answer
GROUP B (addition and subtraction)								
	GEOMETRY	Ms. O'Dell built a wooden fence around her backyard. The yard is 21 feet long by 15 feet wide. Her dog's leash is 18 feet long. What is the total length of the fence?	Determine length of fence needed	L = 21 ft. W = 15 ft.	21+15=36	21+15= 36	36 +36 = 72 ft^2	72 ft^2
			Rationale for Operations	L and W	Add L + W	Add L + W	Total length of sides	
	N&O	A chimpanzee stuck a stick into the termite nest. Six termites ran up the stick. Then eight more termites ran up the stick. Seventeen ants ran into the anthill. If the chimpanzee ate seven termites, then ate three more termites, how many were left?	Find out how many termites were left	Termites on a stick: 6, 8 Termites eaten: 7, 3	8+6 = 14	15-7=8	8-3=5	5 termites
			Rationale for Operations	Termite info	Total termites going up the stick	Subtract 7 because termites eaten	Subtract 3 because more termites eaten	
	ALGEBRA	Mother and Father fox teach their two cubs to hunt. Each cub catches two mice. Mother and Father each catch three mice. The robin ate one worm. How many mice did the foxes catch in all?	Find total # mice caught	Each cub: 2 mice Each parent: three mice	2+2= 4	3+3=6	6+4=10	10 mice
			Rationale for Operations	Fox and mice	Add mice caught	Add mice caught by parents	Total the mice caught	
	MEASUREMENT	A zebra walks 10 miles a day. They graze and drink water. How far could a zebra walk in two weeks?	calculate miles over 2 weeks	Zebra: 10 mi per day	7+7= 14	10*7=70 or 10+10+10+10+10+10+10=70	70*2= 140 or 70+70=140	140 miles
			Rationale for Operations	Zebra info	How many days in 2 weeks?	How many miles in 7 days	Total/ double miles over 14 days	

SET A/SET B (2nd Grade)

GROUP B (addition and subtraction)							
	Word Problem	Rationale for problem	Step 1	Step 2	Step 3	Step 4	Answer
GEOMETRY	Darnell is building a wire fence around his house. The house is 5 feet long by 6 feet wide. His car is 9 feet long. What is the total length of the fence needed to go around the house?	Determine length of fence needed	L: 5 ft. W 6 ft.	6+5=11	6+5=11	11+11	22 ft2
		Rationale for Operations	L & W	One L+W	Another L+W	Total length of sides	
N&O	The walrus found twelve clams and then six more clams and two twigs. If the walrus eats five clams then eats two more clams, how many will be left?	How many clams left?	12, 6 clams found 5, 2 clams eaten	12+5 =17	17-5=12	12-2=10	10 clams
		Rationale for Operations	Clam info	Total clams found	Clams eaten	More clams eaten	
ALGEBRA	The arctic fox has a white coat. It can jump 3 feet 2 inches. How many total inches can it jump?	Total inches it can jump	Fox = 3ft 2in	12+12=24	24+12=36	36+2=38	38 inches
		Rationale for Operations	Fox info	Two feet	Three feet	Three ft. + extra inches	
MEASUREMENT	Sloths sleep about 15 hours each day and eats for 2 hours a day. Pandas sleep for 8 hours a day. How many more hours does a sloth sleep in two days compared to a panda? (grade 1, week 19, page 58)	Difference in hours between panda and sloth over two days.	15 hrs., 8 hrs.	15+15=30	8 +8=16	30-16=14	14 hours
		Rationale for Operations	Sloth & panda	Two days sloth sleeping hours	Panda two days	Difference in sleeping	

INTERVENTION	GROUP B (addition and subtraction)							
		Word Problem	Rationale for problem	Step 1	Step 2	Step 3	Step 4	Answer
	GEOMETRY	Richard is building a wooden fence around his house. The house is 10 feet long by 5 feet wide. His truck is 11 feet long. What is the total length of the fence needed to go around the house?	Determine length of fence needed	L = 10ft W = 5ft	10+10 =20	5+5=10	20+5	25 ft.
			Rationale for Operations	L & W	One L+W	Another L+W	Total length of sides	
	N&O	The elephant found ten peanuts and then eight more peanuts and two ants. If the elephant eats three peanuts then eats two more peanuts, how many will be left?	How many peanuts left?	10, 8 3, 2	10+8= 18	18-3=15	15-2	13 peanuts
			Rationale for Operations	Nuts info	Total peanuts found	peanuts eaten	More peanuts eaten	
	ALGEBRA	There is a kangaroo trying to jump over a fence. Kangaroos have 2 ears. Each can jump 2 feet and 2 inches. How many total inches can it jump?	Total inches it can jump	2 ft. 2 in	1 ft. =12in	12+12 =24	24+2=26	26 in
			Rationale for Operations6	Kangaroo info	conversion	Two feet	Total inches	
	MEASUREMENT	An Orca whale sleeps for 5 hours each day and eats for 2 hours a day. Blue whales sleep for 3 hours a day. How many more hours does an orca sleep in two days compared to a blue whale?	Difference in hours between two days.	5 hrs., 3 hrs.	5+5	3+3	10-6	4 hours
			Rationale for Operations	Orcas 5 hrs., Blue 3 hrs.	Sum orca 2 days	Sum blue 2 days	difference	

SET 1 (1st grade)

	GROUP C (addition)						
	Word Problem	**Rationale for problem**	**Step 1**	**Step 2**	**Step 3**	**Step 4**	**Answer**
GEOMETRY	A tree branch is 1-meter long. There were four rose bushes nearby. There were four tree branches that were laying end to end in a square. What is the total length of the sides of the rectangle?	Length of the triangle sides	1m long	1+1=2	2+1=3	3+1=4	4m
		Rationale for Operations	Branch length	L & W	One L+W	Another L+W	
N&O	April wants to buy supplies for her pet parrot. She buys bird seed for $5.00, a cage for $10.00, shampoo for $5.00, and a water bottle for $5.00. A guinea pig wheel costs $3.00. How much did she spend in all?	Total cost	$5, $10, $5	$5 + $10= 15	$5 + 5= $10	$10+5=$15	$15
		Rationale for Operations	Parrot items	Sum of seed and cage	Sum of seed, cage, shampoo	Sum of seed, cage, shampoo, water	
ALGEBRA	A penguin is in Antarctica. One brown seal is on the ice. Two black seals come and sit on the ice. Two white seals sit down too. Three more black seals then come. How many seals all together?	Total seals	1, 2, 2, 3	1+2=3	3+2=5	5+3=8	8 seals
		Rationale for Operations	Number of seals	Brown and black seals	Brown, black, white seals	All seals	
MEASUREMENT	A baby bear weighs 10 pounds when it is born. A baby turtle weighs three pounds. A puppy weighs 5 pounds when it is born. A kitten weighs 2 pounds when it is born. A gorilla is 15 inches tall. How much do the baby animals weigh all together?	Total weight of baby animals	10, 3, 5, 2	10+3=13	13+5=18	18+2=20	20lbs.
		Rationale for Operations	Baby animal weight	Bear and turtle	Bear, turtle, and puppy	Bear, turtle, puppy, kitten	

SET 2 (1^{st} grade)

GROUP C (addition)							
	Word Problem	**Rationale for problem**	**Step 1**	**Step 2**	**Step 3**	**Step 4**	**Answer**
GEOMETRY	Sarah needed a fence. She purchased 2 gallons of milk at the store. She got one piece of wood that was 4 inches long, another piece of wood that was 2 inches long. She obtained another piece of wood that was 3 inches long, and one more piece of wood that was 2 inches long. What was the total length of the pieces of wood for the fence?	Total length	4 in, 2 in, 3 in, 2 in	4+2=6	3+2=5	6+5=11	11 in
		Rationale for Operations	L & W	Add lengths of wood	add three wood	total of four wood	
N&O	Shawna wants to buy supplies for her pet dog. She buys dog food for $2.00, a kennel for $10.00, shampoo for $5.00, and a water bowl for $5.00. A bird cage costs $3.00. How much did she spend in all?	Total cost	$2, $10, $5, $5	$2 + $10= 12	$5 + 5= $10	$12+5=$7	$22
		Rationale for Operations	Cost of items	total of two items	total of other items	Total cost	
ALGEBRA	A giraffe is in Africa. One brown hippo is near the watering hole. Four black hippos come and sit at the watering hole. Three white hippos sit down too. Three more black hippos then come. How many hippos all together?	Total animals	1, 4, 3, 3	1+4=5	3+3=6	6+5=11	11 hippos
		Rationale for Operations	Number of animals	Brown and black hippos	Brown, black, white hippos	All hippos	
MEASUREMENT	A baby cow weighs two pounds when it is born. A baby fox weighs three pounds. A baby kangaroo weighs six pounds when it is born. A kitten weighs two pounds when it is born. A gorilla is four feet tall. How much do the baby animals weigh all together?	Total weight of baby animals	2, 3, 6, 2	2+3=5	6+2=8	8+5=13	13 lbs.
		Rationale for Operations	Baby animal weight	Cow and fox	Kangaroo and kitten	All animals	

SET 3 (1st Grade)

GROUP C (addition)							
	Word Problem	**Rationale for problem**	**Step 1**	**Step 2**	**Step 3**	**Step 4**	**Answer**
GEOMETRY	Brandy needed a small wire garden fence. She purchased eight gallons of milk at the store. She got one piece of wire that was 8 inches long, another piece of wire that was 2 inches long. She obtained another piece of wire that was 4 inches long, and one more piece of wire that was 6 inches long. What was the total length of the pieces of wire for the fence?	Total length	8 in, 2 in, 4in, 6 in	8+2=10	4+6=10	10+10	20in
		Rationale for Operations	lengths	L & L	L+L	Add lengths	
N&O	Angela wants to buy party supplies for her mom's birthday. She buys party hats for $4.00, a cake for $5.00, ice cream for $5.00, and a piñata for $3.00. A cat food bowl costs $3.00. How much did she spend in all on party supplies?	Total cost	$4, $5, $5, $3	4+5=9	5+3=8	9+8=17	$17
		Rationale for Operations	Cost of items	Add hats and cake	Add ice cream and piñata	Total cost	
ALGEBRA	An octopus lives in the ocean. One sea anemone is near the coral. Five clown fish swim near the coral. Three sea sponges live near the coral. Four more clown fish then come to the coral. How many sea creatures came to the coral?	Total animals	1, 5, 3, 4	1+5=6	3+4=7	6+7=13	13 animals
		Rationale for Operations	Number of animals	Octopus and anemone	Fish and sponge	Total animals	
MEASUREMENT	A female elephant is ten feet tall. A male elephant is fifteen feet tall. A baby elephant is six feet tall. A young elephant is eight feet tall. A gorilla is ten feet tall. How tall would all the elephants be if they were stacked on top of each other?	Total height	10 ft., 15 ft., 6 ft., 8 ft.	10+15=25	6+8=14	25+14=39	39 ft.
		Rationale for Operations	heights	Female + male	Baby + young	Total height	

SET 4 (1st Grade)

GROUP C (addition)

	Word Problem	Rationale for problem	Step 1	Step 2	Step 3	Step 4	Answer
GEOMETRY	Erica needed to dig a hole for a pool. She purchased five juice boxes at the store. She dug one side that was 6 feet long, and another side was 6 feet long. She dug another side that was 4 feet long, and one more side that was 4 feet long. What was the total length of sides of the pool?	Total length	6, 6, 4, 4	6+6-12	4+4=8	12+8=20	20ft
		Rationale for Operations	lengths	L & L	One L+L	Add lengths	
N&O	River wants to buy groceries. She buys milk for $4.00, a ham for $8.00, paper towels for $3.00, and a carton of eggs for $3.00. A new car costs $300.00. How much did she spend in all on groceries?	Total cost	$4, $8, $3, $3	4+8=12	3+3=6	12+6=18	$18
		Rationale for Operations	Cost of items	Cost of Milk + ham	Cost of paper towels + eggs	Total cost	
ALGEBRA	A lizard came to sit on a rock in the sun. Two snakes slithered to the rock. Four iguanas crawled to the rock in the sun. Six cobras slithered to the rock too. A dog ran by the rock. How many reptiles were on the rock?	Total animals	1, 2, 4, 6	1+2=3	4+6=10	3+10=13	13 reptiles
		Rationale for Operations	Numbers of animals	Lizard and snakes	Iguanas and cobras	Total reptiles	
MEASUREMENT	A snail weighs one pound. A squid weighs fifteen pounds. An octopus weighs 20 pounds. A starfish weighs three pounds. A cheetah weighs forty pounds. How much do the sea animals weigh all together?	Total weight of baby animals	1, 15, 20, 3	1+15=16	20+3=23	16+23=39	39 lbs.
		Rationale for Operations	Weights of animals	Add snail and squid	Add octopus and starfish	Total weight	

SET 5 (1st Grade)

GROUP C (addition)

	Word Problem	Rationale for problem	Step 1	Step 2	Step 3	Step 4	Answer
GEOMETRY	Sandra needed to dig a hole for a garden. She ate three bananas. Sandra dug one side that was 5 feet long, and another side was 7 feet long. She dug another side that was 7 feet long, and one more side that was 5 feet long. What was the total length of sides of the garden?	Total length	5, 5, 7, 7	5+7=12	7+5=12	12+12	24 ft.
		Rationale for Operations	Lengths	Length + Length	Length + Length	Total length	
N&O	Becca wants to buy supplies for school. She buys pencils for $2.00, a notebook for $10.00, erasers for $3.00, and a backpack for $4.00. An ice cream cone costs$11.00. How much did she spend in all on groceries?	Total cost	$2, $10, $3, $4	2+10=12	3+4=7	12+7	$19
		Rationale for Operations	List of costs	Pencil + notebook	Erasers+ backpack	Total cost	
ALGEBRA	Two hippos came to the watering hole on the savannah. Four elephants came to drink at the watering hole. Five birds sat at the watering hole. A fish swam in the watering hole. If there were 15 total animals at the watering hole, how many antelope were there?	Total number of antelope	2+4=6	5+1=6	15-6=11	11-6=5	5 antelope
		Rationale for Operations	Hippos and elephants	Birds and fish	Subtract hippos and elephants	Subtract birds and fish	
MEASUREMENT	A frog weighs four pounds. A toad weighs five pounds. A salamander weighs three pounds. A newt weighs two pounds. A fish weighs eight pounds. How much do the amphibians weigh all together?	Total amphibian weight	4, 5, 3, 2	4+5 = 9	3+2= 5	5+9=14	14 lbs.
		Rationale for Operations	Amphibian weight	Frog and toad weight	Salamander and newt weight	Total weight	

INTERVENTION (1st Grade)

GROUP C INTERVENTION

	Word Problem	Rationale for problem	Step 1	Step 2	Step 3	Step 4	Answer
GEOMETRY	Ava needed to buy a fence for a garden. She purchased five pear seeds at the store. Ava bought one side of wire that was 5 feet long, and another side was 4 feet long. She bought another side that was 5 feet long, and one more side that was 4 feet long. What was the total length of sides of the garden?	Total length	5,5,4,4	5+4=9	5+4=9	9+9=18	18 ft.
		Rationale for Operations	Lengths	L + W	L + W	Total length	
N&O	Phoenix wants to buy supplies for the party. She buys soda for $5.00, cookies for $6.00, plates for $3.00, and streamers for $2.00. A new truck costs $500.00. How much did she spend in all on groceries?	Total cost	$4, $10, $6, $2	4+10=14	6+2=8	14+8=22	$22
		Rationale for Operations	Cost of items	Food and cage cost	Water bowl and toy cost	Total cost	
ALGEBRA	Two parrots flew to the tallest tree. Three mockingbirds also flew to the tree. Eight toucans also flew to the tree. Six macaws flew and sat on the highest branch. Two flying squirrels flew to the tree. How many birds were in the tree all together?	Total birds	2, 3, 8, 6	2+3=5	8+6=14	14+5=19	19 birds
		Rationale for Operations	Bird information	Parrots and mockingbirds	Toucans and macaws	Total birds	
MEASUREMENT	One tadpole weighs four ounces. Another tadpole weighs three ounces. Another tadpole weighs two ounces. The biggest tadpole weighs six ounces. How much do all the tadpoles weigh altogether?	Total weight of tadpoles	4, 3, 2, 6	4 + 3=7	2+6=8	7+8=15	15 oz.
		Rationale for Operations	Tadpole weights	First and second tadpole	Third and biggest tadpole	Total weight of tadpoles	