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Reading Strategies in Content Area Math

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This is to certify that the action research study by

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has been found to be complete and satisfactory in all respects,

and that any and all revisions as required by

CT Literacy Specialist Program have been made.

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Reading Strategies in Content Area Math

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Abstract

Since the introduction of the CCSS, expectations in math have placed greater responsibility for problem-solving on students. No longer is computation the primary focus of elementary math instruction; instead the goal has shifted to student understanding of the mathematical contexts. The aim of this action research study, guided by Vygotsky's theory of social constructivism, was to determine the effectiveness of integrating reading and content area math, while deepening students' skills in vocabulary, journaling, and visualizing. Nine fifth-grade students receiving Tier 2 math intervention were selected to participate in the study. Data collection consisted of pre and post measures including criterion-referenced math assessment in problem-solving, aligned with the common core. Results showed that from pre to posttesting participants' mean score increased from 68% correct to 80%, indicating that the integration of reading strategies into math content instruction is effective way for students to increase skill in word problem-solving.

Keywords: problem solving, word problems, vocabulary, visualizing, journaling

Table of Contents

List of Tables.

Section 1: Introduction to the Study……………………………………………………………5

Background of the Study……………………………………………………………………….5

Rationale………………………………………………………………………………………..6

Problem Statement……………………………………………………………………………...8

Solution…………………………………………………………………………………………9

Research Questions ……………………….…………………………………………………...9

Theoretical Framework…………………. …………………………………………………….10

Section 2: Review of Literature…………………………………………………….............12

Mathematics Instruction: Not Just About the Numbers………………………………………12

Linking Math and Literacy Instruction in the Field…………………………………………...13

Making Connections Between Math and Literacy Instruction………………………………..13

Dearth of Research Studies to Confirm the Effectiveness of Integrated Math and

Literacy………………………………………………………………………………………..14

Emphasis on Mathematics Vocabulary………………………………………………………..15

Cracking the Code…………………………………………………………………………….21

Comprehension Strategies: Visualizing, Sketching, Mental Modeling, Mathematics Circles,

Questioning and Journaling…………………………………………………………………...22

Conclusions…………………………………………………………………………………...24

Section 3: Methodology……………………………………………………………………....26

Participants…………………………………………………………………………………....26

Materials. …………………………………………………………………………………..…27

Procedure……………………………………………………………………………………...27

Section 4: Data Collection and Analysis ……………………………………………………..…29

Limitations of the Study…………………………………………………………………....…30

Section 5: Discussion, Recommendations and, Conclusions……………………………………31

Restatement of Research Questions……………………………………………………………...31

Practical Application of the Findings…………………………………………………………....32

References………………………………………………………………………………………..34

Appendix A……………………………………………………………………………………....38

Table

1……………………………………………………………………………………………....…39

Reading Strategies in Content Area Math

Section 1: Introduction to the Study

Mathematics has long been considered a subject area separated from literacy. In the past, mathematics education has focused on computational skills and procedural fluency. Additionally, in 2000, the inclusion of *communication* as a process strand in The National Council of Teachers of Mathematics' *Principles and Standards for School Mathematics* highlighted the need for students to explain their mathematical understanding both in written form and orally (Pierce & Fontaine, 2009). This shows that "doing mathematics is not just about manipulating numerals and symbols, but also about developing and sharing mathematical ideas through a variety of means that support deeper learning" (Lott Adams & McCoy Lowery, 2007, p.165). The development of the Common Core State Standards (CCSS) in 2010 further blurred the boundaries between mathematics and literacy instructional techniques. According to Friedland, McMillen and del Prado Hill (2011), "mathematics teachers should include a focus on reading and writing within their content area to ensure their students' ability to read and write in mathematics" (p. 57). With the adoption of the CCSS, mathematics teachers need to become proficient in literacy comprehension strategies and find ways to integrate literacy strategies into their content instruction.

Background

Since states' high-stakes mathematics tests include complex word problems (Pierce & Fontaine, 2008), mathematics instruction has moved much closer to literacy instruction. In addition to computation and procedural fluency, mathematics teachers are also required to help students learn to comprehend word problems written in a wide variety of contexts, using a range of complex vocabulary, and requiring specific background information. Students need to be able to evaluate novel situations to determine the correct operations to use. In short, students need to develop a deepened understanding of comprehension strategies including visualization, predicting, using text structure to determine meaning, questioning, connecting domain-specific vocabulary to known concepts, and making connections to other texts and situations (Massey & Riley, 2013) before they can use computational skills to solve a math problem. “Reading and mathematics also place a common priority on flexible strategy use. We want students to use strategies flexibly, coordinating and adjusting them in response to specific tasks” (Halladay & Neumann, 2012, p. 471). How can teachers best help students understand mathematics content and flexibly use a variety of strategies to problem solve? Incorporating reading strategies into mathematics instruction is the key to unlocking deeper mathematical understanding.

Rationale

Mathematics involves learning to decode a variety of symbols. Children need to learn mathematical symbols and numbers in the same way they learn letters and punctuation marks, through exposure over time and explicit instruction to help them connect concepts to the symbols. As letters can be confused by beginning readers (b, p, q), the addition sign can be confused with a lowercase “t” and the multiplication sign with a lowercase “x” (Hamilton, 2017). “Explicit instruction at this level of the code for math facilitates fluency and fluency matters” (Hamilton, 2017, p.48).

Once students have mastered the symbols for mathematics, they need research-based instruction in order understand the domain-specific vocabulary. Some terms are homophones with other non-mathematics words (sum/some) and others have different and specific meanings in the math domain (product, difference, plane) (Massey & Riley, 2013 & Hamilton, 2017) and still other words are specific to mathematics (addend, subtrahend, and quotient). Vocabulary strategies such as journal writing (Kostos & Shin, 2010) and a modified Frayer Model (Bruun, Diaz & Dykes, 2015) can be used in mathematics instruction to help students learn and internalize the meaning of mathematics vocabulary.

A Frayer Model is a graphic organizer in which the word is defined and illustrated. It includes a definition of the word, a description of its characteristics in addition to examples and nonexamples of the word. When teaching math vocabulary in the elementary grades, demonstration and manipulation are crucial. Students should hear, read, speak, see, write and manipulate math vocabulary (Fisher & Blachowicz, 2013) in order to obtain a conceptual understanding of the topic under study. "The depth and breadth of a child's mathematical vocabulary is more likely than ever to influence a child's success in math." (Pierce & Fontaine, 2009, p. 239).

When students can understand the symbols and vocabulary of mathematics, they are ready to move on to the complex task of understanding the context in mathematics-related texts including word problems. Just like when learning to comprehend literary texts, students need to access a variety of background information. Sometimes students ignore the words in word problems and focus on the numbers or look for clue words to figure out the operations to use. However, without understanding the context of the problem, they are not always able to accurately solve it. "To comprehend text, good readers engage in mental processes before, during and after they read," (Foster, 2007, p.197) whether the texts are stories or word problems, the strategies to comprehend are the same. Using visualization strategies such as sketching, discussing and writing help students understand the context in word problems. Students can explore open-ended problems in small-group mathematics circles, analogous to literature circles (Kirdler & Moyer-Packenham, 2008).

Problem

The results from the 2017 administration of Connecticut's Smarter Balanced math assessment show that statewide, only 45.6% of students met or exceeded the standards (Connecticut State Department of Education, 2017). Connecticut is not alone is this problem. Nationwide, only 40% of fourth graders performed at or above the third level, known as the *Proficient* level on the NAEP math assessment in 2015, which means that students have demonstrated mastery of a particular skill. This was a statistically significant decrease from 42% at or above the "Proficient" level in 2013. Looking even further back, the percentage of students at or above the "Proficient" level has remained stagnant for the past 10 years (National Association of Educational Progress, 2015). The inception of the common core state standards, CCSS, in 2010 was a direct response to unchanged scores on national and international math assessments (Hamilton, 2017); however, it is clear from the data that merely making the math standards more comprehensive and challenging has not increased student achievement. Standards for mathematical understanding have been raised, but student achievement has not followed. How can teachers develop practices that yield increased achievement and understanding in the math? The grim truth is that teachers have not acquired research-based practices that have advanced student achievement in math.

Solution

In order to accommodate the CCSS and its increased emphasis on problem solving, collaborative mathematical work and the expectation of students across all grade levels to explain mathematical thinking in writing, mathematics instruction needs to incorporate aspects of literacy instruction. One way for teachers to capitalize on similarities between literacy and math instruction is to employ reading comprehension strategies in the teaching of problem solving in mathematics. (Halladay & Neumann, 2012). Teachers want to find ways to help their students meet standards and to develop mathematical skills in reasoning, problem solving and communication. This mirrors goals that teachers have for students in the literacy content area. (Minton, 2007).

Teachers in an elementary school serving students in grades 3-5 in suburban New England are no exception to this trend. Literacy instruction is separate from mathematics instruction, with each subject scheduled during different blocks of the school day. Teachers want to find ways to enhance their mathematical instruction and improve student understanding. Incorporating reading comprehension and vocabulary strategies into math content area instruction is one way to achieve the goal (Halladay & Neumann, 2012; Edwards, Maloy & Anderson, 2017; Hamilton, 2017; Friedland, McMillen & del Prado Hill, 2011). The study will look as the effects of incorporating reading strategies into math instruction through several research questions.

Research Questions

1. How does the direct linking of reading comprehension strategies to the math content area impact elementary students' math problem solving abilities?

2. How does the use of explicit vocabulary instruction in the math content area impact elementary students math problem solving capabilities?
3. What is students' self-efficacy about their math abilities following their exposure to reading comprehension strategies in the math content area?

Theoretical Framework

Mathematical thinking involves more than just numbers. Children need chances to construct meaning as they work to understand the context of problems. "When students read mathematics-related text, they are able to visualize ways in which math plays an important role in the everyday workings of the world" (Wallace, Evans & Stein, 2011, p.156).

Vygotsky's (1978) work on social constructivism will undergird the learning theory, particularly his zone of proximal development, in which students are capable of learning concepts just outside their current capabilities through support, modeling, and scaffolding of teachers and more advanced peers, guides the learning theory for this paper. Additionally, he developed the theory of the zone of proximal development in which students can learn concepts just outside their current capabilities through the support, modeling and scaffolding of teachers and more advanced peers (Vygotsky, 1978).

Bruner's theory of learning (1961) introduced the idea that children learn best when working in groups and are able to learn from each other. Children should be able to explore mathematical concepts and problems through group work and share their ideas with peers to discover efficient ways to problem solve (Bruner, 1961). Teachers need to share their own mathematical thinking explicitly through metacognitive modeling for students and to scaffold new learning onto previously mastered concepts (Vygotsky, 1978). When students apply strategies typically used for reading comprehension when learning math, they can construct and find connections between the content area of math and what they experience around them.

Section 2: Review of Literature

Mathematics Instruction: Not Just All About the Numbers

Much time and research has been spent on developing strategies and pedagogy to help children learn to become better readers. However, when the parameters are expanded to encompass content area math, the scope of the learning includes skills that are common to both math and literacy, such as making predictions, monitoring for understanding, making connections, and using strategies flexibly (Halladay & Neumann, 2012). Mathematics teachers need to recognize that they are also teachers of reading and that their students would benefit from the inclusion of literacy strategies, such as robust vocabulary instruction and questioning to activate prior knowledge, in day-to-day teaching (Carter & Dean, 2006; Pierce & Fontaine, 2009).

Mathematics instruction has developed into much more than merely teaching children the rote number skills of the past. Now "students are presented with words and context packed around numbers," (Friedland, McMillen & del Prado Hill, 2011). The National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (NCTM, 2000), and the CCSS have helped to increase rigor by moving mathematics instruction away from a focus on computational skills and instead towards fostering a deeper understanding of mathematical thinking and the ability to demonstrate mathematical thinking both orally and in writing (Kostos & Shin, 2010; Pierce & Fontaine, 2009). The emphasis on the ability of children to communicate mathematical understanding is a requirement of high stakes testing (Kostos & Shin, 2010). Math teachers need to start looking at mathematics instruction through a reading lens (Hamilton, 2017) if they are to help students meet rigorous mathematical expectations. Teachers not only need literacy comprehension and vocabulary strategies that have been adapted for mathematics instruction, they also need guidance in order to effectively implement them.

Linking Math and Literacy Instruction in the Field

The recent literature in this topic is divided into two broad categories. The first category consists of case studies and action research projects. In these articles, mathematics educators, for a variety of different reasons, have an awakening, which propels them to try a reading strategy in their own classrooms with positive results (Kridler & Moyer Packenham, 2008; Foster, 2007; Kostos & Shin, 2010; Bruun, Diaz & Dykes, 2015; Edwards, Maloy & Anderson, 2009). Sometimes the epiphany is born out of desperation. When math students are struggling, their teachers address their mathematical needs with the literacy tools and strategies-at-hand.

Other times the realizations are the result of collaboration with a coach or mentor teacher and the careful consideration of available literacy strategies. The literacy strategies employed vary greatly, ranging from journal writing to explicit vocabulary instruction, to using pictures to help students visualize word problems.

Making Connections Between Math and Literacy Instruction

The majority of the articles on the topic fit into a second category: an examination of the similarities between teaching mathematics and literacy. The articles highlight the changes in mathematics instruction, especially the moving away from teaching mathematics skills in isolation and shifting pedagogical emphasis to a context and comprehension-driven subject (Edwards, Maloy & Anderson, 2009; Wallach, Evans & Stein, 2011; Smith & Angotti, 2012; Halladay & Neumann, 2012; Kovarik, 2010; Friedland, McMillen & del Prado Hill, 2011). The focus of the literature is to provide practical reading strategies that can be utilized in meaningful and productive ways to further mathematical understanding, developed to help teachers make the connection between math and literacy instruction, which have been adapted to assist in mathematical instruction. Thus, time-tested strategies, rather than research-based methodology is presented as an effective alternative to encourage teachers to integrate literacy and mathematics, and to find connections between numeracy and literacy as content areas in the curriculum (Dietiker, 2013) .

Dearth of Research Studies to Confirm the Effectiveness of Integrated Math and Literacy

Missing from the recent literature on the topic are rigorous research studies that encompass large numbers of students and their mathematical achievement over an extended period of time (Freidland, McMillen & del Prado Hill, 2011). Do the reading strategies suggested in the literature truly help to improve student understanding of math vocabulary and word problems? This gap between research-based methodology suggested strategies and student outcomes is a major concern with math infusion into literacy. It seems intuitive to integrate reading and mathematics, but the evidence to substantiate the assertion that an integrated math-literacy approach is the most effective way to increase student achievement is less convincing in the corpus of research (Freidland, McMillen & del Prado Hill, 2011). In fact, the "apparent paucity of articles that are based on empirical studies," (Friedland, McMillen & del Prado Hill, 2011, p. 62) affirms the need for the topic of math and literacy to be included on researchers'agendas.

The review of literature will focus on the available case studies and reviews to synthesize literacy strategies and to delineate a plan for integrating literacy strategies into the math content area. Literacy strategies that focus on strengthening content-area vocabulary are cited most often as being helpful in the mathematics classroom. While the available case studies have small sample sizes, they are from peer-reviewed journals, which strengthen the expectation that the findings contain positive implications for practitioners. The review of literature will highlight what has been working and what has the potential to work in diverse classrooms.

Emphasis on Mathematics Vocabulary

Intentionally teaching specific mathematics vocabulary is overwhelmingly the most recommended and field-tested strategy in the literature. Carter & Dean (2006), found that by far the most prevalent reading strategies math teachers used involved vocabulary. The researchers listened to 72 audiotaped math lessons from eight graduate-student instructors in a summer mathematics clinic for students in grades 5-11 who were unaware that their math lessons were going to be analyzed for the extent to which the lessons included instruction in literacy. Researchers found that the math instructors taught vocabulary strategies in 70/101 instances of reading instruction. The finding demonstrates that math instructors teach vocabulary during math lessons. However, mathematics teachers must assure that research-based principles for vocabulary instruction are incorporated into lessons (Pierce & Fontaine, 2009) to assure that students meet rigorous standards and firmly understand mathematical content.

The instructors designed many lessons around mathematics vocabulary, indicating that they knew the importance of direct vocabulary instruction in the content areas. This follows the National Reading Panel's (2000) finding that "learning vocabulary through context is an important skill, but that direct vocabulary instruction greatly improves both vocabulary knowledge and comprehension." The lessons most often consisted of an activity in which involved students built a mathematical definition from a vague notion into a precise definition through exploration and teacher questioning (Carter & Dean, 2006).

Vocabulary instruction in math gained increased importance with the advent of high-stakes math tests which contain content vocabulary words that can be difficult for students to understand without prior experience (Pierce & Fontaine, 2009). Munrow and Panchyshn (1995) determined that such tests contained two types of math vocabulary, technical and subtechnical (as cited in Pierce & Fontaine, 2009, p.240). Technical words, also known as tier 3 or content-specific words, are ones that have a specific mathematical meaning and must be taught to students explicitly (Pierce & Fontaine, 2009). For example, words such as isosceles or perpendicular are technical math vocabulary words (Pierce & Fontaine, 2009). Teachers may have an understanding that technical words must be taught explicitly, however, it is less obvious that subtechnical words also must be explicitly taught (Pierce & Fontaine, 2009).

Subtechnical words are also known as tier 2 words and have different meanings in the math content area than in regular daily usage or other content areas (Pierce & Fontaine, 2009). Some examples of subtechnical words are table and mean. Given their multiple meanings, these words can be especially difficult for students to understand. (Pierce & Fontaine, 2009). Vocabulary instruction is necessary to understand subtechnical words in a mathematical context such as standardized tests (Pierce & Fontaine, 2009).

Pierce and Fontaine (2009) maintained that the best methods of teaching math vocabulary, especially the subtechnical words, involves following the recommendations of Isabel Beck and her colleagues (2002). “This includes offering student-friendly definitions of math terms, encouraging deep processing of word meanings, providing extended opportunities to encounter words and enriching the verbal environment of the mathematics classroom," (Pierce & Fontaine, 2009, p.241). Pierce and Fontaine (2009) include a vignette that illustrates the progression of vocabulary lessons for the subtechnical word, "true." First, the class brainstormed and developed a common definition of the word "true." Next, the students were given the mathematical definition as well as time to explore that mathematical definition. Finally, the children delved into the definition with hands-on activities involving number balances (Pierce & Fontaine, 2009).

Bruun, Diaz and Dykes (2015) also explored the use of reading vocabulary strategies to foster an understanding of both technical and subtechnical mathematics vocabulary in elementary students. The research explored two proven ways to improve vocabulary learning: using a modified Frayer model (Hamilton, 2017) and journal writing (Bruun, Diaz & Dykes, 2015). In one fourth-grade classroom, students copied standard definitions for a math "word of the day" and then added a personal illustration of the word and provided examples and non-examples (Bruun, Diaz & Dykes, 2015). In a second classroom, the teacher directed the class to record a traditional definition of a math vocabulary word in journals. The students combined the definition and background knowledge, wrote about understandings of new vocabulary word and shared their ideas through a "turn and talk" activity with a peer (Bruun, Diaz & Dyles, 2015).

At the end of the month-long study, Bruun, Diaz and Dykes (2015) compared student vocabulary knowledge on pre and post-tests, noting increased student achievement in both classrooms. However, the researchers noted that the journal writing strategy was not as successful with English Learners and that in both classrooms enthusiasm waned over the course of the study (Bruun, Diaz and Dykes, 2015). Bruun, Diaz and Dykes (2015) recommended varying the vocabulary strategies to increase engagement.

Hamilton (2017) also suggested the use of graphic organizers to explicitly teach math vocabulary, especially those subtechnical words that have multiple meanings outside of the math domain. The use of graphic organizers can help students improve their understanding of challenging math vocabulary (Hamilton, 2017). For example, a graphic organizer featuring the subtechnical word “plot” could consist of four quadrants (See Appendix A). Students record different definitions of the various uses of the word in each section, accompanied by a relevant illustration to help “students visualize the differences and identify with its use in a mathematical context,” (Hamilton, 2017, p.48). In order to help solidify understanding, students then write sentences demonstrating the different meanings and solve riddles involving the vocabulary to extend their thinking (Hamilton, 2017).

Edwards, Maloy, and Anderson (2009) addressed vocabulary instruction by suggesting that reading coaches can play a vital role in supporting mathematics teachers by providing vocabulary strategies to help solve word problems. Unfamiliar vocabulary causes difficulty in solving math word problems (Edwards, Maloy & Anderson, 2009). The authors recommended having students skip over unfamiliar words and attempting to make meaning with the remaining words (Edwards, Maloy & Anderson, 2009), which has the potential to work for certain problems where the context is not integral to the actual math procedures required to solve it. For example, Edwards, Maloy and Anderson (2009) utilized an example which involved determining the numbers of laps a child swam on 28 consecutive days. Though lacking background knowledge about swimming laps, a student could find that multiplication is the correct operation for the problem (Edwards, Maloy & Anderson, 2009).

However, when content-specific words are included in math word problems, reading coaches should help math teachers purposefully and directly teach the vocabulary to the students (Edwards, Maloy & Anderson, 2009). Edwards, Maloy and Anderson (2009) suggested that students develop and produce their own reminder placemats or posters for math-specific vocabulary words. Memory aids included the mathematical terms needed to solve word problems with definitions, examples and illustrations. Songs and skits can also help children learn vocabulary words (Edwards, Maloy & Anderson, 2009).

Fisher and Blachowicz (2013) highlighted the best practices for teaching mathematics vocabulary, emphasizing that mathematics vocabulary is different from vocabulary in other subject areas, since math vocabulary definitions can best be visualized through pictures and physical models. Moreover, math terms are often defined through other math vocabulary (Fisher & Blachowicz, 2013). For example, a right angle is understood through comparison to other types of angles. Additionally, math vocabulary should be revisited multiple times to ensure that words are understood and retained (Fisher & Blachowicz, 2013). Further, multimodal experiences connect learners with the concepts, such as using bodies to create angles, drawing and measuring angles with protractors and discussing angles with peers using the new mathematical terms (Fisher & Blachowicz, 2013).

Fisher and Blachowicz (2013) also recommended directly teaching morphemes commonly featured in math vocabulary because as students learn the roots, prefixes and suffixes, their understanding of this vocabulary increases. The researchers state that practicing decomposing words by taking whole vocabulary words and examining their component parts is one effective way to learn new math vocabulary (Fisher & Blachowicz, 2013). Additionally, Fisher and Blachowicz (2013) also suggest that students combine morphemes to build words and use word ladders to build word families with the same affixes.

Smith and Angotti (2012) suggested a framework to help teachers thoughtfully and intentionally select and plan lessons using content-area vocabulary words. The 5 Cs (Concepts, Content, Clarify, Cut, and Construct) tool is based on research that shows that students learn new words by connecting them to known facts and ideas, (Smith & Angotti, 2012). “Concepts” refers to teachers focusing on the mathematical concepts in a lesson, especially words that are domain-specific and new to the students or words that have multiple meanings. “Content” asks teachers to identify subject-matter words that are not specifically math concepts, but rather other words that might be new to the students. The next steps guide teachers through the use the words selected during the previous two steps. Teachers can simply “clarify” words that are not crucial to the main concepts of the lesson and they can “cut” words that are too complex and might derail student learning. Finally teachers can “construct” a short list of words to teach explicitly, focusing on the final list of words for use in a variety of meaningful activities connecting the new words to previously learned concepts (Smith & Angotti, 2012).

Kostos and Shin’s action research project (2010) explored the use of math journals to enhance students’ mathematical understanding and vocabulary comprehension. Students in a second grade classroom were given math journals and the opportunity to respond to mathematical prompts over the course of five weeks. The teacher anecdotally noticed that students used more precise examples of math vocabulary as they had more opportunities to express their mathematical thinking in writing (Kostos & Shin, 2010). The students themselves recognized that usage of math vocabulary and understanding increased through journal writing. One student who participated in the study summed it up well, saying "I understand them more because I use them more," (Kostos & Shin, 2010, p.229).

The studies all have a similar theme: that vocabulary instruction in the mathematics content area is vitally important. The literature confirms the need for teachers to address students' mathematical vocabulary deficiencies in specific and thoughtful ways. It is not enough to indirectly teach math vocabulary, nor to address it sporadically. Mathematics vocabulary instruction should be the construct of careful planning, giving children time to connect the math vocabulary to prior learning and chances to explore the concepts with hands-on experiences, in writing, through drawing, and with peers (Carter & Dean, 2006; Pierce & Fontaine, 2009; Bruun, Diaz & Dykes, 2015; Hamilton, 2017; Edwards, Maloy & Anderson, 2009; Fisher & Blachowicz, 2013; Smith & Angotti, 2012; Kostos & Shin, 2010).

Cracking the Code

Reading the language of mathematics involves more than just decoding words. Mathematics has its own set of symbols that children need to learn in order to successfully problem solve, (Hamilton, 2017). Math students need to simultaneously decode letters to understand words, while also having to understand the meaning of mathematical symbols and numbers, which are often embedded within words. "Teachers need to remember that math is a unique and challenging language comprised of sophisticated words, concepts, and symbols," (Hamilton, 2017, p. 51).

Adding to the complexity, numbers can be represented by both symbols and words (Hamilton, 2017). The symbols that mathematicians use can be visually similar, for example the plus sign for addition is similar to the line and dots of the division symbol and the plus sign becomes the multiplication sign when it is placed on its side (Hamilton, 2017). Students face a multi-level decoding process when they encounter mathematical symbols, (Kenney *et al*., 2007). Readers of mathematics must first recognize the symbol, then associate the symbol with a word and finally connect the word to a mathematical concept. Carter and Dean (2006) found only two examples of decoding instruction in the 72 lessons of the study, suggesting that teaching decoding in the math content area is an underused strategy.

To address the intricacies of reading mathematics texts, Hamilton (2017) recommends that teachers follow the National Reading Panel's recommendations in 2000 by carefully examining "the discrete nature of these symbols and the building blocks of words," (p. 47). In reading, the knowledge of sound-symbol relationships is the foundation for decoding and then automaticity and comprehension. Likewise, in mathematics, an understanding of mathematical symbols sets the stage for comprehension of word problems and fluency in solving them, (Hamilton, 2017).

Starting in the primary grades, the explicit instruction of the words associated with mathematical symbols and practice of the pronunciation of those words helps children with their mathematical fluency, (Hamilton, 2017).

Comprehension Strategies: Visualizing, Sketching, Mental Modeling, Mathematics Circles, Questioning and Journaling

In order to understand word problems and logically solve them, mathematics students can borrow from several reading comprehension strategies. Foster (2007) described a math comprehension situation in her fourth grade classroom through her action research project. The students had all failed to understand a word problem on a class assessment and were unable to solve it. The researcher utilized the previously taught reading comprehension of visualization as a bridge to connect mathematical problems with understanding. Through mental modeling, Foster (2007) worked through the problem on the board with a continuous commentary of her thinking. As the mental processes became explicit, sketching was added to show a visual representation of the problem. The class then practiced problem solving and sketching in pairs and independently, using the visualization strategy first introduced in reading to successfully solve math word problems (Foster, 2007).

Kridler and Moyer-Packenham (2008) used another reading strategy successfully in a mathematics classroom. In order to keep students engaged in math problem solving and to encourage oral communication about mathematics, Kridler borrowed the classic literature circles from literacy classes and implemented them in her mathematics classroom. The students in each mathematics circle had defined roles (such as “vocabulary master,” “computation kid,” or “model maker”) that were integral to solving the problem and the group worked together to develop ideas for a solution, discussing many before selecting one to record. As in literature circles, the mathematics circles encourage student discourse and responsibility to fulfill a given role and engagement (Kridler & Moyer-Packenham, 2008).

Hamilton (2017) described questioning techniques to deepen understanding. Rather than asking students direct questions with single answers, the researcher suggested using open-ended questions that require critical thinking. Math journals provide students a place to share thinking, practice using specific mathematics vocabulary in context and sketch to deepen understanding, (Hamilton, 2017). Students can also use the math journals to describe the information they learn from graphs and charts, (Hamilton, 2017).

Conclusions

The literature around the topic coalesced into several areas of focus. The largest section of the research revolved around the importance of teaching mathematics vocabulary explicitly and intentionally to help maximize student understanding of word problems. In order for children to successfully problem solve, they need to know mathematics vocabulary, both technical, content-specific words, in addition to more general, subtechnical words that have different meanings in different contexts (Pierce & Fontaine, 2009). Additionally, teaching math symbols directly, especially in the younger grades, was an important step to helping children become fluent math readers, (Hamilton, 2017). Finally, comprehension strategies borrowed from the literacy realm also show promise in helping students to understand and solve word problems. Visualizing and sketching helped students better understand the context of the word problems and isolate the relevant information (Foster, 2007). Math journals provided a place for sharing mathematical thinking and mathematics circles gave students chances to share their ideas with peers, (Kridler & Moyer-Packenham, 2008). Teacher "think alouds" provided modeling in comprehension strategies and open-ended questions gave students the opportunity to stretch their thinking by digging deeper into the math of the problems, (Hamilton, 2017).

The literature does not contain any large-scale studies of the effectiveness of reading strategies in the math content area, rather the research consists of small explorations and action research studies. Given the preponderance of literature that focuses on math vocabulary, it is clear that successful mathematics teachers need to find ways to teach specific content-area terms in order to help their students understand math word problems that are so prevalent on high-stakes testing (Carter & Dean, 2006; Pierce & Fontaine, 2009; Bruun, Diaz & Dykes, 2015; Hamilton, 2017; Edwards, Maloy, & Anderson, 2009; Fisher & Blachowicz, 2013; Smith & Angotti, 2012; Kostos & Shin, 2010). Teachers also need to explicitly teach the math symbols to help children become fluent math readers (Hamilton, 2017, Kenney *et al*., 2007; Carter & Dean, 2006). A wide variety of reading comprehension strategies also has the potential to improve student understanding of math word problems (Foster, 2007; Kridler & Moyer-Packenham, 2008; Hamilton, 2017).

Section 3: Methodology

The purpose of the action research project was to verify the importance of incorporating reading strategies into the mathematics content area. Through the integration of vocabulary and reading comprehension strategies in small-group math intervention instruction with elementary school students, the research examined the effectiveness of specific reading strategies to improve scores on a criterion-referenced math test. The goal of the research was to provide both classroom and math intervention teachers with readily-available, accessible ideas for incorporating reading strategies into mathematics instruction.

Participants

Nine students in fifth grade participated in the pilot study through convenience sampling. The small size of the sample is adequate to meet my primary purpose of informing my own instructional decisions as a math interventionist, although the sample is not extensive enough to draw conclusions across a large scale. If I were successful, then I would have the ability to provide staff training in my district and would be able to attempt the study with a larger size sample at a future time.

Each of the students had been identified as at-risk in math through universal district assessments administered at the beginning of the 2017-2018 school year. The participants scored below the 35th percentile, indicating that they were on track to perform below the proficient level on the Smarter Balanced Assessment (SBA) state assessment. Students received Tier II or Tier III math support, delivered in a small group through daily pull-out instruction for an average of 38 minutes per day.

Participants attended a 3-5 elementary school with a student body of approximately 971 children (CSDE, 2017). Eighty-one percent of the students were white and fewer than 1% of students were designated English Learners (ELs). SBA results from the 2015-2016 school year indicated that 67% of students in the school scored at the goal level 3 or higher for math.

Materials

At the beginning of the action research project, students were assessed with the Math Navigator Common Core pretest for the Using Operations to Solve Problems module, a criterion-referenced test measuring students' ability to solve one and two-step word problems using one or more of the four basic operations: addition, subtraction, multiplication and division, that comprises part of the district's assessment system for math. The Math Navigator Common Core pretest for Using Operations to Solve Problems module is an untimed test, consisting of twenty-five multiple-choice questions in which mastery is attained with a score of 80% or greater, and proficiency is measured through pre and posttest gains.

Procedure

Participants received intervention services daily for an average duration of 38 minutes over the course of an eight-week period. Research-based reading strategies were incorporated into the mathematics intervention instruction. Weekly lessons focused on the explicit instruction of mathematics vocabulary using a modified Frayer model, in which new vocabulary words were recorded along with a student-created illustration, examples, and non-examples (Bruun, Diaz and Dykes, 2015; Hamilton, 2017). Vocabulary words included both content-specific terms as well as subtechnical words having different meanings in the math-content area from other contexts.

The graphic organizers were shared with classmates and then displayed in the intervention classroom for reference.

Mental modeling, visualizing, sketching,and journaling were also focuses for lessons (Foster, 2007; Bruun, Diaz and Dykes, 2015; Hamilton, 2017). As a facilitator, I incorporated mental modeling, visualizing, and sketching into daily instruction, in addition to the students' use of journaling. Woven throughout the lessons, I explicitly modeled thinking, sketching and visualization for a variety of problem solving activities, including one and two-step word problems which incorporated all of the basic mathematical operations. After exposure to mental modeling, visualizing and sketching, students then repeatedly practiced the strategies independently and with partners as they solved problems, reflecting on mathematical understandings on journal pages after completing activities.

Administration of the Math Navigator Common Core posttest for the Using Operations to Solve Problems module at the end of the study revealed the extent to which students increased their skill in the ability to solve one and two-step word problems.

Section 4: Data Collection and Analysis

In order to assess the effectiveness of adding reading strategies to math instruction, I administered the Math Navigator Common Core pretest for the Using Operations to Solve Problems module, a criterion- referenced test. At the end of the eight week instructional cycle, I administered the Math Navigator Common Core postest for the Using Operations to Solve Problems module, comparing the differences in the percentage correct from pre to post-testing.

Nine students participated in the study. Data from the Math Navigator Using Operations to Solve Problems module pretest shows a range of scores from a low of 48% correct to a high of 84% correct, with a mean score of 68% correct. The posttest data has a range of 48% correct to 96% correct with a mean score of 80%, which is exactly the mastery level of 80%. From pre to posttesting the average score increased by 14 percentage points.

Results from posttesting (see Table 1) show an increase in percentage correct for 78% (n=7) of students sampled, while 11% (n=1) of students decreased percentage correct and 11% (n=1) remained unchanged from pre to posttesting. At pretesting only 11% (n=1) of students were at or above the mastery level of 80%. However, at posttesting, 78% (n=7) of students tested at or above the mastery level. These results demonstrate the effectiveness of incorporating reading strategies, including explicit vocabulary instruction, modeling, visualizing and journaling, to improve students' understanding and ability to solve one-step and two-step word problems involving all four operations.

Interestingly, the two students who had the lowest scores at pre-testing (students 3 and 4) made the most significant gains at post-testing, increasing their scores from 52% to 80% and from 48% to 88% respectively, with both students moving from well-below mastery to mastery levels. Students who started with more robust scores at pre-testing showed more modest gains at post-testing; for example, students 2 and 9 each increased from 76% to 84% and student 8 increased from 72% to 80%. The data indicate that students who struggle the most with comprehension of word problems might be the most in need of incorporating reading strategies into the math content area, with the explicit connections between the two content areas the key to helping them unlock the understanding of complex word problems.

Limitations of the Study

Although 7/9 students exhibited gains from pre to posttesting, the limited number of participants (n=9) and the RTI status of the students must be considered when making general statements about the performance of the group, and whether the results are applicable to average or above-average students. Additionally, there was no control for comparison. Gains from pre to posttesting may not be attributable solely to the instruction delivered in this study as other factors may have influenced student performance as well. Coincidentally, during the study's duration, classroom math teachers started a district-developed unit of study focused on test preparation skills for the upcoming SBA assessment. The use of these strategies might have positively impacted students' scores on the Math Navigator posttest. Outside factors, such as the large number of snow days during the study's duration, may have also negatively impacted or muted the students' posttest scores since instruction was interrupted for many days.

Section 5: Discussion, Recommendations and Conclusions

Since the adoption of the common core standards, mathematics teachers have the added responsibility of teaching children not only computation, but also how to read and write in mathematics (Friedland, McMillen & del Prado Hill, 2011). Additionally, high-stakes standardized testing introduced “a new kind of problem that required the ability to read and write while demonstrating knowledge of mathematics concepts and skills” (Friedland, McMillen & del Prado Hill, 2011, p.57). These new problems are not focused on computation alone; rather, they require students to understand the context of the problems in order to find a solution. (Friedland, McMillen & del Prado Hill, 2011; Pierce & Fontaine, 2009). Consequently three research questions guided the implementation of the study, which focused on effective ways to integrate the use of reading strategies in the math content area.

Restatement of Research Questions

As I delved further into the implementation of the study, I noticed that my first two research questions, “ How does the direct linking of reading comprehension strategies to the math content area impact elementary students’ math problem solving abilities?” and “How does the use of explicit vocabulary instruction in the math content area impact elementary students’ math problem solving capabilities?” were inextricably connected. While my instruction featured a number of reading strategies, including journaling, visualizing, and mental modeling, the primary focus of my lessons was vocabulary instruction. Helping students acquire an understanding of technical mathematics vocabulary was crucial to problem solving success (Pierce & Fontaine, 2009). Though different reading strategies were used with the students, the incorporation of each strategy presumed on students’ understanding of mathematics vocabulary, especially in their journaling activities and mental modeling. Without a strong mathematics vocabulary; understanding, solving and writing about math problems would only have been partly effective (Kovarik, 2010). Consistent with prior research, I found that strategy instruction in content area math had a positive impact on their math problem solving abilities (Gifford & Gore, 2008; Pierce & Fontaine, 2009; Korarik, 2010; Bruun, Diaz & Dykes, 2015).

My final question, “What is students’ self-efficacy about their math abilities following their exposure to reading comprehension strategies in the math content area?” focused on students’ attitudes and behaviors towards math problem solving. While I did not explicitly measure changes in student attitudes before and after learning to apply reading strategies in the math content area, anecdotal notes reflected increased student engagement while solving word problems. For instance, one student was excited to notice the word “perimeter” when it appeared in a practice problem several days after discussion of the word during a lesson. She was proud to understand the word and correctly solved the problem.

Practical Application of the Findings

The action research study sampled only a small group of fifth-grade students, so the findings may not be generalizable to other grades or students. Future studies should be conducted with larger samples of students across different grades, socio-economic groups, disparate geographic areas, and with varying levels of mathematical achievement in order to determine if the findings from the study are relevant across a larger population. Having a control group for comparison would also help to verify the results of the study.

Further, the study omitted the use of quantitative data on students’ self-efficacy in math. Future research should include a self-reflection component for students to complete before and after the additional instruction to determine whether increased vocabulary knowledge directly correlates with increased self-confidence in this academic area.

I shared my research findings at Sacred Heart University's annual Literacy Conference in April, 2018 and additionally published the study on the university's Digital Commons, affording the public online access to the research. Plans to share my findings with my peers in my school district in an effort to better incorporate reading strategies in the math content area are in place for the near future.

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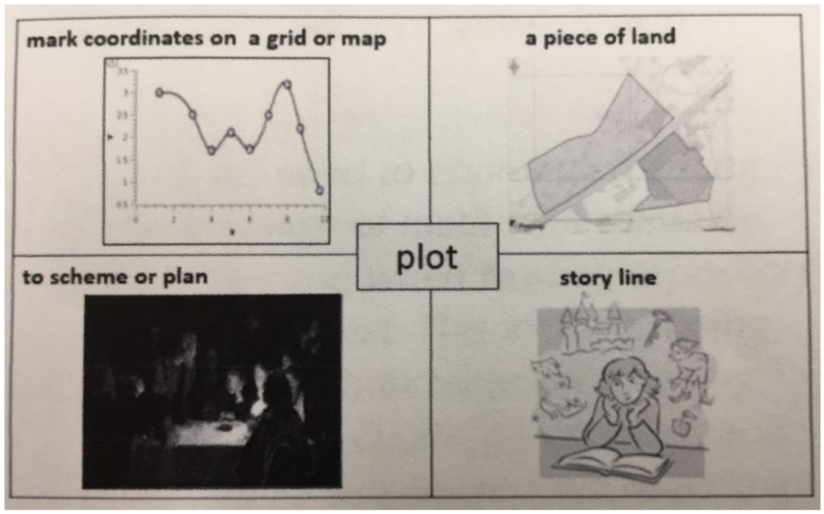
Appendix A

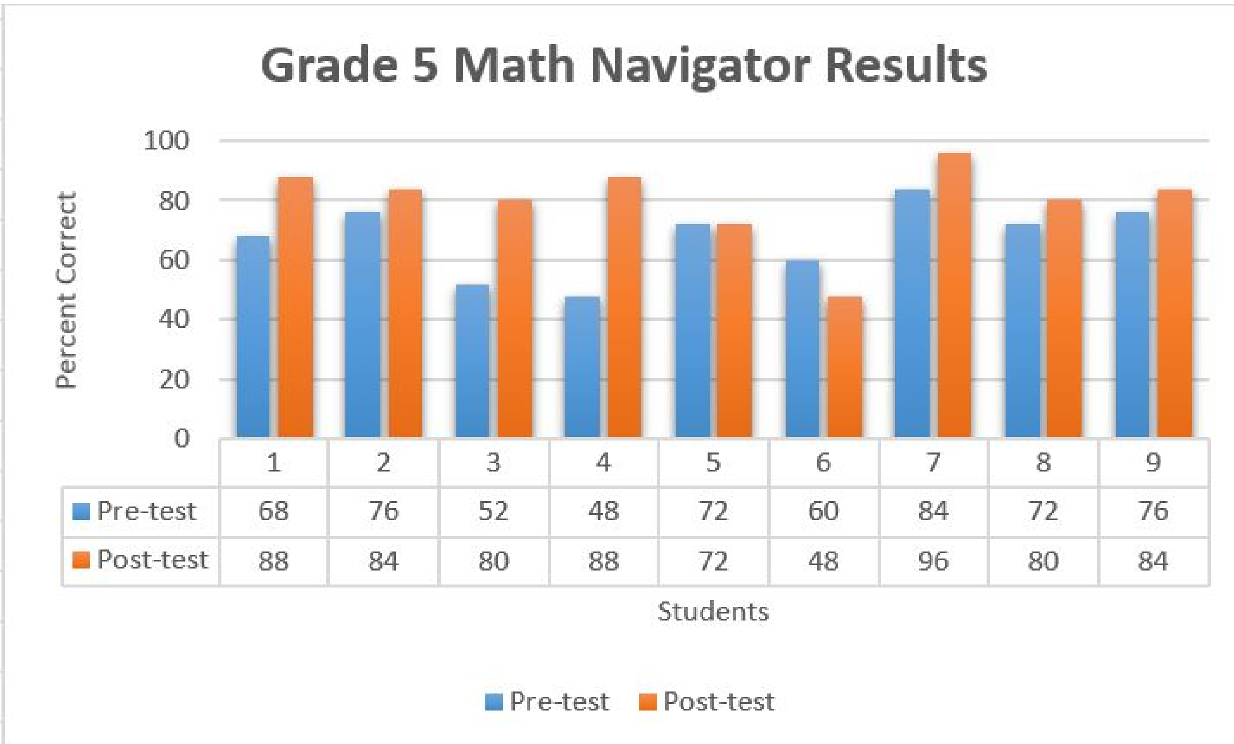
Graphic Organizer for Subtechnical Words



(Hamilton, 2017, p.48)

Table 1

Pre and Posttest Results for Math Navigator Assessment



	1	2	3	4	5	6	7	8	9
Pre-test	68	76	52	48	72	60	84	72	76
Post-test	88	84	80	88	72	48	96	80	84