LITERACY INSTRUCTION IN MATH CLASSES

by

Shannon M. Near

A Master's Thesis Capstone Project
Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science in Education
Literacy Graduate Program
Department of Language, Learning and Leadership
State University of New York at Fredonia
Fredonia, New York

May 2014

State University of New York at Fredonia

Department of Language, Learning, and Leadership

CERTIFICATION OF THESIS WORK

We, the undersigned certify that this thesis by Shannon M. Near, candidate for the Degree of Master of Science in Education, is acceptable in form and content and demonstrates a satisfactory knowledge of the field covered by this thesis.

[redacted]

Dr. Cindy M Bird
Master's Thesis Capstone Advisor
EDU 659 Course Instructor
Department of Language, Learning and Leadership

May 16, 2014
Date

[redacted]

Department Chair: Dr. Anna Thibodeau
Department of Language, Learning and Leadership

May 16, 2014
Date

[redacted]

Dean: Dr. Christine Givner
College of Education
At SUNY Fredonia

5-22-14
Date

ACKNOWLEDGEMENTS

First and foremost, I would like to thank my husband, Eric, for his constant and abundant support, attentiveness, and love throughout this Master's Thesis Project as well as throughout my Graduate education. I am also deeply grateful for my family and their "cheerleading," encouragement, and support through my educational journey.

I would also like to express my deep appreciation for all the help, reassurance, and collaboration from my colleagues – the *Literacy family*. Additionally, I am appreciative for the caring and supportive Literacy Program Faculty that helped me become confident in supporting our future, "strategic readers".

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ABSTRACT

This thesis capstone project is a research synthesis to address the question of which literacy instructional practices, when applied to mathematics teaching, produce positive math performance results for elementary students? For this exhaustive literature review, 36 published studies were found that addressed the question. These studies were grouped into four categories: the relationship of reading performance to math performance, the relationship of comprehension of reading and the comprehension of math problems, vocabulary instruction in reading and mathematics, and specialized instruction in reading and mathematics. Synthesis of the findings produced a number of results: first is that this problem of the relationship between literacy and math has been around and been researched for decades and in many countries besides the United States, with the main focus being on students in grades three to six. A major result from this study is that there appears to be a direct correlation between reading performance and math performance but not math to reading: proficient reading performance translates to proficient math performance, but proficient math performance does not appear to directly correlate to proficient reading performance. The two subcategories of reading performance that appear to most significantly impact math performance are comprehension and vocabulary development, while the instructional strategies of conducting think-alouds, providing direct instruction, modeling, and using graphic organizers appear to have a positive impact on both literacy and mathematics learning. These results are packaged for the professional development of elementary teachers in the form of a DVD.

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Chapter 1: Introduction

Statement of Problem

New York State adopted the Common Core Learning Standards (CCLS) in July of 2010 (NYSED, 2013). The CCLS are "internationally-benchmarked and evidence-based" (NYSED, 2013) and more rigorous than the previous New York State Learning Standards. In Spring 2013, after the release of the first CCLS test scores, Commissioner King told parents that "more students struggled on this year's test than in previous years ... because we [NYSED] changed the expectations for New York State students when we adopted the Common Core State Standards" (NYSED, 2013). Commissioner King also indicated that State Education had "been working with teachers and principals to understand how instruction should change to get students where they need to be" (p. 2). The existence of these rigorous standards, the results from the CCLS tests, and State Education's desire to work with teachers to change classroom instruction raise questions for educators of precisely how teachers can change instruction to assist students in meeting the CCLS. One change may be for teachers to use techniques that increase both reading and mathematical achievement simultaneously. The National Center for Educational Achievement (NCEA) (2009) states that high-performing schools use mathematical instructional strategies that "include integrating literacy activities into courses including content-based reading strategies and academic vocabulary development" (n.p.). The practice of integrating into math lessons some specific literacy comprehension practices targeted for reading in mathematics, may offer educators the benefit of simultaneously increasing reading and mathematical performance for all students with a minimum of instructional change. The following thesis presents an extensive literature review to answer the question, which literacy instructional practices, when applied to mathematics teaching, produce positive math performance results for elementary students? The findings from the review are then applied to a professional development workshop.

Background

As an Intervention Specialist at a local public school district, I find the possibility of incorporating reading strategies to positively impact mathematics achievement, to be personally motivating. After the NYS CCLS trial test results for my school district became known this past school year, many of my colleagues were frustrated at the complexity of the tests, specifically the mathematics tests. Through personal conversations, it became evident that a similar opinion about the NYS Mathematics test was shared among the Grade 3, Grade 4, and Grade 5 teachers: *this is not a math test, it is a reading test that has some math*. Since it was my school district's first year of implementing the Annual Professional Performance Review (APPR) plan, many teachers felt concerned about their performance in terms of APPR because the new standardized tests were of greater complexity and rigor than previous years' tests. After hearing my colleagues' comments and concerns, and feeling my own stress about APPR, I realized there was a need to investigate ways to make students more successful at meeting the CCLS and more prepared for the amount of reading required on the new tests. Thinking about my previous literacy training, I determined that one way might be to have a "toolbox" of instructional practices for reading that could also be applied to reading in mathematics. This thinking led to my research question for this study: which literacy instructional practices, when applied to mathematical learning, produce positive performance results for elementary students?

Terminology

Definitions for some of the key terms in this research study will provide the reader with a better understanding of the topic. The first significant term is "instructional practices," which, for the purposes of this research study, means "general principles, guidelines, and suggestions for good and effective teaching that are supported by research" (Division of Instructional Innovation and Assessment, n.d.). There are many synonyms for this concept, including "teaching practices," "teaching strategies," and "teaching techniques" and these terms may be used interchangeably due to authors' preferences in studies. Also for the purposes of this study, the term "expository text" will refer exclusively to math-based texts, and the terms "math texts" and "expository texts" may be used interchangeably. Another significant term is "word problems" or "story problems," which means problems that involve written-out math scenarios that require students to apply mathematical knowledge in realistic situations. (Jacobse & Harskamp, 2009). Another definition for word problems or story problems is, "a mathematics exercise presented in the form of a hypothetical situation that requires an equation to be solved" (word problem, n.d.). Therefore, for the purposes of this study, word problems or story problems will mean a written, hypothetical, math scenario meant to prepare students to utilize mathematical knowledge in realistic situations.

Theoretical Framework

This research study ties to psychological theories of the reading process. It relates to Kucer's (2004) "cognitive dimension" (p. 101) of the reading process. Comprehension of expository texts involves finding the author's intended meaning. For math texts, this meaning resides in the numbers and story problems. Surface cues in a text enable a reader to find the meaning. Math texts also contain a non-verbal component where readers must find the shared meaning in the signs, or visual components to construct meaning of the text (Moline, 1995). To help students read, teachers are actually intending to get students to interpret the "shared meaning" that the signs in the text represent. However, math texts also contain many story problems, which involve the English language and all its surface cues. Thus literacy and its verbal reading skills are integral to reading math texts.

Rationale

New regulations for Annual Professional Performance Review (APPR) and teacher evaluation in New York State (NYS) are creating pressures for educators to prepare students to successfully complete the NYS Common Core Learning Standards (CCLS) tests. Elementary educators sense a strong desire to prepare students more thoroughly to meet the CCLS in both Mathematics and English Language Arts (ELA). However, teacher time management is more essential now than ever required before in order to meet the CCLS, prepare for APPR pressures, and provide effective instruction. Therefore, reading strategies applied to both mathematical learning and expository texts appear to be a means of maximizing instruction and allowing students to make the connections between ELA and Math. This research into the determination of literacy instructional strategies appropriate for use with the reading of math texts, is therefore a noticeably relevant and timely study.

Chapter 2: Literature Review

Introduction to the Review

An initial search of the major educational databases for literacy found a large number of research studies addressing strategies that positively affect content-area learning. However, a smaller number of empirical studies focus on reading techniques that increase mathematical performance. As a result, the number of studies to specifically address the research question of literacy instructional practices for use with mathematics teaching that produce positive math performance results in elementary school is 36. However, there are many related studies which through synthesis can contribute to address this question. The studies in this review are grouped into the following categories: relationship of reading performance to math performance, relationship of comprehension of reading and the comprehension of math problems, vocabulary instruction in reading and mathematics, and specialized instruction in reading and mathematics.

Relationship of Reading Performance to Math Performance

In order to determine what literacy strategies are available to integrate in mathematics teaching, it would be beneficial to determine the relationship between reading performance and math performance. A positive correlation would allow educators to consider transference of literacy practices in the math classroom. The next six articles examine the relationship of reading performance and math performance based on analysis of assessment data. Thurber, Shinn, and Smolkowski (2002) researched the relationship between math computation, math applications, and reading tests. Math computation, math applications, and reading tests were administered to 207 grade 4 students in midsized Northwestern public school districts. A total of 12 tests were administered for 45 minutes over 3 separate days. Data analysis indicates that "students who were not proficient in reading did not perform well on the measures" (p. 511) and "reading may be a necessary and important component in overall math competence and should not be overlooked in drawing conclusions about mathematics skills" (p. 511).

Also studying both reading and mathematics performance is Lerkkanen, Rasku-Puttonen, Aunola, and Nurmi (2005) who explore the relationship between mathematical performance and reading comprehension. The study involved 114 Finnish students (61 boys, 53 girls) from six classes and four schools in an urban district of central Finland. The students participated in this two-year longitudinal study and were administered assessments that tested general concept ability in math, visual-motor skills, initial mathematical skills, and initial reading skills. Students were tested a total of seven times throughout each year of the study. The researchers used the Maximum Likelihood Estimates, Bentler's Comparative Fit Index, Root Mean Square Error of Approximation, and Standardized Root Mean Square Residual to analyze the data and find areas of significance. Lerkkanen, Rasku-Puttonen, Aunola, and Nurmi (2005) found that mathematics and reading comprehension are "highly associated with each other across both years" (p. 121). Additionally, data analysis suggest that mathematical performance "predicted subsequent reading comprehension during the first year" (p. 121). Although this study involves students in Finland, transference of this knowledge may be possible for students in the United States.

A later study conducted by Grimm (2008) examined the association between early reading skills and changes in math curriculum to determine whether students who have a greater level of reading skills in elementary school exhibit more gains in math tests. From a large

Chicago public school, 46,373 grade 3 students were administered the standardized measure from IOWAS test of Basic Skills. A series of growth models were made to show correlations between performances of the same students from third to eighth grade. Three aspects of mathematics were focused on including problem solving and data interpretation, math concepts and estimation, and mathematical computation. The effects of "early reading achievement on changes in mathematics skills were evaluated within a latent growth modeling framework" (p. 421). Grimm (2008) concludes that "students' third grade reading achievement scores were positively related to the rate of change for each mathematics component to varying degrees" (p. 421). Also, "the effect of third grade reading comprehension on changes in Problem Solving and Data Interpretation was stronger than the effect for third grade mathematics achievement" (p. 421).

Similarly, Rutherford-Becker and Vanderwood (2009) examined the relationship between reading performance and math performance of upper elementary students in California. Participants were 97 grade 4 students and 83 grade 5 students from an urban school: 46 % were English Language Learners (ELLs). Each participant was given three Oral Reading Fluency (ORF) passages from AIMSWeb, a Curriculum-Based Measurement Maze (CBM-MAZE), comprehension problems from AIMSWeb, two basic math computation problems from the Monitoring Basic Skills Progress assessments, and four basic math concepts and application probes from Monitoring Basic Skills Progress assessments. All tests were individually administered. Analysis of the test data results indicate a "correlation" (p. 32) between reading comprehension and applied mathematics. Researchers conclude that it is "possible that a reading comprehension intervention can increase performance on applied mathematics tests" (p. 31), and also "when intervening with students with math difficulties, reading influences applied-math skills" (p. 32).

Another study seeking correlations between reading and math performance is Vukovic and Siegel's (2010) study on the reading and cognitive characteristics of students who had "persistent mathematic difficulty (MD-p)" (p. 25). In a diverse district on the west coast of Canada, 99 students from grades 1 to 4 participated in a four-year longitudinal study. Participants were placed in one of three groups: persistent Mathematics Difficulty (MD-p), transient Mathematics Difficulty (MD-t) or "typically developing" (p. 25). Participants were assessed using 13 formal norm-referenced assessments for both math and reading. Assessment results provided the data for the study, and analysis of this data reveals students in the persistent Math difficulty (MD-p) group are more likely to "experience deficits on measure of mathematics and reading achievement" especially in the areas of "math concepts and phonological decoding" (p. 37).

One study by Keller-Margulis, Shapiro, and Hintze (2002) studied the relationship between benchmark data and the rate of growth in reading, math computation, math concepts, and applications. Curriculum-based measures and statewide, large-scale achievement tests were used to assess the reading and math performance of 1,461 students in reading and 1,477 students in math. Keller-Margulis, Shapiro, and Hintze (2002) found that reading and math benchmarks were "significantly and moderately correlated" (p. 374) with performance on both achievement measures 1 and 2 years later. The researchers conclude that "results of this study provided strong evidence for the long-term diagnostic accuracy of CBM scores and performance on statewide and large-scale achievement tests" (p. 377).

The next two studies focus on the math and reading performance of students with math disabilities and/or reading disabilities. Fuchs, and Fuchs (2002) researched the mathematical problem-solving profiles of students with math disabilities with and without reading disabilities. A hierarchy of mathematics problem solving tasks were administered to 62 grade 4 students from a southeastern city. Students met two criteria: scores on an individually administered intelligence test was 90 or above, and students had a math goal on their Individualized Education Program (IEP). Three problem types were given to the students including arithmetic story problems, complex story problems, and real-world problem solving in small groups. Quantitative features of the text which included word length, number of sentences, words per sentences and number of verbs, increased along with the difficulty of test questions. ANOVAs (analyses of variance) were used. Analysis shows that "the accuracy of the students' performance decreased across the three problem-solving tasks" (p. 570). Also, for students whose performance was "comfortably higher" (p. 570) than other participants, "the drop from complex word problems to real-world problem solving was more sizable and statistically significant" (p. 570). Students with math disabilities and reading disabilities "manifested reliably lower scores" (p. 570) than peers in the math disabilities only group.

Similarly, Wise, Pae, Wolfe, Sevcik, Morris, Lovett, and Wolf (2008) studied the analysis of problem-solving profiles of students with math disabilities with and without reading disabilities. Wise *et al.* (2008) specifically examined the phonological awareness (PA) and the rapid automatized naming (RAN) skills in children who met criteria for reading disabilities (RD) only and children with RD who were at risk for mathematics difficulties (MDR). From a public elementary school in a metropolitan area, 114 grade 2 and grade 3 students with RD took the norm-referenced KEYMath-Revised test. Data analysis through NANOVA indicates that children with RD only show a different pattern of results as compared to children with RD and MDR. Analysis indicates that “RAN skills were the best predictor of reading achievement while PA skills were the best predictor of math achievement” (p. 132). It was also found that students with RD and MDR was “conceptually and functionally different from children with RD only” (p. 132). Results also indicate that students meeting “less stringent criteria may only need additional instructional assistance rather than services in a remedial classroom” (p. 134).

Another study that explored correlations between reading performance and math performance is Powell, Fuchs, Fuchs, Cirino, and Fletcher’s (2009) study. The researchers examined the relationship between word-problem features and reading difficulty. Across three studies, 134 participants in grade 3 classrooms from 24 different Title 1 and non-Title 1 schools from a southeastern metropolitan school district were examined. Based on scores from norm-referenced tests administered at the beginning of the year, students who scored below the 25th percentile were put in the Mathematical Difficulty and Reading Difficulty (MDRD) group, those scoring at or above the 40th percentile were put in the Mathematical Difficulty (MD) group. Students were then given four different sets of word problems including total problems or the “combining of two parts to make a whole” (p. 107), difference problems that has a “difference between [numbers] or compares quantities,” (p. 107) or change problems that have a “starting amount that changes into another quantity” (p. 107). Data analysis shows that Mathematics Difficulty-only (MD-only) students outperformed MDRD students on the “total problems” word problems, and students with MDRD have “poorer word-problem deficits relative to MD-only students” (p. 109). Findings suggest that “reading difficulty may provide a productive scheme for sub-typing MD and provide potential directions for differentiating interventions” (p. 109). This suggests that there is a relationship between reading and math performance and that there is a need to investigate interventions that involve reading in math learning, specifically in word/story problems.

Relationship of Comprehension of Reading to Comprehension of Math Problems

The Common Core State Standards (CCSS) introduces six instructional shifts in mathematics teaching. One of the shifts, Shift 5: Application, requires students to “use math and choose appropriate concepts for application even when they are not prompted to do so” (NYSED, 2013). The most common form of application is found in story problems or word problems that offer a mathematical scenario in written words. Therefore, students must be able to comprehend the text they are reading in order to apply the correct mathematical concept. The next two studies examine one type of reading comprehension strategy. Baumann, Siefer-Kessell, and Jones (1992), who examine the effects of a comprehension strategy called think-alouds on 66 grade 4 students (32 girls, 34 boys) from a rural Midwestern elementary school. Students were randomly assigned to three different study groups: Think-Aloud (TA) instruction where students were taught various comprehension monitoring strategies (self-questioning, prediction, retelling, rereading), Directed Reading-Thinking Activity (DRTA) instruction where students were taught a “predict-verify” (p. 143) strategy for reading and responding to stories, and Directed Reading Activity (DRA) instruction that served as a control group where instruction was established as a “typical” guided reading group. Pretests and posttests were given that assessed comprehension and strategy use. Treatment groups ran for three weeks until posttests were administered. Data analysis reveals TAs are a successful strategy in comprehension performance in students because they promote student comprehension of monitoring abilities.

The contribution of this older research has not diminished over time; more recently Ketterlin-Geller, Chard, and Fien, (2008) have discussed the importance of think-alouds in mathematical learning.

Ketterlin-Geller, Chard, and Fien (2008) examined the effects that think-aloud reading protocols and vocabulary development had for struggling math students when implemented through Knowing Math and Extended Core interventions. This study was performed on 51 grade 5 students from a district in the Pacific Northwest who were grouped according to performance on a grade-level district wide mathematics screening from the previous year. The Knowing Math intervention, “designed to reteach fundamental mathematics” (p. 33), was implemented with 17 students and the Extended Core intervention, “designed to provide extended time on the context of the core curriculum” (p. 33), was implemented with 27 students. The eight remaining students served as the control group receiving typical instruction in the general education classroom. The interventions ran for 16 weeks. ANOVAs were conducted to ensure validity of assessment results. Analysis of ANOVA results indicates that there was a “significantly higher” (p. 41) performance achievement for the Knowing Math group than for the other groups. This group focused on think-aloud protocols and “extended opportunities to verbalize their conceptual development of the mathematical principles” (p. 41). The researchers find a “moderately strong” (p. 41) effect that both these instructional supports have for low-performing students.

The next two studies examine the effects that reading comprehension has on math word problem skills. Søvik, Frostrad, and Heggberget (1999) studied the relation between reading comprehension and task-specific strategies used in math word problems. Twenty students from a large city school in Norway were administered the WISC intelligence test and the students were put into four groups. Group 1 consisted of students who were considered “good” at both reading and math; Group 2 included students who were “good” at math and poor at reading; Group 3 students were “good” at reading and poor at math; Group 4 included students who were poor at both skills. After grouping students and analyzing data, researchers found a “strong linear relationship” (p. 371) between predictors and criteria used. Researchers found that IQ was the only “significant predictor” (p. 371) for relating the reading comprehension and word problem solving.

Further investigating the relationship of comprehension of texts and mathematical word problems is the study by Vilenius-Tuohima, Aunola, and Nurmi (2008). The researchers specifically examine the relationship between mathematical word problem skills and reading comprehension. Their study involved 255 grade 4 children (107 girls, 118 boys). Families of the participants were sent a questionnaire about parental levels of education, and questionnaires had a 92% response rate. Students were administered Lindeman’s ALLU primary school reading text with two narrative texts and two expository texts along with 12 multiple choice comprehension questions. Students were also administered the Mathematical Word Problems subtest from NMART counting skills with 20 word problems. ANOVA was used to analyze the significance in the data from all the assessment scores. Vilenius-Tuohima, Aunola and Nurmi (2008) find that student performance on math word problems was “strongly related” (p. 409) to performance results on reading comprehension. The researchers also found reading fluency to be “crucial” (p. 421) to both math word problem solving and reading comprehension. Data analysis also suggests that student’s text comprehension skills and mathematical word problem solving performance are “interrelated” (p. 422). The researchers also found a correlation between maternal education level and student performance – the higher the maternal education level, the more likely the student is to have a higher level of reading comprehension and performance in math word problems.

The following four studies examine how the structure of word problem language affects reading comprehension of math story problems. Littlefield and Rieser (1993) studied the difference that irrelevant information added to story problems has on children's strategies for solving story problems. From an urban school in southeastern United States, 30 grade 5 children were selected based on reading and math scores on a comprehensive test of basic skills from the district. Of the 30 participants, 16 students were considered "successful" (p. 144) in math according to baseline standardized scoring and 14 were considered "less successful" (p. 144) in math. Story problems were selected by the researchers and 16 versions of each original problem were created, starting with the most basic form of the problem, increasing irrelevant information to the problem. Students were asked to identify semantic categories in each problem type such as the agent, action, and unit of measure. They were also to identify numbers in the problems that were relevant to their solution. Strategies used by individual students were documented. Data analysis indicates that successful students used strategies based on "analysis of the problems' semantic features" (p. 183), and "tend to look at the question more often and earlier during problem solution" (p. 183).

Related to the findings of Littlefield and Rieser (1993), Swanson, Orsco, and Lussier (1999) studied the effects of strategy instruction to teach children to focus on word problem structure. In a southern California public school, 193 grade 3 students (83 female, 110 male) were given two norm-referenced story problem subtests. Of the participants, 73 students were diagnosed with MD. The participants were placed in a control group or one of four treatment groups (verbal strategies, verbal and visual, visual only, verbal only, or materials only no strategies). Data analysis after ANCOVAs reveal that children with MD who participated in the verbal and visual as well as the materials-only groups outperformed children with MD in control conditions. Swanson, Orsco, and Lussier (1999) found that "if declarative knowledge is intact (reading comprehension and computational knowledge) strategy instruction may be redundant and fail to provide helpful information" (p. 150). Researchers also found that instruction that includes solving problems with "gradual increases in irrelevant propositions" (p. 152) may "boost solution accuracy" (p. 152).

Also examining language structure of story problems is Leong and Jerred (2001) who examined the effects that language information had on the comprehension of word problems. In a western Canadian city, 91 grade 3, 4, and 5 children participated in a 120 month study that involved two parts. In the first part of the study, students were given a task that contained 12 consistent and 12 inconsistent language problems in addition, subtraction, multiplication and division. The second part included a task that included 36 word problems containing adequate, inadequate, and redundant information. Analysis of ANCOVA show "significant main effects of grade, consistency and adequacy of linguistic information in problem solution" (p. 277-278). Also, "word problems containing inconsistent information were more difficult" as were the word problems containing "inadequate and redundant information" (p. 278) than word problems with "just enough information" (p. 278). Interviews were given with 12 students to gather more information in regards to strategies used for problem solving. The interviews showed that "not enough" (p. 288) word problems were most challenging for both more successful and less successful students.

Further examining language structure of story problems is Xin, Wiles, and Lin (2008) who examined the effect of teaching word problem story grammar on arithmetic word problem solving. Two urban public elementary schools in the Midwest selected five students in grades 4. Students took criterion-based assessments on math word problems, as well as a standardized math measure and pre-algebra probes. Participants received a word problem intervention three times a week for 20-35 minutes. Interventions included graphic organizers and explicit strategy explanation and modeling, dynamic teacher-student interaction, guided practice, performance monitoring with corrective feedback, and independent practice. Data analysis indicates “a gradual increase of students’ performance from baseline to post intervention probes as the instruction on each problem type proceeded” (p. 174). Researchers note that at the beginning of the interventions, students selected mathematical operations based on syntactical surface cues rather than conceptual understanding of the structure or schemata. Conceptual model-based intervention results showed “students with or at risk for Math Disabilities were able to articulate or describe key elements in the conceptual model of each problem type” (p. 175) and were even able to write their own word problems following the format.

Rather than researching how reading comprehension and math comprehension relate, Pimperton and Nation (2010) explore the “mathematical profiles” (p. 255) of students who struggled with comprehension to seek conclusions about reading comprehension and math comprehension. Two standardized measures of mathematical ability, one measuring procedural prowess, and one measuring higher-level mathematical reasoning, were given to 109 grade 2 students in schools from two small counties (Oxfordshire and Lancashire) in England. Of the 109 students, 14 students were considered “poor comprehenders” (p. 255) and 14 students were in the control group. Data analysis of the assessments reveal that “poor comprehenders showed significantly lower scores than the controls on the mathematical reasoning task” (p. 255) and that poor comprehenders “exhibited impaired verbal ability relative to controls” (p. 255). Pimperton and Nation (2010) conclude that poor comprehenders' profiles seem to indicate that the impairments found through tests seem to "impact certain components of mathematical ability" (p. 255).

In addition to using student performance results to determine the relationship between reading comprehension and math comprehension, another determiner is the one used by Pearce, Bruun, Skinner, and Lopez-Mohler (2013) studying teachers' perspectives of difficulties students have when solving and reading mathematical word problems and the causes of math difficulties. In the south-central region of the United States, 42 different schools participated in the study, which included 70 grade 3 through grade 5 teachers. Interviews were conducted with 12 open-ended questions that were audio-recorded. Interviews were transcribed and the "Priori approach" (p. 7) was used to analyze the data from the interviews. Analysis indicates that "students' abilities to read and understand the problem was the most frequently cited difficulty" (p. 3). Also, "standardized testing and text difficulties" (p. 3) were the most cited causes of difficulties. Pearce *et al*. conclude that the "role reading plays in teachers' perspectives of students' difficulties solving mathematical word problems" is "significant" (p. 3).

McKeown, Beck, and Blake (2009) examined comprehension instructional strategies that six grade 5 classrooms of 132 students, from a small urban district in Southwestern Pennsylvania, participated in during a two-year longitudinal study. Students were randomly assigned to three different groups: strategies instruction, content instruction, and basal instruction. Participants were given learning probes that served as a baseline. Teacher training was given along with scripted lesson plans. All three groups read the same stories within the five week program. In year two, 116 students within the same six grade 5 classrooms were studied. The same teacher from the previous study implemented the same strategy from the previous year. Three sets of test results were used to determine the pre-intervention and post-intervention growth, and ANOVA was conducted to compute significant differences among the approaches. Analysis of the results for both years indicate that scores for both "length and quality of recall were higher for content than they were for strategies and about equal to that of the basal-comprehension group" (p. 242). The content approach for increasing comprehension studied in this research appears to have been the most beneficial means of increasing reading comprehension as well as understanding the content being read.

Vocabulary Instruction in Reading and Mathematics

The subject of mathematics is a vocabulary-intensive discipline, and part of the difficulty for a student learning math is that the vocabulary has a highly discipline-specific meaning, not the more common general meaning. For example, the word "square" has two meanings in mathematics: the more common one used in geometry (for a four-sided shape with equal sides) and the one for algebra (a numbers times itself). A study that examines the relationship between vocabulary building and math development is by Gifford and Gore (2010) who worked with 15 of the lowest-performing grade 6 math students in a Tennessee school of 175 students. Gifford and Gore (2010) used Robert Marzano's program outlined in his book *Building Academic Vocabulary: Teacher's Manual* (2005) to guide instruction. In this program, students received a brief definition of each term prior to units. The teacher would model the meaning of the word through pictures, diagrams, and other aids. Students would then write the definitions in their own words. They also included non-examples in their illustrations. Students were selected based on the students' normal curve equivalent (NCE) scores on the Tennessee State standardized test as well as students' perception of potential for success as measured through a questionnaire. In terms of long-term effects, the study spanned three academic years. The first year served as a baseline with the absence of a vocabulary program, Year 2 implemented the program, as well as Year 3. The same group of students participated and were followed. The Dependent Variable Mean (DVM) showed that in Year 1, the mean was 34.846, Year 2 was 40.308 and Year 3 was 45.846, indicating an increase in mathematical performance within this longitudinal study. After the completion of a problem, student self-confidence in math performance increased as indicated on comparison of pretest to posttest results. Students who participated in the vocabulary program made Adequate Yearly Progress (AYP), experiencing a 93% increase above AYP on NCE points. The vocabulary program created a common language for the students and teachers. The researchers conclude that vocabulary building, following the Marzano model, is a literacy instructional strategy that can assist in math development.

The next two studies explored vocabulary practices through a read-aloud. Silverman and Crandell (2010) studied the effectiveness of various vocabulary strategies. Sixteen teachers in an urban Northeastern school district were trained on how to implement five vocabulary building strategies: acting out, illustrating words, applying words in new contexts, defining words explicitly in rich context, and word studies. Instruction was given to 244 Pre-kindergarten (Pre-K) and Kindergarten (K) students through 30 pre-determined texts. Prior to the interventions, the Peabody Picture Vocabulary test III was administered to students in the fall and again in the spring to test students' vocabulary growth. Analysis of the results indicate that students who participated in the acting out and illustrating words groups show greater results over students who started out with low initial vocabulary scores. The "applying words in a new context" (p. 334) strategy appears to be most successful for students with high initial vocabulary scores. The "defining words explicitly in rich context" (p. 334) strategy appears to be most successful for students with high vocabulary scores initially, and the "word studies" (p. 334) strategy appears successful for both low and high initial vocabulary scoring students.

Another study examining vocabulary instruction is conducted by Fien, Santoro, Baker, Park, Chard, Williams, and Haria (2011) who examined the effects that small group instruction has on vocabulary and comprehension ability of grade 1 students with low language and vocabulary skills. Participants included 102 students scoring below the 50th percentile on a norm-referenced vocabulary assessment; they were placed in 18 classrooms in a Pacific Northeastern Title 1 school. Fifty-four of the participants were randomly assigned to receive small group instruction targeting vocabulary and comprehension skills, and the remaining 52 students participated in typical whole-group instruction. The small group instruction was provided for 20 minutes, three times a week, for eight weeks by the classroom teacher, as the norm group continued to receive whole-group instruction. The intervention group practiced activities that involved read aloud activities, "opportunities to preview, review, and enhance vocabulary instruction aligned with the whole-class Read Aloud Curriculum" (p. 307). The texts included narrative and non-fiction (science) texts. At the completion of eight weeks, all students were assessed with the same vocabulary assessments and expository and narrative retells as given in the pretests. Fien *et al.* (2011) found that students who received small group instruction "reliably outperformed their controls on vocabulary assessments and expository retells" (p. 317); however they did not outperform on narrative retells. Implications from this research suggest that small-group instruction in addition to whole-group instruction produces positive results for vocabulary development and expository retelling skills.

The next two studies focus on small-group vocabulary interventions. Carter and Dean (2006) studied the effects that specific reading strategies, with an emphasis on vocabulary, had on math performance for students in grades 5 through 11. Fourteen students from a large southern public school attended a three-week summer intervention program targeting areas of greatest need in math, as indicated by Key-Math Revised norm-referenced testing. Students attended the intervention three hours a day, four days a week, and received vocabulary instruction, dense questioning, and anticipatory guides to improve reading comprehension. All 72 lessons were recorded and coded as well as analyzed to calculate the amount of instances of "reading instruction" (p. 144) that occurred during math lessons. Out of 101 instances of reading instruction, 70 instances were categorized as "vocabulary strategies" (p. 144) and 29 instances included "reading comprehension skills" (p. 144). Researchers conclude that "reading comprehension is an essential component of successful problem solving which is the primary goal of mathematics lessons" (p. 144). Researchers also stated:

> instructors in this study have demonstrated, mathematics teachers can include reading comprehension in their mathematics instruction by asking the students to read aloud, assisting with decoding when necessary, providing opportunities for detailed vocabulary exploration, and asking questions that help students activate prior knowledge and monitor their understanding (p. 144).

Also focused on the intervention mode of vocabulary instruction, is the study by Lubliner and Smetana (2005), who researched the effects that a 12-week vocabulary intervention program had on 77 Title 1 grade 5 students (36 girls, 35 boys). A class of 34 grade 5 students from an above-average performing school in the same district served as the comparison group. All participants were given norm-referenced assessments and those in the Title 1 School received the Comprehensive Vocabulary Development (CVD) intervention that focused on word-learning skills and reading comprehension. CVD instruction focuses on a metacognitive approach to vocabulary instruction. The same norm-referenced assessment was given as a posttest. The researchers found a “significant impact” (p. 182) on reading comprehension when students received CVD instruction for 45 minutes, twice a week for 10 weeks. Limitations of the study include that lessons were provided by teachers with less than three years of teaching experience, that data analysis was interpreted from researcher-designed instruments of measure, and that frequent absences occurred because of students moving in and out of the school district.

The following two studies used graphic organizers as a mean to improve vocabulary instruction. Monroe and Pendergrass (1997) researched the effects of integrated graphic organizers/discussion model and definition-only model of vocab instruction use. In a rural area of a western state, 58 grade 4 students were “randomly assigned” (p. 120) to one of the two vocabulary groups and participated in ten lessons in a math unit. The integrated model group used a modified “concepts of definition graphic organizer” (p. 120) with the “Frayer discussion model” which “teaches students to analyze and acquire new concepts as reported by IRA” (p. 120). The definition-only model followed district curriculum and required students to participate in an oral review of the definition as well as writing the definition and key terms in a notebook. As lessons were taught, another teacher observed and scripted each lesson. Analysis of the scripts and performance of writing prompts via MANOVA indicate that a larger number of math concepts were retained by the integrated Frayer model. Monroe and Pendergrass (1997) conclude the CD-Frayer model is an ‘effective method’ for teaching mathematical vocabulary” (p. 123).

Similarly, McAdams (2012) studied the effect that direct instruction in math and science vocabulary had on student achievement. Two math and two science classes totaling 114 grade 5 students participated in the study. The control group of 56 students followed the district’s math and science curriculum and pre-taught vocabulary before each unit as outlined in the curriculum. In the “experimental group” (p. 17), students were provided with direct instruction with content-specific vocabulary using the “Vocabulary Builder” graphic organizer adapted from the Verbal and Visual Word Association Graphic Organizer (Eeds & Cockrun, 1985). Significance was determined based on the state science and math test. Data analysis presents a “statistically significant finding” (p. 20) with student achievement in science. Although there was not enough evidence in students’ Math state scores to consider results “significant” according to the researchers, McAdams (2012) concludes students “must possess an understanding of specialized mathematical terms in order to comprehend mathematical readings such as word problems” (p. 20).

Aside from viewing vocabulary instruction, Hairrell, Rupley, Edmonds, Larsen, Simmons, Willson, Byrns, and Vaughn (2012) researched the effects that teacher quality had on vocabulary and comprehension performance of grade 4 students. In two districts of central Texas, 36 teachers and their 679 students participated in an intervention-based instruction for 30 minutes, three times a week. Students were assessed using standardized testing in reading and were randomly assigned to a comprehension or content vocabulary intervention group. Teachers received 15 hours of content-based and curriculum-based professional development prior to performing interventions. Teacher variables that were tracked included teacher quality, fidelity, usage of corrective feedback, instructional pacing, and levels of student engagement. Measures of teacher characteristics and qualifications were measured by a scaled rubric where a perceived knowledge score was given, measures of instructional practices were scored by members of the research team using a rubric for recorded lessons, measures of teacher effectiveness was measured by coding audio-recorded intervention implementation lessons, using a 7-point scale, as well as a curriculum-based vocabulary measure to record student growth. Data analysis in the form of a qualitative analysis of data from the standardized tests, instructional proficiency forms, and the open-ended survey items concludes that "teacher's education, fidelity, and indicators of teacher quality were significantly related to student outcomes on a standardized measure of reading comprehension." (p. 254).

Specialized Instruction in Reading and Mathematics

Vocabulary instruction is a crucial aspect in teaching mathematics. However, there are other methods and strategies that offer specialized instruction that also contribute to successful mathematics teaching. This section will present the current available research that connects reading strategies and math practice. The following three studies examine the effects of tutoring for math problem solving. Fuchs, Seethaler, Powell, Fuchs, Hamlett, and Fletcher (2008) assessed the effects of preventative tutoring of math problem solving for 35 grade 3 students with math and reading difficulties. The students were assigned to small groups, based on scores from pretests given by the researchers. Of the students who received the screening, those performing below the 26^{th} percentile were placed in tutoring sessions and the remaining students continued in the regular general education classroom to serve as the norm group. Tutoring was provided three times a week for 30 minutes for 12 weeks. The focus of the tutoring was on learning three mathematical types of story problems and then transferring that learning to problems including irrelevant information, two-digit operands, missing information in algebraic equations, and information in charts, graphs, and pictures. The same word problem assessment that served as a pretest was also administered as a posttest. Analysis of the data indicates that there were “statistically significant effects of the performance of word problems” (p. 170) for the students who received the tutoring as compared to the norm group. Fuchs *et al.* (2008) conclude that the tutoring protocol outlined in this study presents implications for educators to consider in preventing word-problem deficits of grade 3 students with math and reading deficits.

Further examining tutoring in mathematics is Maloy, Edwards, and Anderson (2010) who studied the effect that a computer-based tutoring system has on 125 grade 4 students. Three rural school districts in western Massachusetts participated in the study that used the 4mality online math tutor intervention program as a center rotation in math classes. The intervention lasted ten weeks during math or computer instruction time. Two of the three schools use the program in conjunction with three other centers that include computer math games, math board games, and creative writing (writing math word problems and solving them). The difference of the pretest and posttest scores of a researcher-made assessment consisting of ten questions from previous MCAS tests were found to be “statistically highly significant” (p. 88). Researchers found a mean gain of 25.51% in test scores while 36 participants had 40% or more gains from pretest to posttest. Maloy, Edwards and Anderson (2010) also state that they “cannot claim that this [the statistical gains in scores] was due solely to the effect of our program since we do not have a control group” (p. 87). Researchers note, “students began proceeding thoughtfully and strategically when solving math problems in class are on tests” (p. 89).

Concurring with Maloy, Edwards, and Anderson’s (2010) stance on computer software, is Glenberg, Willford, Gibons, Goldberg and Zhu (2011) who focused on the impact that a software program can have on reading and mathematics performance. The researchers examined the influence of the Moved by Reading software on mathematic performance for four grade 3 classrooms and three grade 4 classrooms. Of the 97 participates, 53% were girls. Students from the seven classes were randomly assigned to a control conditions group (not using the software, but the same math problems) or the Moved by Reading software group. The study involved three successive days of interventions using the software, or using pencil-paper problems. In the software group, six initial texts were presented on the Moved by Reading software where students manipulated pictures to simulate sentence content. This helped to facilitate the reading strategy of visualization. The next set of texts involved math story problems where students were asked to imagine manipulating the pictures, but instead used pencil-paper problems with the pictures. All students in the seven classes were given a researcher-created story problem exam. The math story problems were evaluated by proportion of correct problems, the proportion of correct solution procedures, and if the solution procedure included “any irrelevant numerical information” (p. 1). Students who used the Moved by Reading software solved more math problems correctly than the control group were not provided the software to use. The Moved by Reading group also had a greater proportion of correct solution procedures and included less irrelevant information on their solution procedures than those students consistent in control conditions. This study reveals that “building mental models [or the visualizing for comprehension strategy] provides the core of comprehension in a variety of genres [including mathematics]” (p. 16).

The next three studies focus on changing the structure or administration of word problems in mathematics. Helwig, Rozek-Tedesco, and Tindal (2002) researched the effect that reading math test items orally had on student achievement. In grades 4, 5, 7, and 8, 1,343 students participated in a standardized administration of a large-scale math test. Two tests formats were available, each including 30-items of multiple-choice test questions that ranged from 7 words to 45 words. One standard format was administered to students without a diagnosed disability. The alternative format was read aloud to students with learning disability from a video monitor. Data analysis with ANOVA reveals students with a Learning Disability "performed better when items were read aloud" (p. 39) and that "General Education students performed better when the test was administered in standard format" (p. 43).

Another study that changed the structure of word problems was conducted by Moreau and Coquin-Viennot (2003) who studied 91 grade 5 students' comprehension of arithmetic word problems. Students were divided into two groups according to math ability and were given two tasks. The first task was to cross out all non-essential words in order to make the word problem as short as possible: this strategy was considered finding the solving information. In the second task, participants were asked to select items that would make the word problem easier to understand: this strategy was considered finding the situational information. The amount of information selected for each story problem was recorded. Data analysis via researchers' formula concludes that the math ability of the participants had "an influence" (p. 119) on the selection of information in the word problems. Moreau and Coquin-Viennot (2003) found that participants with higher math ability were able to demonstrate an understanding of word problems as situations that involve events, actions, and relationships (situation model). However, students with lower ability in math "adopt a more random selection strategy" where these students "do not have schemata to guide their selection and the fact that the situation associated with the problem is too complex to enable them to construct a relevant situation model" (p. 119).

Similarly, Vicente, Orrantia, and Verschaffel (2007) defined and distinguished between two kinds of reworded math word problems. Grade 3 (79), grade 4 (64) and grade 5 (65) students from two city schools in Salamanca, Spain were involved in two studies. Students were asked to solve 8 word problems. The problems were defined by researchers, using levels of difficulty dependent upon wording and number of steps. Student responses were coded as correct, by procedure, not exactness of final answers. Analysis shows that adding information resulted in a “significantly greater number of correct answers” (p. 839) than the standard problems. In study 2, the researchers focused on situational rewording in story problems.

One study that focused on incorporating writing into a mathematics class setting is conducted by Kostos and Shin (2010). The study investigated how math journals affected the communication of math thinking of grade 2 students. In a large suburb of Chicago, 16 students wrote in journals three times a week using 16 different math prompts for a five week period. Students received math journal instruction with modeling prior to writing each day. Pretest and posttest math assessments were administered along with interviews of the students. Students wrote a step-by-step explanation of what student did to solve the math problem. The researcher used a mathematics scoring rubric, the Saxon math teacher rubric for scoring, and “coded and memoed” (p. 230) interview answers. Kostos and Shin (2010) found an “increased use of mathematics vocabulary, improvement on students’ mathematical thinking through math communication” (p. 230). The researchers also note that math journals can serve as a “communication tool between the students and an assessment tool for the teacher” (p. 230).

One study that examined the quality of math trade books was researched by Nesmith and Cooper (2010). The researchers focused on the impact of background perspectives on determining the quality of math trade books. Nesmith and Cooper’s (2010) study involved 30 reviewers that conducted 180 evaluations of six different math trade books. The math trade books were in McGraw-Hill’s curriculum list. Each reviewer was given a set of six trade books, six corresponding evaluation forms, and a brief overview of the intent of the study. The statistical distinctions between the evaluation scores for each text as well as the mathematical and literacy elements of each text were determined using ANOVA. Nesmith and Cooper (2010) find that the background of the reviewer (experience, exposure to texts) and the number of reviewers involved in the evaluation largely affected the results. Based on data analysis results, Nesmith and Cooper (2010) give suggestions for educators to consider when using mathematical texts, including that teachers "should explore and assess the evaluation and recommendations process to judge the quality of math trade books by grade level" and educators "must become more familiar with and conduct more inquiry into recommended curricula materials" (p. 297) prior to using them. The researchers also suggest that educators conduct a review of math trade books using Schiro (1997) or Hunsader (2004) instruments used in this study. Nesmith and Cooper (2010) conclude that "at a time when the mathematics and literature connection has quickly gained popularity, there must be developed and incorporated powerful methods, procedures, and protocols for determining high-quality children's literature for use in the mathematics classroom" (p. 297).

Summary of the Review

The research studies found for this review and presented in this literature review were found through thoroughly searching from relevant educational databases. A total of 36 articles were found to address the research question or some aspect of it. The studies were grouped into four categories implied by the research question. These categories are the relationship of reading performance to math performance, the relationship of comprehension of reading to comprehension of math problems, vocabulary instruction in reading and math, and specialized instruction in reading and math. The range of the studies in this synthesis covers the years from

1992 to 2013, and the range of participant ages covers the elementary grade levels of kindergarten to grade 6.

Chapter 3: Methodology

In order to answer the research question, what literacy instructional practices for mathematics learning in elementary schools produces positive performance results, a thorough and extensive literature review was conducted. This chapter will analyze and synthesize the studies that were found to be relevant to the research question. The findings will then be applied to a professional development project in Chapter 4.

Data Collection

An initial search of the major educational databases for literacy found a large number of research studies addressing strategies that affect content-area learning. After an exhaustive search of databases such as ERIC database, Google Scholar, ProQuest, Questia, EBSCO, SAGE, Educational and local library searches, the number of studies to specifically address the research question of literacy instructional practices for mathematics learning in elementary school is 36. Common terms and phrases that were used to search the database included *expository text*, *reading strategies in mathematics*, *content area reading strategies*, *literacy in mathematics,* v*ocabulary instruction in mathematics*, *comprehension instruction in mathematics*, *literacy strategies in mathematics*, *literacy practices in mathematics*, as well as *relationship between reading and math*. These published studies become the data for this research study. From an initial review of the found studies, the data emerged into four categories: relationship of reading performance to math performance, the relationship of comprehension of reading to comprehension of math, vocabulary instruction in reading and math, and specialized instruction in reading and math. The remainder of this chapter presents the analysis of the data and the resulting findings.

Data Analysis

This research synthesis examines studies relating to four categories implied by the research question of possible literacy instructional practices for use with mathematics teaching that may produce positive math performance results in elementary school students. The literature review found 36 studies related to this question. After closely reading and reviewing the 36 articles, the results were synthesized and patterns in the data were determined. Some patterns emerged from the review of the 36 studies as a whole. The range of years for the selected studies covers the past 21 years from 1992 to 2013. In that time frame, 20 studies were conducted using a quantitative methodology. From 1997 to 2013, 10 studies used a mixed methodology. Only six studies used a qualitative methodology; these were conducted in the last ten years (with the exception of one in 1993). This finding of the methodology and time periods suggests that this topic has been a concern for a while. It may also suggest a shift in research methodology from quantitative studies in the earlier years, to mixed studies, then qualitative studies within the last 10 years. This shift may indicate an instructional change in mathematics from performance-focused instruction to a more student-centered approach.

In addition to more than twenty years of research into this topic, the studies also covered a wide geographical area. Most geographical regions of the United States served as locations for the relevant studies; these regions include the Northwest with two studies, Midwest (including Chicago) with four studies, West (including California) with four studies, South-central with two studies, Southwest (including Texas) with two studies, Northeast (including Massachusetts and Pennsylvania) with six studies, and Southeast (including Tennessee) with five studies. Only one study (Helwig, Rozek-Tedesco, & Tindal, 2002) was conducted across multiple states and regions of the US. In addition, seven studies were conducted in international locations: Canada with two, Finland with two and Norway, England and Spain with one each. Only two studies did not specify a geographic location where the research was conducted (Moreau & Coquin-Viennot, 2003; Glenberg, Willford, Gibons, Goldberg, & Zhu, 2011). This range of geographical areas for the studies suggests that the problem of the relationship between reading and math is one that is experienced not only across the United States, but is a problem internationally as well. This topic is a widespread concern.

A third pattern emerging from analysis of the data as a whole is the grade range of participants. A total of 8 studies worked with students in grade Kindergarten to grade 2. A total of 28 studies worked with students in grades 3 to 6. This uneven distribution of studies suggests that researchers may prefer to concentrate on older students whose cognitive development is sufficient for more abstract mathematics concepts and functions.

After closely reading and reviewing the 36 articles as a whole, other patterns in the data emerged from an analysis of the four individual categories: the relationship of reading performance to math performance, the relationship of comprehension of reading and the comprehension of math problems, vocabulary instruction in reading and mathematics, and specialized instruction in reading and mathematics. For the category of performance, analysis shows that there appears to be a correlation between reading performance and math performance. In this category, six studies found a positive correlation between reading performance and math performance. More specifically, reading performance identified as poor phonological decoding in reading was linked to deficits in math achievements (Thurber, Shinn, & Smolkowski, 2002; Rutherford, Becker & Vanderwood, 2009; Vukovic & Siegel, 2010).

The performance of reading comprehension was also tied to overall math competence, especially in mathematical problem solving: the better the reading comprehension, the better the math problem solving (Thurber, Shinn, &Smolkowski, 2002; Grimm, 2008; Rutherford-Becker, & Vanderwood, 2009). When performance is identified as generally not proficient in reading, math performance was poor, even years afterward (Lerkkanen, Rasku-Puttonen, Aunola, & Nurmi 2005; Vukovic & Siegel 2010). Analysis of the studies in this category indicates that the relationship between reading performance and math performance appears to be a direct one, where performance in math reflects performance in reading. This direct relationship between reading performance and math performance means that when reading performance is proficient, math performance is proficient as well.

Another finding in this category relates to performance of students with disabilities. Data show that students with math and reading disabilities have a lower math performance than students with only math disabilities (Fuchs & Fuchs, 2002; Wise, Pae, Wolfe, Sevcik, Morris, Lovett, & Wolf, 2008; Powell, Fuchs, Fuchs, Cirino, & Fletcher, 2009). One study found that phonological awareness in students with reading disabilities was the best predictor of math achievement (Wise, Pae, Wolfe, Sevcik, Morris, Lovett, & Wolf, 2008).

The majority of studies addressed the relationship between reading performance and math performance through synthesizing assessment data. Overall, the findings of this category suggest that reading ability influences math performance. Synthesis of the studies' results supports that students with greater skill knowledge and application of reading can perform better in math than students with lower skill knowledge an application of reading. Therefore, there appears to be a positive and correlated relationship between math performance and reading performance.

In the category of the relationship between comprehension of reading and comprehension of math, there appears to be a correlation between reading comprehension and math comprehension. Effective reading comprehension strategies are also successful as math comprehension strategies. There are 11 studies addressing the category of the relationship of comprehension between reading and math. Comprehension skills used when reading text are also utilized when reading math word problems (Vilenius-Tuohima, Aunola, & Nurmi, 2008). For students who had poor comprehension, their impairments seemed to impact math ability and they exhibited lower scores in mathematical reasoning tasks when their reading comprehension skills were lower (Pimperton & Nation, 2010). IQ (intelligence quotient) also appears to be a contributing predictor for reading comprehension and math problem solving (Søvik, Frostrad, & Heggberget, 1999). The specific reading comprehension strategy of think-alouds involves self-questioning, prediction, retelling, and re-readings. Think-alouds have been shown to be an effective comprehension strategy that improves mathematic problem solving for fourth and fifth grade students (Baumann, Siefer-Kessell, & Jones, 1992; Ketterlin-Geller, Chard, & Fien, 2008).

Another finding in this category is that students are more successful at comprehending math word problems when they learn to compute them by following a progression of increasingly difficult problems: from a “simple” structure of the word problem followed by a progression of challenging word problems taught through modeling and guided practice, much like learning how to read (Littlefield & Rieser, 1993). The structure of word problem language also appears to affect reading comprehension of math story problems. Students exhibited improved performance in math story problems when they looked at the questions more often

(Littlefield & Rieser, 1993), and used graphic organizers to facilitate vocabulary acquisition and aid in comprehension (Xin, Wiles, & Lin, 2008). Instruction that included gradual increases in irrelevant information and explicit strategy explanation with modeling and guided practice produced favorable results in increasing problem solving solution accuracy (Swanson, Orsco, & Lussier, 1999). Additionally, word problems that involved inconsistent, inadequate and redundant information were most difficult for students to solve (Swanson, Orsco, & Lussier, 1999; Leong & Jerred, 2001). The length and quality of recall of expository text was higher with content instruction (McKeown, Beck, & Blake, 2009). Teachers also viewed reading level in mathematics texts such as word problems as being a contributing factor for student struggles in math (Pearce, Bruun, Skinner, & Lopez-Mohler, 2013).

Overall, the findings of this category suggest that reading comprehension skills influence comprehension of math problems. Synthesis of the studies' results supports that students with greater reading comprehension ability can perform better in math than students with lower reading comprehension abilities. There appears to be a direct relationship between the comprehension of reading and the comprehension on math problems, and that strategies such as think-alouds, direct instruction, and using specific graphic organizers are successful in both reading and math.

Another frequently researched topic in regards to reading strategies in mathematics is vocabulary instruction. Analysis shows that quality vocabulary instruction through various methods may be an integral aspect of mathematics development. Eight studies were found to address vocabulary instruction. A study examining vocabulary building and math development, shows evidence that by using Robert Marzano's program of reading vocabulary instruction that involves read-alouds, student self-confidence and math performance increased (Gifford & Gore, 2010). For students with average-to-high results on pretests of vocabulary measures, applying words in a new context, defining words, word studies, and small group instruction proved to be beneficial in increasing vocabulary development (Gifford & Gore, 2010). With students who performed low on the initial vocabulary pretest, acting out and illustrating words showed greater results for students and word studies as well as small group instruction (Silverman & Crandell, 2010; Fien, Santoro, Baker, Park, Chard, Williams, & Haria, 2011).

Small group interventions in vocabulary instruction proved to be successful for intermediate students. Reading comprehension increases when vocabulary instruction is presented in a small-group setting and involves metacognitive skills (Lubliner & Smetana, 2005; Carter & Dean, 2006). Benefits in mathematic performance found through vocabulary instruction in mathematics, can also be discovered through use of graphic organizers (Monroe & Pendergrass, 1997; McAdams, 2012). A graphic organizer following the Frayer Discussion model is a successful means to teaching mathematical vocabulary. The Vocabulary-builder graphic organizer from Verbal and Visual word associations (Eeds & Cockrun, 1985) increased vocabulary knowledge and performance in math classes. This is not seen with evidence in students' math state scores for this particular study, but rather through observations and classroom assessments (McAdams, 2012). Teacher quality also impacts students' ability to increase vocabulary skills. Teachers' education, fidelity, and indicators of teacher quality significantly related to student outcomes (Hairrell, Rupley, Edmonds, Larsen, Simmons, Wilson, Byrns, & Vaughn, 2012).

The findings in this literature review category indicate vocabulary instruction in reading appears to have a direct correlation to vocabulary instruction in mathematics learning. Specific strategies such as read-alouds, general reading comprehension strategies, modeling, and use of graphic organizers and small group vocabulary instruction appear to benefit both mathematics comprehension and reading comprehension for elementary students.

The eight studies in the category of specialized instruction in mathematics also indicate benefits for students' math performance. Math problem solving tutoring that focused on the structure and types of wording, produced statistically significant results between pretest and posttest results (Fuchs, Seethaler, Powell, Fuchs, Hamlett, & Fletcher, 2008; Maloy, Edwards, & Anderson, 2010; Glenberg, Willford, Gibons, Goldberg, & Zhu, 2011). The reading strategy of visualization increases students' ability to solve word problems correctly (Glenberg, Willford, Gibons, Goldberg, & Zhu, 2011). Direct instruction about vocabulary and approaches to word problems allowed students to approach word problems thoughtfully and strategically (Fuchs, Seethaler, Powell, Fuchs, Hamlett, & Fletcher, 2008; Maloy, Edwards, & Anderson, 2010). Another specialized instruction is changing the structure or the standard administration of word problems; this proved beneficial in increasing reading performance (Helwig, Rozek-Tedesco, & Tindal, 2002; Moreau & Coquin-Viennot, 2003; Vicente, Orrantia, & Verschaffel, 2007). When word problems were read aloud to lower performing students (Helwig, Rozek-Tedesco, & Tindal, 2002), and when students can identify the situation model which includes information in the word problems that reveal the events happening in the word problem, (Moreau & Coquin-Viennot, 2003), students are more successful at solving word problems. For the specialized instruction of writing, when writing was modeled and used to communicate mathematical thinking to solve word problems, student performance increased (Kostos & Shin, 2010). Only one empirical study was found to involve writing in mathematics. The background of reviewers (experience and exposure to texts) that examined the quality of mathematics trade books greatly affected results in this study (Kostos & Shin, 2010).

A synthesis of the findings in this category of specialized instruction indicates that certain instructional practices produce positive impact on literacy skills and mathematics skills. Instruction in reading and mathematics that involves small groups, metacognitive reasoning (such as in think-alouds and read-alouds), writing, identifying the structure of word problems, and visualization appear to produce positive performance results for students in mathematics.

A synthesis of the findings from each of the four categories presents some interesting results for this research study. One is that a direct relationship between reading performance and math performance exists, but not math to reading. Also, proficient reading performance translates to proficient math performance, but proficient math performance does not appear to directly correlate to proficient reading performance. The two subcategories of reading performance that appear to most significantly impact math performance are comprehension and vocabulary development, while the instructional strategies of conducting think-alouds, providing direct instruction, modeling, and using graphic organizers appear to have a positive impact on both reading and mathematics learning.

Chapter 4: Results and Application

Results of the Review

After careful analysis of the results of the studies to address literacy practices that produce positive performance results in mathematics, the researcher found several findings. Overall analysis reveals a shift in research methodology from quantitative to mixed to qualitative, which indicates a shift in research focus that may reflect a shift in mathematics instruction: from performance-focused instruction to a more student-centered approach. Overall analysis reveals a lengthy and universal recognition and concern for this problem of the relationship between literacy and math as evidenced by the number of years it has been studied and the geographical spread of the studies. The predominant age of the participants being the intermediate or upper elementary grades indicates the problem and its proposed solutions have focused on these grades. Other results from this study are that a direct relationship between reading performance and math performance, but not math to reading: proficient reading performance translates to proficient math performance, but proficient math performance does not appear to directly correlate to proficient reading performance. The two subcategories of reading performance that appear to most significantly impact math performance are comprehension and vocabulary development, while the instructional strategies of conducting think-alouds, providing direct instruction, modeling, and using graphic organizers appear to have a positive impact on both reading and mathematics learning.

Application of Results to a Professional Development Project

Results of this research synthesis suggest reading performance appears to have a direct relationship to math performance. Results also show that two subcategories of reading performance, comprehension and vocabulary development, provide the most impact on math performance. Findings further show that the instructional strategies of conducting think-alouds, providing direct instruction, modeling, and using graphic organizers appear to have a positive impact on both reading and mathematics performance. These results are very relevant to elementary teachers and have a strong application to the professional development of grades 3 to grade 6 teachers because of the heavy emphasis from the Common Core State Standards on reading and math. Teachers who teach math or reading, or especially those who teach both English Language Arts and Mathematics, would benefit from understanding the direct relationship between reading and math; that reading performance impacts math performance. Teachers would also benefit from applying the knowledge collected from this research synthesis to classroom practices. The most efficient way to distribute the results of this synthesis to teachers is through professional development, specifically professional development delivered through a DVD.

Design of Professional Development Project

The design of the Professional Development Project is a professional development DVD. The schedules of elementary teachers are becoming more and more demanding, especially due to mandates from the Common Core and other state initiatives. Therefore, a DVD format allows flexibility in timing and location for teachers to engage in professional development. Those participating in viewing the DVD have the option of re-viewing the DVD any time afterward as well as viewing a specific part or section of relevance to them. The hour-long DVD includes modeling of sample activities that correlate to the research results. The DVD focuses on the use of reading strategies and practices in the mathematics classroom. The intent is to increase teachers' awareness of using reading strategies that can increase student math performance.

Literacy coaching DVD goals and objectives.

The goals of this Professional Development DVD are to allow kindergarten to grade 6 teachers, as well as administrators, to increase their knowledge and understanding of the direct relationship between student performance in reading and math. The objectives of this DVD are that teachers will be able to apply effective reading comprehension practices to mathematics, as well as focus on reading skills in order to improve math skills. Other objectives are that teachers are to be able to identify effective research-based literacy practices that will benefit mathematics performance and be able to apply these findings to their own teaching of mathematics.

Proposed audience and location.

This professional development DVD is intended for elementary teachers, kindergarten to grade 6, who teach math, reading, or both. Administrators and paraprofessionals might also benefit from watching this DVD. Pre-service teachers (student teachers) in a program for elementary teaching would also benefit from watching this DVD. The DVD format provides not only flexibility in terms of viewing time, but also in viewing location. The video may be viewed individually or as part of a whole group workshop. One recommendation for use of this DVD as professional development is to have all math and reading teachers of a certain grade level view together so they can share ideas and collaborate on lesson planning. The DVD is suitable for viewing on a large scale, such as when using a SMARTboard or projector. The DVD itself will be distributed free of charge to local schools in the researcher's school district. It will also be promoted on the TeachersPayTeachers website or other similar sites, and made available to educators who request it.

Proposed DVD format and activities.

This proposed professional development video is in the form of a user-friendly DVD which also includes a user guide. Elementary teachers and administrators can view this video using any device compatible for viewing a DVD. The DVD begins with a title screen (see Appendix A) that allows viewers to select the portion of the professional development relevant to their teaching. This option allows viewers to work through the professional development at their own pace, and enables the DVD to be viewed in multiple sessions. The DVD is divided into five sections: *Background*, *Significance*, *Strategies*, *Documents*, and *Feedback*. The first section, *Background*, presents information from this research synthesis on the relationship between reading and math; the *Significance* section discusses the significance of the research synthesis results and their application to teacher practice. The *Strategies* section then provides viewers with specific applications to practice, including teaching vocabulary and specialized strategies that can be integrated into the mathematics classroom. The fourth section, *Documents*, refers viewers to the user guide with its reproducible lesson aids and graphic organizers that can be adapted for classroom use. Finally, there is a section titled *Feedback* that refers viewers to an evaluation survey on SurveyMonkey.com.

Proposed resources for DVD.

In order to participate in the professional development video, participants will need access to the DVD and equipment capable of viewing a DVD. Materials provided include the DVD and the user guide, which contains discussion questions, lesson plans, and other teaching resources. The guide will accompany the DVD.

Proposed evaluation of video.

The conclusion of the DVD encourages viewers to provide feedback on their viewing experience and on the contents of the DVD itself. Viewers are directed to the SurveyMonkey website to complete an online evaluation survey (see Appendix B).

DVD Ties to Professional Standards

Participants who view the professional development DVD will be meeting several *Standards for Reading Professionals –Revised 2010* from the International Reading Association (IRA).

Standard 1: Foundational Knowledge:
Candidates understand the theoretical and evidence-based foundations of reading and writing processes and instruction.

Classroom teachers who view this DVD meet this standard when they learn about what research says about the relationship between reading and math performance. The video presents current research of reading processes and instruction in the mathematics classroom and assists teachers in reflecting on their own literacy practices of how to use the current research in math classes.

Standard 6: Professional Learning and Leadership:
Candidates recognize the importance of, demonstrate, and facilitate professional learning and leadership as a career-long effort and responsibility.

Classroom teachers who view this DVD meet this Standard because they have chosen to participate in this form of professional development and thus demonstrate their understanding of professional learning as a career-long effort. This professional development DVD addresses Standard 6 through providing teachers who view this DVD an opportunity to actively advance professionally in their career. This video will allow teachers to take responsibility in increasing their professional knowledge.

Chapter 5: Discussion and Conclusion

Overview of Study and Findings

This thesis capstone project is a research synthesis to address the question of, which literacy instructional practices, when applied to mathematics teaching, produce positive math performance results for elementary students? For this exhaustive literature review, 36 published studies were found that addressed the question. These studies were grouped into four categories: the relationship of reading performance to math performance, the relationship of comprehension of reading and the comprehension of math problems, vocabulary instruction in reading and mathematics, and specialized instruction in reading and mathematics. Synthesis of the findings produced a number of results: first is that this problem of the relationship between literacy and math has been around and been researched for decades and in many countries besides the United States, with the main focus being on students in grades three to six. A major result from this study is that there is a direct correlation between reading performance and math performance but not math to reading: proficient reading performance translates to proficient math performance, but proficient math performance does not appear to directly correlate to proficient reading performance. The two subcategories of reading performance that appear to most significantly impact math performance are comprehension and vocabulary development, while the instructional strategies of conducting think-alouds, providing direct instruction, modeling, and using graphic organizers appear to have a positive impact on both literacy and mathematics learning. These results are packaged for the professional development of elementary teachers in the form of a DVD.

Significance of the Findings

The findings from this research synthesis are highly significant to elementary teachers who instruct students in reading, math, or both subjects. The findings offer teachers some insight into the relationship between reading and math performance. It also provides some relevant classroom application in the form of specific instructional strategies that teachers can use to assist students to learn math. These findings are also significant to the field of literacy because they offer further insight into this decades-long inquiry.

Limitations of the Findings

Even though this research synthesis provided new knowledge about literacy practices in the math classroom, the findings exhibit limitations. The found studies focused more heavily on student performance than on actual strategies teachers could use to benefit reading comprehension in mathematics. Writing in mathematics was researched only once at the elementary level. Because findings of that one time research show writing does increase the performance in mathematics, it would be beneficial for additional studies to be conducted on this topic and in a variety of grade levels and regions. Findings of this synthesis were also limited to the published research that was available to the researcher.

Conclusion: Answer to the Research Question

Improving math comprehension appears to be a universal concern for teachers in elementary schools. The question addressed in this research is, what literacy practices produce positive performance results for elementary students in mathematics? To address this question, an exhaustive literature review was conducted and the research findings from the literature review was synthesized. Results are that this problem of the relationship between literacy and math has been around and been researched for decades and in many countries besides the United States, with the main focus being on students in grades 3 to 6. Another result is that there is a direct correlation between reading performance and math performance but not math to reading. The two reading subcategories of comprehension and vocabulary development appear to be the most impactful ones on math performance, while the instructional strategies of conducting think-alouds, providing direct instruction, modeling, and using graphic organizers appear to have a positive impact on both literacy and mathematics learning. Therefore, the answer to the question of what literacy practices improve math performance is, all literacy practices; but especially comprehension and vocabulary practices when delivered through certain instructional strategies.

Recommendations for Future Research

The limitations of the findings offer implications for future research. Throughout the study, there were aspects of reading that were not addressed within mathematics. Research on incorporating writing instruction into mathematics lessons at the elementary level could benefit teachers in creating higher order of thinking lessons. This research synthesis only found one study pertaining to writing in the elementary mathematics classroom. Additionally, further research specifies what *reading strategies* are effective in mathematics rather than general approaches or programs. Since my research is relevant to the situation of my own existing classroom, I plan on using this research as personal professional development and improve my instruction based on the findings from this research synthesis: plus conduct my own action research to determine the impact of the results on my students.

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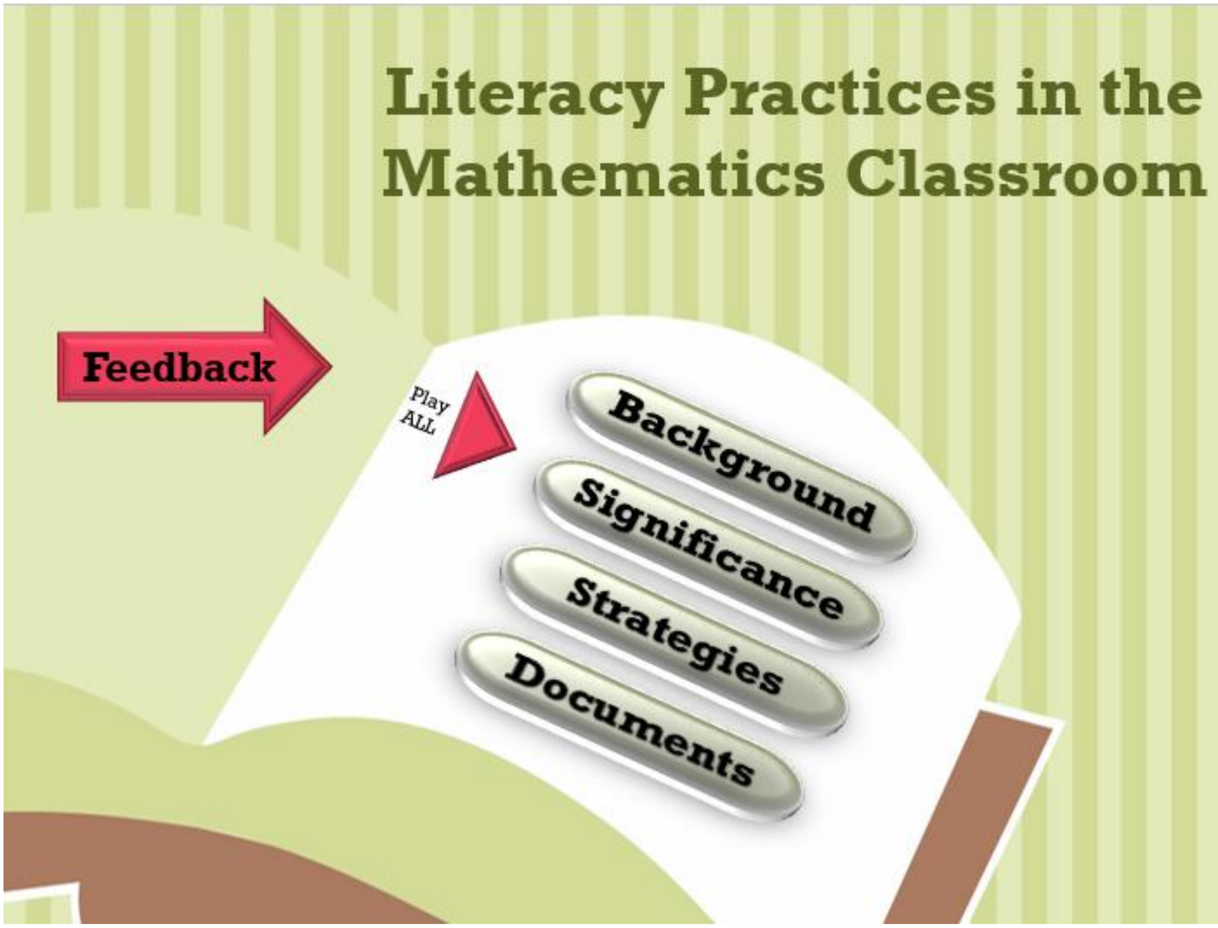
Appendix A: Professional Development DVD Menu

DVD Menu



Appendix B: Professional Development DVD Evaluation Survey

Reading in Math Classes

1. Overall, were you satisfied with this presenter?

- ○ Extremely satisfied
- ○ Quite satisfied
- ○ Moderately satisfied
- ○ Not at all satisfied

2. How useful was the information presented at this workshop?

- ○ Extremely useful
- ○ Quite useful
- ○ Moderately useful
- ○ Slightly useful
- ○ Not at all useful

3. How clear is the information presented in this DVD?

- ○ Extremely clear
- ○ Quite clear
- ○ Moderately clear
- ○ Slightly clear
- ○ Not at all clear

4. How helpful was the format of this professional development DVD?

- ○ Extremely helpful
- ○ Quite helpful
- ○ Moderately helpful
- ○ Slightly helpful
- ○ Not at all helpful

5. What additional information would you like to see on this DVD in the future?

Copy and paste the following address in an internet browser: https://www.surveymonkey.com/s/VT233YK