1-1-2017

Readin', Writin', An' 'rithmetic: Literacy Strategies In High School Mathematics

Angela Margaret Principato
Wayne State University,

**READIN', WRITIN', AN' 'RITHMETIC:
LITERACY STRATEGIES IN HIGH SCHOOL MATHEMATICS**

by

ANGELA M. PRINCIPATO

DISSERTATION

Submitted to the Graduate School

of Wayne State University,

Detroit, Michigan

in partial fulfillment of the requirements

for the degree of

DOCTOR OF PHILOSOPHY

2017

MAJOR: CURRICULUM & INSTRUCTION

Approved By:

Advisor Date

DEDICATION

For my parents

John & Donna Smeekens

ACKNOWLEDGEMENTS

I would like to thank my advisor, Dr. Tom Edwards for his patience, encouragement, motivation, inspiration, support, and for helping me see this through to the end. I have enjoyed learning from you and I am grateful for all the wisdom you have shared.

I would like to thank Dr. Asli Koca, Dr. Dan Frohardt, and Dr. Ben Pogodzinski for agreeing to be members of my doctoral committee. Dr. Frohardt, you have inspired me to learn mathematics and Dr. Koca, you have inspired me to become a better mathematics teacher. Dr. Pogodzinski, thank you for supporting me in the brief time that we have worked together. I have much to learn and the time and suggestions you have all offered have been greatly appreciated. Thank you.

There are several colleagues I would like to thank as well. Gail Ashburn, thank you for being patient with me as I transitioned from the "it's not my job" math teacher to fully embracing the literacy strategies you shared. Thank you for reading, proofreading, and offering suggestions throughout this process. Thank you for being a literal shoulder to cry on. Thank you friend! Carmen Kennedy, thank you for being a strong and resilient role model for me. Your inspiration through your trials helped see me through this endeavor. In a world of ordinary mortals, thank you for being a Wonder Woman.

I don't think I can thank my husband Antonio enough for all his support. I know it has been a long, tough road. There have been far more difficult times than easy times for us throughout this journey. Thank you for encouraging me to become the power suit woman that you have always seen in me! I love you.

I began this journey after I lost my first child and I thought it was unlikely that I would become a mother. It started as a way for me to fill my time as I grieved. By immersing myself in learning to become a better mathematics teacher, I was able to move beyond my grief. Out of that, I have been granted two wonderful children. There were long nights away from you at class and early mornings while I worked and you slept. Thank you Sophia and Victor for the happiness you have given me. I hope that my journey reminds you to live our family motto, "Never give up, never surrender!" I love you.

I would not have been able to reach this point without the help of my family. From my earliest memories, my parents emphasized the importance of school. As a child, I hated doing my homework before I could go out and play, but it instilled in me the work ethic that has gotten me to this point. Thank you Mom and Dad for everything! I also want to thank my sisters Lisa and Janet for their continued support and love. You have all made this possible in your own way and I love you all very much. Thank you. I also could not have done this without my parents and in-laws who took time out of their retirements to watch my kids so I could get some work done. Thank you!

And finally, to my students. Thank you for inspiring me to continue to hone my craft. Thank you for working hard to get better at math. Thank you for appreciating my nerdy love of math. Thank you for teaching me as I sought to teach you. I never thought so many of you would want to call me doctor, even before I had officially earned the title.

My love for all of you has no limit!

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1 INTRODUCTION

The idea for this study came to me during summer vacation 2013. In 2011, my high school was placed on a state designated list for having poor performance on state standardized assessments. The state top-to-bottom ranking is created every year based on student achievement in core academic subjects, school improvement, and achievement gaps between the top and bottom 30% of students. These factors had placed my school at the 4^{th} percentile in the state. My district brought in a promising young principal who was full of passion and energy. We followed in the footsteps of a nearby high school that was similarly low achieving, but made impressive gains in one year. Immediately, teachers were required to implement reading strategies in their classrooms on a quarterly basis. We were asked to incorporate textbook tours, talking to the text, and word walls into all content areas.

I am a mathematics teacher and I thought those strategies were not for me; they were not going to help my students think and reason mathematically. I did the bare minimum. Once per quarter, I used the designated strategy and completed the survey to document my compliance. Then, in the 2012-13 school year, we had even more strategies to implement: vocabulary strategies and writing across the curriculum on top of the strategies from the year before. I found myself grumbling about those reading teachers and what they were making us do.

But then we got our state standardized test results. My school had moved from the bottom 5% in the state to the bottom 15% in one school year! I began to wonder if there was something to the reading strategies we were implementing. I befriended the reading teachers and sought out ways to incorporate the reading strategies with fidelity in my classroom.

Over summer vacation before the 2013-14 year, I began doing some reading about implementing literacy strategies in high school mathematics classes. I read Fisher, Frey, and Williams (2002) and learned about the significant changes they impacted in a large, public school in California by implementing seven specific literacy strategies throughout the school. I realized that what I had been forced to incorporate into my classes was research and evidence based. I decided to implement literacy strategies with fidelity and see what happens. I started the 2013 school year with the news that my school had moved to the bottom 18% on the state top-to-bottom ranking.

Local and national standardized assessments give us insight into our student's reading, writing, and mathematics abilities. For decades, multiple organizations have made it their mission to collect and analyze data regarding the achievement of students. The National Assessment of Educational Progress (NAEP) as well as the American College Test (ACT) track such data across the United States of America while the Programme for International Student Achievement (PISA), the Trends in Mathematics and Science Study (TIMSS), and the Progress in International Reading Literacy Study (PIRLS) report data internationally. Our lack luster performance in mathematics has given rise to various attempts to improve mathematics education in the United States. The adoption of the Common Core State Standards (CCSS) throughout most of the country has been seen as an opportunity to improve mathematics education in the United States and help move our students to higher achievement on these national and international measures. In addition to these unified standards, new instructional strategies appear regularly in practitioner journals and professional development workshops. This study will provide evidence that the inclusion of literacy strategies in high school mathematics may support the mathematics achievement of high school students.

Background of the Problem

The lack of significant growth on national standardized testing has given rise to reform efforts in education. Hall (2002) suggests that some standardized tests are truly tests of reading comprehension. Content area reading and disciplinary literacy form a foundation for a potential means to improve scores on standardized tests. A small, suburban high school showed gains on state rankings based on standardized tests in a few short years after the implementation of specific literacy strategies in all classes.

Standardized Testing. One of the most common measures of student achievement throughout the country is the use of standardized tests. The National Assessment of Educational Progress (NAEP) provides evidence of student achievement in both elementary and secondary schools while the American College Test (ACT) provides evidence of student achievement near the end of secondary education. Over the last several administrations of these assessments, the nation has seen little to no improvement in student achievement.

The National Assessment of Educational Progress (NAEP) shares data regarding student achievement in reading and mathematics every two years. A representative sample of students in grades 4, 8, and 12 across the country participate in NAEP. In both reading and mathematics, students who score proficient “demonstrate competency over challenging subject matter" (https://www.nationsreportcard.gov/reading_math_2015/files/infographic_2015_math.pdf). In comparing the results from 2015 to 2013, across all three grade levels and both subjects, the percent of students at or above proficient decreased, save fourth grade reading. Additionally, within each subject, the percent of students at or above proficient continues to decrease as the students progress through their schooling.

Another measure of student achievement that receives a great deal of attention is college entrance exams. The ACT is widely used throughout the United States and until 2015 was required of all high school juniors in the State of Michigan. The 2014 report indicates that 44% of tested high school graduates met the college readiness benchmark in reading and 43% met the college readiness benchmark in mathematics. Although the student achievement data of the ACT is not necessarily representative of the national population of all secondary school students, the results still provide evidence of subpar reading and mathematics achievement in the nation.

While NAEP provides a representative sample of students across grade levels and the ACT provides a non-representative sample across high school graduates, both show evidence of little to no growth in reading or mathematics. Many reform efforts have been introduced to help improve student achievement across the country.

Reform Efforts. In 2010, the Council of Chief State School Officers (CCSSO) published the Common Core State Standards (CCSS) in English Language Arts (ELA) and mathematics. In 2014, the National Council of Teachers of Mathematics (NCTM) published *Principles to Action: Ensuring Mathematical Success for All.* These two publications have provided the standards and vision for implementation to combat the limited growth on national standardized assessments over the last several testing cycles.

The CCSS in English Language Arts (ELA) and mathematics were published in 2010 and are currently being utilized in more than forty states. Throughout the country, the implementation of the CCSS has begun to unify exactly what content we expect students to master. They "provide clear and consistent learning goals to help prepare students for college, career, and life" (http://www.corestandards.org/read-the-standards/). This uniform set of standards has been seen as an opportunity to improve reading, writing, and mathematics education in the United States and help move our students to higher achievement nationally and internationally.

In addition to the content standards, the CCSS in mathematics include Standards for Mathematical Practice (SMP) which describe the ways that students should interact with the mathematics. Teachers should aim to develop these practices in their students so that they become more effective learners of mathematics. While the CCSS in mathematics and the SMP outline the content and practices students aim for, NCTM has offered their vision to make the CCSS in mathematics into a reality.

NCTM published *Principles to Action: Ensuring Mathematical Success for All* in 2014 and work to disseminate their vision of mathematics education to educators across the country. It provides principles for teaching and learning high quality mathematics. *Principles to Action* "describes the conditions, structures, and policies that must exist for all students to learn" (p. vii). The CCSS outlines the necessary content, the SMP offer the habits of mind for students, and *Principles to Action* provides the framework for teacher implementation.

The adoption of the CCSS throughout most of the country is an indication of our commitment to ensure that our students are fully prepared for life beyond the classroom including giving them the tools to compete in a global economy. The content standards for mathematics and the SMP outline the necessary concepts, skills, and attitudes students need to master in order to be successful in mathematics. NCTM's *Principles to Action* offers the means for teachers to make their classrooms conducive to doing so.

Content Area Reading and Disciplinary Literacy. The CCSS in ELA include standards for literacy in history/social studies, science, and technical subjects. This is evidence of the need for content area teachers to do more than simply teach content. The CCSS expect teachers of history/social studies, science, and technical subjects to help students meet the literacy needs of their disciplines; however, the CCSS do not necessarily include mathematics in those literacy standards. In the section titled "What is not covered in the Standards," the CCSS authors state:

> Similarly, the Standards define literacy expectations in history/social studies, science, and technical subjects, but literacy standards in other areas, such as mathematics and health education, modeled on those in this document are strongly encouraged to facilitate a comprehensive, schoolwide literacy program. (http://www.corestandards.org/ELA-Literacy/introduction/key-design-consideration/)

Content area reading has a long history (Mraz, Rickleman, and Vacca, 2009) of general strategy instruction across the curriculum. It has supported the implementation of general literacy strategies such as predicting, questioning, and summarizing across the curriculum. Such strategies can be adopted across the curriculum due to their generalizability. The emerging field of disciplinary literacy has a much shorter history (Moje, 2008; Shanahan and Shanahan, 2008), but is the foundation of the CCSS literacy strategies in history/social studies, science, and technical subjects. Disciplinary literacy seeks to help students use literacy skills based on the needs of individual disciplines. The CCSS promote this idea by noting "Literacy standards for grade 6 and above are predicated on teachers of ELA, history/social studies, science, and technical subjects using their content area expertise to help students meet the particular challenges of reading, writing, speaking, listening, and language in their respective fields" (CCSS ELA, 2010b, p. 3). Unlike content area reading, disciplinary literacy is not generalizable across the curriculum because the strategies develop out of the specific needs of the disciplines. Here, general strategies are not sufficient and must be adapted to fit the needs of the curriculum.

Because this study focuses on the inclusion of literacy strategies in high school mathematics, we must emphasize the role of content area reading and disciplinary literacy in mathematics. In tandem, the adoption of general strategies provided by content area reading and the adaptation of them to support disciplinary literacy provides the framework for this study. Brozo, Moorman, Meyer, and Stewart (2013) suggest a compromise between these two as what is best for students.

My High School. In 2011, my high school was identified as a Persistently Low Achieving (PLA) school due to our low student achievement on state standardized assessments. The state top-to-bottom ranking is created every year based on student achievement in core academic subjects, school improvement, and achievement gaps between the top and bottom 30% of students. These factors placed my school at the 4th

percentile in the state. In the five years leading up to this label, the average ACT Mathematics score at my school varied between 17.8 and 18.5. While relatively consistent within my school, the state average in that same window varied between 18.6 and 19.5. Similarly, my average ACT Reading scores fell between 16.4 and 18.3 while the state varied between 18.7 and 19.4. While the student achievement on the ACT at my school fell below the state average, it was relatively stable from year to year within my school. However, once we were compared and ranked against other schools in the state, it appeared as though my school was not very successful and we began a four-year cycle of monitoring by the School Reform Office (SRO).

Our principal was replaced and we were required to submit a plan for turning our school around. A nearby high school showed achievement gains in their state ranking and attributed their success to the addition of literacy strategies, so my school followed their plan and our new principal required all teachers to implement literacy strategies in their classrooms on a quarterly basis.

National results from standardized tests show that US students are not achieving at high levels in mathematics or reading. The adoption of the CCSS in ELA and mathematics were seen as a means to combat this, but after several years of implementation, US students are still not showing significant growth. A revitalization of content area reading and the introduction of disciplinary literacy has motivated the use of literacy strategies across the curriculum to promote academic achievement. My school has implemented school wide literacy strategies and seen significant growth in their ranking on the state top-to-bottom ranking.

Statement of the Problem

National standardized tests provide evidence of little to no growth in student achievement in reading and mathematics over the last several testing cycles. In an effort to improve achievement, many states have adopted unified standards in ELA and mathematics. Within the CCSS in ELA, there is a focus on disciplinary literacy in history/social studies, science, and technical subjects. There are not literacy standards for mathematics, but the authors suggest that such literacy expectations would enhance a school wide literacy program.

A growing number of high school mathematics teachers have successfully implemented literacy strategies (VanGarderen, 2004; Sliman, 2013; Roepke & Gallagher, 2015). Recent empirical studies of specific literacy strategies in mathematics show positive effects (Ives & Hoy, 2003; Fisher, 2007; Ives, 2007). This study will provide evidence that the school wide use of literacy strategies may have an impact on student achievement in mathematics.

Purpose of the Study

The purpose of this study is to explore the relationships between students' mathematics and reading achievement scores at a specific school and the implementation of school wide literacy strategies to inform curriculum development and teaching strategies. As a mathematics teacher, my primary interest is how the literacy strategies impact mathematics achievement. However, the impact on reading will also be explored due to the natural connection to literacy strategies. Though national standardized assessments show little to no growth in reading and mathematics over multiple testing cycles, a small, suburban high school has shown consistent growth over several years on the state top-to-bottom ranking. Having moved from the 4th percentile on the state top-to-bottom ranking to the 25th percentile in three short years, district administration attributed this growth to the school wide implementation of literacy strategies. Throughout the school, all teachers were required to implement specific literacy strategies in all classes. In addition, various student achievement measures were gathered to provide evidence of school improvement. Students completed practice mathematics ACTs, NWEA mathematics, and NWEA reading assessments in the fall and the spring. Together with the increase in the state top-to-bottom ranking, these factors motivated me to explore the discrepancy between the national trends compared to the local results we had seen in a few short years.

Significance of the Study

This study will explore the relationships between students' mathematics and reading achievement scores and the implementation of school wide literacy strategies at a small, suburban high school. The results of this study will be used by the school improvement team and the staff to determine if the addition of literacy strategies contributed to an increase in student achievement. The results will only be applicable to this particular school and will be used to inform future curriculum development and teaching strategies for use within this school. While the results will not be generalizable to a broader population, the analysis will provide evidence that future studies can be designed to contribute to a larger body of knowledge.

Research Questions

In this retrospective study, I sought to analyze the mathematics and reading data from the school to see if any significant changes occurred in the academic achievement of students during the implementation of these school wide literacy strategies over a two-year span. More specifically, as a result of incorporating literacy strategies throughout the high school, I sought to answer two questions:

1. How was student achievement in mathematics affected by the school wide implementation of literacy strategies?
2. How was student achievement in reading affected by the school wide implementation of literacy strategies?

As a mathematics teacher, I suspected that the implementation of literacy strategies would have little impact on the mathematics achievement of the students. At the time, I viewed the implementation of literacy strategies as intrusions into my classroom that took valuable time away from my content. However, I anticipated the reading achievement of the students would improve. I felt that the purpose of the literacy strategies was to aid in reading and writing and that the strategies that we implemented were designed to support literacy, not mathematics.

Summary

The results of national and international standardized testing have been stagnant over the last several testing cycles. The primary reform efforts to combat this in mathematics have been the implementation of the Common Core State Standards and NCTM's *Principles to Action*. A developing research base has shown that implementing literacy strategies in mathematics can lead to improved student achievement. A small, suburban high school has shown consistent growth on the state top-to-bottom ranking in the years following a school wide literacy effort. Do the results from this school provide evidence to utilize literacy strategies on a larger scale?

Readin', writin' and 'rithmetic were once taught in a one room schoolhouse by a single educator. At the elementary level, the three Rs are still taught by a single educator, though typically in blocks assigned for each discipline. At the secondary level, reading and writing are typically taught in tandem by an English Language Arts teacher and mathematics is taught in isolation by a mathematics teacher. Do the results from this school provide us with any reason to consider utilizing literacy strategies in high school mathematics classes? This study will attempt to provide information that will help school staff plan future curriculum and teaching strategies by exploring the relationships between students' mathematics and reading achievement scores during the implementation of a school wide literacy intervention.

CHAPTER 2 LITERATURE REVIEW

The purpose of this study is to explore the relationships between students' mathematics and reading achievement scores and the implementation of school wide literacy strategies to inform curriculum development and teaching strategies at a specific school. The research is grounded in a combination of the frameworks of content area reading and disciplinary literacy. Brozo, Moorman, Meyer, and Stewart (2013) suggest a compromise between these two as what is best for students.

Theoretical Framework

Content area reading has been around for nearly a century (Mraz, Rickleman, and Vacca, 2009). Sometimes referred to as general strategy instruction, content area reading has supported the implementation of general literacy strategies such as predicting, questioning, and summarizing. Such strategies can be adopted across the curriculum due to their generalizability. The emerging field of disciplinary literacy has been around for less than a decade (Moje, 2008; Shanahan and Shanahan, 2008). Unlike content area reading, disciplinary literacy is not generalizable across the curriculum because the strategies develop out of the specific needs of the disciplines. Here, general strategies are not sufficient and must be adapted to fit the needs of the curriculum.

Content Area Reading. General reading strategies such as predicting, questioning, and summarizing have been the foundation of content area reading for many years. The focus on adopting general reading strategies within other content areas has been seen as a way to reach all learners and support the college and career readiness of secondary students. Conley (2008) focuses on general reading strategies as a means to ensure that students are college and career ready. Faggella-Luby, Graner, Deshler, and Drew (2012) suggest that general strategies are applicable to all learners. However, Siebert and Draper (2012) argue that traditional print text and general reading and writing strategies have "limited relevance in mathematics classrooms" (p. 180).

Content area reading emphasizes adopting reading strategies within other content areas. A focus on writing to learn, note taking, and vocabulary strategies have been the hallmark of content area reading strategies. These traditional content area reading strategies have yielded success in the past; however, the CCSS focus on disciplinary literacy requires teachers to adapt literacy strategies based on the needs of the discipline.

Disciplinary Literacy. The concept of disciplinary literacy is based on the notion that literacy within a specific discipline is dependent on the nature of the subject matter and in turn, requires content-specific skills (Lee & Spratley, 2010; Moje, 2008; Shanahan & Shanahan, 2008). In contrast to content area reading, disciplinary literacy requires teachers to adapt strategies for use within their particular content areas. Lee & Spratley (2010) suggest building specialized vocabulary, using knowledge of text structure, and using norms for reasoning to evaluate claims as examples of discipline specific literacy strategies. The CCSS push for a disciplinary literacy approach in ELA, history/social studies, science, and technical subjects. They also suggest similar literacy standards be utilized in mathematics, yet they are not explicitly defined.

The CCSS Standards for Mathematical Practice outline the habits of mind students should engage in as they study mathematics and provide an entry point for disciplinary literacy in mathematics. Hillman (2014) offers connections between the CCSS Standards for Mathematical Practice and disciplinary literacy practices through a student's ability to communicate mathematics. Additionally, Houseal, Gillis, Helmsing, and Hutchinson (2016) connect the Next Generation Science Standards to the CCSS Standards for Mathematical Practice. Here, the SMP are seen as the means to establish disciplinary literacy in mathematics and science.

Since the development of the CCSS, there has been increased attention to adapting literacy strategies for use in high school mathematics. Sliman (2013) discusses the use of chalk talks to help make student thinking visible. Adams, Pegg, and Case (2015) use anticipation guides to engage students in reading and comprehending mathematical text. Roepke and Gallagher (2015) give samples of semantic feature analyses that can be used in precalculus and calculus.

While the CCSS promote a disciplinary literacy approach to the content areas, there are concerns about the viability of such approaches. The challenges of struggling adolescent readers, English language learners, and students with disabilities are the primary justification against a disciplinary literacy approach (Faggella-Luby et al., 2012). In addition, Heller (2010) argues that a disciplinary literacy approach can be seen as the focus of post-secondary education and apprenticing secondary students to this method is unnecessary.

The solution seems to be a blending of the two approaches—content area reading and disciplinary literacy. Lee and Spratley (2010) recognize that both have a place in schools, but emphasize that the CCSS are about disciplinary literacy. Brozo, Moorman, Meyer, and Stewart (2013) believe that disciplinary literacy cannot completely replace content area reading. In tandem, the *adoption* of general strategies provided by content area reading and the *adaptation* of them to support disciplinary literacy provides the framework for this study.

The Combined Approach. Dunkerly-Bean and Bean (2016) note that "disciplinary literacy draws heavily from previously existing content area reading strategies" (p. 464). The generalized nature of content area reading strategies allow for the adaptation of them to fit the needs of specific disciplines. Additionally, Ippolito, Dobbs, Charner-Laird, and Lawrence (2016) suggest that "much about disciplinary literacy instruction was still to be invented and adapted from older ideas of literacy instruction" (p. 36). In short, disciplinary literacy is rooted in content area reading and it would be difficult to consider disciplinary literacy without also considering content area reading.

Fisher, Frey, and Williams (2002, 2004) incorporated content area reading strategies in a multi-year, school wide intervention at a large, urban high school in California. Over the course of several years, teachers, administrators, and university colleagues united to make positive changes based on these seven literacy strategies: reading to learn, vocabulary instruction, writing to learn, note-taking, anticipatory activities, graphic organizers, and reciprocal teaching. They implemented them at all grade levels and across the curriculum with the expectation that all teachers would use them. Their discipline and dedication was rewarded with great advances in student achievement.

Over the course of three years, this high school made the largest gain in their city on the state's accountability test. They have increased their students' reading achievement by an average of 2.4 years, though still below grade level. In addition to the academic gains, expulsions and drop outs have decreased. When many would look upon this school and think there is no hope, a concentrated, collaborative effort has shown positive results.

Lai, Wilson, McNaughton, and Hsaio (2014) conducted a multi-year, multi-school study on the impact of a combined content area reading and disciplinary literacy program in New Zealand. Their focus was on using the content area and disciplinary literacy strategies to improve reading comprehension. All teachers were engaged in professional development to implement content area reading strategies: reading instruction, vocabulary instruction, writing strategies, and reading and writing for deeper purposes. English and mathematics teachers had additional professional development in the following year with a focus on disciplinary literacy strategies: analyzing course texts, conducting student-centered inquiry, vocabulary instruction, and reading and writing in their content area.

Over the course of three years, students saw statistically significant improvement on reading comprehension in the equivalent of grades 8 and 9 in the US. Additionally, students in the equivalent of grade 10 in the US saw statistically significant increases on their national secondary school qualifying exam.

Fisher et al. (2002, 2004) and Lai et al. (2014) provide evidence that school wide implementation of content area reading and disciplinary literacy strategies can improve the reading achievement of students and positively impact scores on standardized tests, but there is no evidence that school wide implementation of such strategies can improve student achievement in mathematics. However, there is evidence that these strategies can improve the content area academic achievement of students on a smaller scale.

Content area reading strategies such as vocabulary instruction and writing to learn have had positive effects on student achievement. Brown and Concannon (2016) used vocabulary strategies to improve the science achievement of middle school students. Students in the study significantly ($p<.01$) out-performed the national sample of students on seven out of eight test items. The authors note that the vocabulary strategies "were a viable way to help students learn the intended content" (p. 403).

De La Paz and Felton (2010) offer empirical evidence that disciplinary literacy strategies in high school history has positive effects on student achievement. In De La Paz and Felton (2010), the disciplinary literacy practices included considering the author and understanding and critiquing the source of the documents that were utilized. After reviewing multiple primary sources, students wrote an argumentative essay. Students in the experimental group wrote longer essays, had more developed claims and rebuttals, and referred to or cited the primary documents within their essay with greater frequency than those in the control group.

Guzzetti and Bang (2011) investigated the use of a literacy-based unit in high school chemistry. They utilized vocabulary strategies, graphic organizers, and readings from a variety of different texts. Their study found that students who were exposed to the literacy-based instruction had statistically significant increases in chemistry knowledge ($p<.01$) and scientific inquiry skills ($p<.01$) when compared to students who were received no literacy instruction. Though there were no statistically significant changes in attitudes towards science, half of the students who received the literacy-based instruction indicated that the unit caused them to like science more.

Spires, Kerkhoff, and Graham (2016) provide a model for using disciplinary literacy in conjunction with project-based inquiry which can deepen student learning. They outline the disciplinary literacy practices within their inquiry model in ELA, science, history and social studies, and mathematics. They also provide a sample biology lesson including a planning template. While their work is not empirical, it provides a framework for implementing disciplinary literacy practices in mathematics.

Friedland, McMillen, and del Prado Hill (2011) offer an annotated bibliography of literacy strategies for the mathematics classroom. Their goal was to provide a comprehensive list of effective literacy strategies to use in secondary mathematics so that literacy and mathematics coaches could begin to meet the disciplinary literacy demands of the CCSS. In reviewing existing research, they found many articles that identified and described the use of literacy strategies in mathematics, but “the findings regarding their effectiveness are anecdotal rather than evidence based” (p. 62). Of the 24 strategies they included, only 2 were empirical. The lack of empirical evidence on the use of literacy strategies in high school mathematics remains a primary motivation for this study.

School wide implementation of a variety of content area reading and disciplinary literacy strategies has shown increases in the reading achievement of students, but not necessarily in mathematics achievement. Small scale implementation of individual content area reading or disciplinary literacy strategies has shown improvement in student achievement in content areas such as history and science. There is little evidence that small scale use of such strategies and no evidence that school wide implementation of such strategies can impact student achievement in mathematics. Can the school wide implementation of literacy strategies increase student achievement in mathematics?

The review of the literature presented here begins with an expanded view of literacy and text in order to authentically identify the literacy practices in high school mathematics. The connection between mathematics and literacy is examined to make a case that the implementation of literacy strategies can support the mathematics achievement of high school students. Finally, the literature review concludes with an examination of specific literacy strategies that can be adopted or adapted for use in high school mathematics.

Literacy

Literacy has at its roots the Latin word literatus whose literal meaning is "one who knows the letters" (http://www.etymonline.com/index.php?term=literate&allowed_in_frame=0). Consequently, it makes sense that the colloquial meaning of literacy is the ability to read and write. Draper and Siebert (2010) suggest three problems that arise when literacy is limited to this view:

> First, literacy specialists may overlook many of the literacy events that are already present in the classroom. Second, content-area teachers may fail to notice literacy processes that are integral to learning and engaging in disciplinary activities. Third, when literacy instruction is limited to facilitating fluency with printed words, conflicts can arise between literacy and content-area learning goals. (p. 24)

Draper and Siebert offer a vignette of a mathematics teacher presenting a lesson in which students work in pairs to discover the effects of the parameters *m* and *b* on the slope-intercept form of a line. A literacy specialist observes the lesson and concludes that it was lacking any literacy instruction. Their vignette models all three of the problems that arise when literacy is limited to the ability to read and write printed words. First, the literacy specialist fails to notice the literacy events taking place in the class. Specifically, Draper and Siebert suggest that “students should be able to *read* a slope-intercept equation…and *write* a slope-intercept equation” (p. 25). The mathematics teacher is helping her students “become literate with slope-intercept equations of lines” (p. 25). Second, the mathematics teacher is consciously helping her students read information from the equation. Draper and Siebert wonder if the teacher is aware “that students may have difficulty *reading* the calculator-generated graphs” (p. 25). This is a literacy event that is essential to the mathematics lesson, but one that a mathematics teacher may not see as a literacy event. Finally, Draper and Siebert note that the literacy specialist is likely to suggest something akin to reading about or writing a research paper on a mathematician to the mathematics teacher in order to incorporate literacy events in the classroom. The literacy teacher sees this as a great literacy activity, whereas, the mathematics teacher sees this as a distraction from the content. This conflict in what constitutes literacy in the content-area classroom can be counterproductive and disenfranchise colleagues from one another.

In order to alleviate such problems, Draper and Siebert offer a more encompassing view of literacy:

> Literacy is the ability to negotiate (e.g., read, view, listen, taste, smell, critique) and create (e.g., write, produce, sing, act, speak) texts in discipline-appropriate ways or in ways that other members of a discipline (e.g., mathematicians, historians, artists) would recognize as “correct” or “viable.” (p. 30)

This revitalized view of literacy has given rise to the concept of disciplinary literacy—the notion that literacy within a specific discipline is dependent on the nature of the subject matter and in turn, requires content-specific skills (Lee & Spratley, 2010; Moje, 2008;

Shanahan & Shanahan, 2008). In this sense of the word, literacy applies to much more than simply reading and writing and it looks differently depending on the content area.

Borasi and Siegel (2000) provide a means to rethink what texts look like in mathematics classes. Their list of mathematics texts was generated by answering the question "What counts as reading in this classroom?" (p. 112). Their results included notes, lists, drawings, posters, questions, diagrams, charts, concept maps, rulers, and directions for folding paper (p. 139). Siebert and Hendrickson (2010) also include equations, graphs, proofs, and calculator displays as mathematical text. They go on to say "For each of these types of texts, there is a specific literacy—a discipline-appropriate way of creating and interpreting a mathematical text—that students need to develop" (p. 41). This is precisely the concept behind disciplinary literacy.

These expanded notions of literacy and text allows us to more readily see that the reading and writing that students do in mathematics encompasses much more than simply engaging with printed words. As such, literacy strategies have a place in the mathematics classroom.

Adolescent Literacy

In early education, children are learning the foundational skills for literacy in the colloquial sense of the word. However, once they have mastered those foundational skills, students use their ability to read and write in order to learn new material. Chall (1983) developed six stages of reading development to categorize how children transition from those foundational skills into experienced readers. Stage 0 begins with pre-reading skills such as knowing the letters in the alphabet. Stages 1 and 2 generally occur in grades one through three and are considered the phase where students are learning to read. Stages 3-5 occur from fourth grade on and are typically characterized by students reading for learning new material.

Chall, Jacobs, and Baldwin (1990) investigated the transition from stage two to three whereby many students, often from lower income households, begin to lag behind their counterparts in terms of reading achievement. Chall et al. followed 30 students over two school years (beginning with 2^{nd}, 4^{th}, and 6^{th} grade) and found that the second and third graders from low income households scored as well as national averages. It was not until fourth grade that the economically disadvantaged students began to fall behind. This transition period is commonly referred to as the fourth grade slump. Gaps emerged in the areas of word meaning, word recognition, spelling, oral reading, and silent reading comprehension.

In a follow up study with the same students five years later, Snow, Barnes, Chandler, Goodman, and Hemphill (1991) found the gaps were exacerbated. By 11^{th} grade, students from the original study were now reading at the 25^{th} percentile—far below national averages. High expectations were also diminished as only a few students were taking college preparatory classes. As the reading difficulties grow from middle school to high school, students lack the coping skills to be successful and tend to fall behind in other subjects which are text-dependent such as literature and social studies.

Secondary teachers are content area specialists and tend to be unaware of key components of teaching in other disciplines. Key components of literacy instruction include decoding, morphology, fluency, vocabulary, and text comprehension.

Understanding the basic components of literacy as well as specific challenges faced by adolescents will enhance a teacher's ability to infuse literacy strategies in high school mathematics classes.

Decoding. Decoding is also referred to as word identification and is the ability to recognize a word out of a group of letters. Two important skills required for decoding are phonemic awareness and phonics. Phonemic awareness is "the understanding that spoken words are made up of individual units of sound" (Baxter & Reddy, 2007, p. 3) and phonics is "the understanding of the relationship between the letters in the written words and the sounds of these words when spoken" (Baxter & Reddy, p. 4). Phonemic awareness can allow students to decode new words out of ones they recognize by varying a consonant sound. Phonics allows students to decode unfamiliar words by following the patterns they have learned for sounding out words. Such skills are typically taught in lower elementary grades and correspond to Stage 1 in Chall's (1983) reading development. However, it is estimated that about 10% of adolescents struggle with these decoding skills (Baxter & Reddy, p. 4).

Adolescents who struggle with decoding skills have difficulty in making out new words which impacts their reading comprehension and fluency. Additionally, grade-level and content area texts include as many as 10,000 new words for students each year in grade five and beyond (Baxter & Reddy, p. 6). The breadth of new vocabulary and the inability to sound out unfamiliar words contributes to the challenges of adolescent literacy.

Morphology. Morphology is the ability to understand the patterns of word formation or structure using morphemes—the small parts that make up words. Morphemes can be a single letter, such as -*s*, an affix (prefix or suffix), a root word, or a word in and of itself. Understanding the difference in word and sentence meaning by changing a word from singular to plural or from present to past tense is morphology. Understanding how roots, prefixes, and suffixes can be put together to make words are also examples of morphology.

Adolescents who struggle with morphology have difficulty understanding the meaning of words. They may have decoding skills to read or say the word, but without morphological awareness, they are unable to decipher meaning (though they may be able to with context clues). Nagy, Berninger, and Abbott (2006) found that morphological awareness significantly contributes to reading comprehension and is also positively correlated with vocabulary knowledge and reading comprehension. Other researchers suggest that explicitly teaching morphology to adolescents will provide them tools to become better readers (Kieffer & Lesaux, 2010; Gabig & Zaretsky, 2013; Pacheco & Goodwin, 2013).

Fluency. The ability to read smoothly with minimal error is called fluency. Fluent readers can read, either silently or aloud, and are able to comprehend the text automatically. There is no need to decode words as they approach them in their reading so they are able to concentrate on interpreting the meaning of the text.

Adolescents who struggle with fluency tend to read more slowly and stumble over more words in their reading. This impedes their comprehension of the text and they tend to lack a deep understanding of what they have read because they are focusing their attention on decoding the words. Fluency can vary within a particular student based on factors such as "the level of difficulty of the text; the degree of familiarity the reader has with the words, content, and genre of the text; and the amount of practice with the text" (Baxter & Reddy, p. 12). Providing adolescents with opportunities to engage in oral reading as well as modeling oral reading are instructional strategies to help adolescents read more fluently.

Vocabulary. Vocabulary is the literacy component with which content area teachers are likely most familiar. Vacca and Vacca (2008) suggest that direct vocabulary instruction should not be overlooked by content area teachers. However, there are subtleties to vocabulary instruction that content area teachers may not recognize. A key skill associated with vocabulary development is word analysis, which is the ability to understand the parts of the word in order to decode its meaning. Successful word analysis also includes an understanding of the syntax, or the grammatical use of the word. For example, derivative, differentiate, and differentiable are all related, but their use as a noun, verb, and adjective designate different meanings to the words themselves.

The difference in the syntax of content-specific academic vocabulary is one challenge for adolescent readers to notice. Another challenge for adolescents is the variance in meaning of a word from one setting to another. For example, in everyday use the word odd means bizarre or unusual whereas in mathematics odd is used to denote the parity of a number. Finally, Baxter and Reddy noted "In content areas in which text is more technical and abstract, insufficient vocabulary knowledge can become especially problematic for struggling readers" (p. 15). This is especially true for students when reading formal mathematical definitions, theorems, and proofs.

Text comprehension. At the secondary level, students are not simply expected to read text; rather, they must make meaning out of what they read. Chall's idea (1983) that students in grades 4-12 are reading to learn is precisely the concept of text comprehension. Students need to combine all the literacy components of decoding, morphology, fluency, and vocabulary in order to become adept at text comprehension. Challenges in any one of these components impacts the comprehension of what is being read.

Adolescents struggle with comprehension due to content, style, and text structure (Baxter & Reddy, p. 20). High school students are expected to read a variety of texts including narrative, expository, argumentative, persuasive, comparison/contrast, cause/effect, and chronological text. They read from primary sources such as newspapers and magazines, but also speeches and historical documents from generations before they were born. The skills for understanding these types of text are widely varied. Just being able to read the words does not imply that students will comprehend the impact of the words.

Chall's catch phrase (1983) that students in K-3 are learning to read and students in 4-12 are reading to learn minimizes all the work that needs to happen in order for middle and high school students to truly be successful readers. Snow and Biancarosa (2003) suggest that the "later stages might be more appropriately termed 'learning to read to learn' than simply 'reading to learn'" (p. 5). But whose responsibility is it help students learn to read to learn in high school?

Impact in High School Mathematics

The CCSS expect teachers of history/social studies, science, and technical subjects to help students meet the literacy needs of their disciplines; however, the CCSS do not necessarily include mathematics in those literacy standards. In the section titled "What is not covered in the Standards," the CCSS authors state:

> Similarly, the Standards define literacy expectations in history/social studies, science, and technical subjects, but literacy standards in other areas, such as mathematics and health education, modeled on those in this document are strongly encouraged to facilitate a comprehensive, schoolwide literacy program. (http://www.corestandards.org/ELA-Literacy/introduction/key-design-consideration/)

Historically, when content area teachers have been asked to incorporate literacy strategies, they have resisted, claiming that it is not their responsibility to teach reading or they do not feel qualified to do so (Hall, 2005; Ness, 2009; Meyer, 2013). Given that content area teachers resist the incorporation of literacy strategies in their classroom, the *suggestion* for mathematics teachers to use them can be seen as motivation for not using them at all. The following connections between mathematics and literacy provide a case for such efforts to be made.

Hunsader (2004) assessed the quality of mathematical trade books for grade 3 and claims that "the content of both English and mathematics requires development of many of the same skills: pattern recognitions, classifying, examining relationships, organizing thoughts, and solving problems" (p. 618). Mathematically speaking, these skills lay the foundation for the study of algebra. In addressing the growing use of interdisciplinary teaching in elementary schools, Halladay and Neumann (2012) note "in both reading and mathematics, we want students to make predictions, monitor understanding, determine importance, and make connections" (p. 471). While both argue the connection at the elementary level, the same skills transcend middle and high school mathematics. Additionally, the language of mathematics becomes increasingly complex and is traditionally used only in classrooms (Friedland et al., 2011).

Literacy Strategies that Work

If one considers our colloquial definition of literacy, it would be easy to conclude that literacy strategies would simply be strategies for reading a textbook. Our broadened definition of literacy as well as text allow us to consider a wider range of literacy strategies. This section will discuss the impact of literacy strategies across grade levels and disciplines in order to substantiate the rationale for this study. The strategies have been organized into three categories based on their primary use: vocabulary strategies, note-taking strategies, and reading comprehension strategies. However, it should be noted that many strategies are fluid and can be modified for use in a different capacity. The focus on grades 4 and above reflects Chall's idea (1983) that reading to learn is the goal of education at this level. The scarcity of empirical studies regarding the effectiveness of literacy strategies in high school mathematics remains the primary motivation of this retrospective study.

Vocabulary strategies. The primary role of vocabulary strategies is to ensure students understand specific vocabulary. Nagy and Townsend (2012) suggest that "vocabulary learning must occur in authentic contexts, with students having many opportunities to learn how target words interact with, garner meaning from, and support meanings of other words" (p. 98). Such strategies include word walls, word building (understanding root words and affixes), vocabulary sorts, and visual representations like a semantic feature analysis (SFA).

Vocabulary at the secondary level can be categorized as general academic vocabulary or discipline specific vocabulary. General academic vocabulary is used across various disciplines. Coxhead (2000) updated previous research on general academic vocabulary and identified 570 word families to create an updated Academic Word List (AWL). Some of the words on the AWL that appear with the greatest frequency are approach, interpret, require, and significant. Coxhead also investigated the frequency of the word families within different disciplines and found that more than 30% of the word families on the AWL appear in all the disciplines that were investigated. Mathematics was included in the science category and Coxhead found that 9.1% of the words on the AWL were found in all the science texts that were investigated. One of the major criticisms of Coxhead's work is that, while the words span multiple disciplines, their uses within the disciplines can vary. This is often cited as the primary justification for teaching vocabulary in context.

Vocabulary that is typically utilized in a single discipline with a unique meaning in that discipline is called discipline specific vocabulary. Nagy and Townsend (2012) offer polynomial, cytoplasm, and federalism as examples of discipline specific vocabulary. In contrast to general academic vocabulary, one would not use the previous words outside of a math, science, or history classroom, respectively. The presence of both general academic vocabulary and discipline specific vocabulary supports the combined frameworks of content area reading and disciplinary literacy.

Typically used at the elementary level for sight words, word walls have become a more prominent vocabulary strategy at the secondary level. Words are posted in an easily visible location in the classroom for all students and provide a reference point for vocabulary. They allow students to see words that are essential to their understanding of the unit of study. The ability to utilize word walls in all disciplines allows us to classify them as a content area reading strategy.

Yates, Cuthrell, and Rose (2011) investigated the use of word walls among eighth graders in a rural, public middle school in the southeastern United States. Word walls were utilized within ELA, mathematics, and science classrooms as well as in the main eighth grade hallway. The word walls in the classrooms and in the hallway were initially created by the teachers, but as the year progressed, students began to take ownership of the word walls by suggesting words to include and creating the displays. In the one year that the eighth grade students were exposed to word walls, the school saw "double-digit increases from the previous year in percentage of students proficient in all state-tested content areas" (p. 32). Additionally, this school met their Adequate Yearly Progress (AYP) in the year that word walls were used when they had not met AYP in the year prior. The authors are clear that the increases cannot be attributed to the word walls, but neither can the use of them be ignored.

Vintinner, Harmon, Wood, and Stover (2015) interviewed high school English teachers to gather their perceptions on the effectiveness of the use of word walls in older adolescents. Rather than a school wide approach, teachers from North Carolina and Texas volunteered to participate in the study which included an initial interview, teacher training on the use of word walls, journaling while implementing word walls, and post-interviews after having implemented word walls. The teachers in this study reported higher levels of student engagement, deeper and longer-lasting word knowledge, and higher levels of reading comprehension.

Another vocabulary strategy that can be employed in mathematics is the use of root words, affixes (prefixes and suffixes), and connecting related words. For example, the prefix *dia-* means through or across and the root word *–gon* means angle. This knowledge can help students make sense of the geometry vocabulary term diagonal as a segment that goes through an angle. Access to common root words, prefixes, and suffixes on the internet is what makes this strategy particularly accessible to all teachers. As no specific adaptation is needed, implementing this vocabulary strategy is also a content area reading strategy.

Visual approaches that can be used for vocabulary instruction in mathematics include the Frayer Model and the Verbal Visual Word Association (VVWA). These strategies are often considered graphic organizers because of their visual nature and will be explored in more detail in that section. Additionally, a vocabulary sort allows students to activate prior knowledge related to upcoming vocabulary words. Students are presented with the upcoming key terms and asked to sort them into one of three categories: I can define this word, I've heard this word, I have no clue.

Another vocabulary strategy that can be applied in mathematics is the semantic feature analysis (SFA). These are typically arrays which have vocabulary listed along the left side and properties or characteristics along the top. Students would then place a check mark in the appropriate place to indicate if the designated vocabulary word had that property. Two very prolific uses of this in mathematics are in discussing the characteristics of quadrilaterals and the classification of real numbers. Roepke and Gallagher (2015) present sample SFAs for precalculus (functions and inverses) and calculus (limits and differentiability). These examples are not specific to vocabulary knowledge; rather, they apply the vocabulary to various functions.

Fisher (2007) investigated the impact of a school-wide vocabulary program in an urban, California high school over four years. The school instructs 2,300 students where 100% qualified for free or reduced lunch and 76% spoke a language in addition to English at home. His study included five school-wide components: wide reading (including silent sustained reading [SSR] and independent reading across content areas), read alouds and shared reading, content specific vocabulary instruction, academic vocabulary development, and words of the week. In the beginning of the study, the average student read at a 4.3 grade level and by the end of the study, the average student was reading at a 7.6 grade level. Additionally, on state-level standardized assessments, students improved their vocabulary and reading comprehension scores. Finally, the vocabulary scores of a randomly selected group of ninth graders were tracked over four years. They grew from a 6.01 grade level to a 9.94 grade level and 39% of them scored at the post-high school level. Fisher's study shows that change can happen even with the lowest performing students and on a grand scale. He also noted that teacher buy-in and active participation at all levels played a key role.

Note taking strategies. Note taking is probably the most common literacy strategy that mathematics teachers employ. In many high school classes, students are expected to take notes during class lectures or on independent reading assignments. Without direct instruction, many students struggle with the most appropriate ways to take notes. Teaching note taking strategies can help students become more efficient note takers and help them better use their notes to review new learning and prepare for quizzes and tests. Common note taking strategies include two-column notes (Cornell notes), guided notes, and more modern digital notetaking.

Marzano, Pickering, and Pollock (2001) reiterate earlier research that verbatim note taking is “the least effective way to take notes” (p. 43). More appropriate strategies include structured outlines, guided notes, interactive virtual notebooks, or foldables. A typical foldable is taped into a student’s notebook and includes flaps that are folded to strategically reveal definitions, examples, characteristics, notation, or other relevant content. A number of digital tools are also available for students and teachers to share files, such as Google Docs. This technology can allow students to collaborate with each other, provide teachers a way to get students their missing work, or provide teachers a way to provide feedback to students.

Cornell notes are an easy form of note taking to use in mathematics. Little preparation is required due to easy access to multiple templates on the internet that are blank, lined, or grids. The format of Cornell notes is to divide each page into 3 sections. Two vertical sections about 1/3 and 2/3 of the page respectively and a short horizontal section at the bottom of the page. The first vertical column is for keywords or questions, the second vertical column is for the main ideas or notes, and the horizontal section is for a brief summary of the notes. The generic format of Cornell notes makes them a content area reading strategy.

Donohoo (2010) describes the application of Cornell notes in high school science classes. With the help of a literacy coach, science teachers implemented Cornell notes in some classes. The literacy coach was in the science classes and helped teach the technique in conjunction with the science teacher while they gradually released the responsibility of note taking to the students. At the end of the semester, the class averages of those who had used Cornell notes was 10-12% higher than it had been in the previous semester. One teacher who had utilized Cornell notes had all of her students pass the midterm, where a teacher who did not use Cornell notes only had a 70% pass rate.

Guided notes are teacher prepared handouts that provide some of the details of the lesson. They require students to be actively engaged in the lesson in order to fill in the missing pieces of the notes. They are a content area reading strategy as no special adaptations are required to use them across content areas. Among students with disabilities, guided notes have long been considered the most effective note taking strategy. Lazarus (1991) and Hamilton, Seibert, Gardner, and Talbert-Johnson (2000) found that test and quiz scores, respectively, increased significantly after using guided notes with high school students with disabilities. In addition, Hamilton et al. (2000) also found that the quality of student's notes improved.

An emerging means of note taking includes using digital note taking. Some interpret this as taking notes in a digital form, for example, typing them in a word document. Others consider digital note taking as using a shared digital document in which many people contribute simultaneously to the creation of the notes. Orndorff (2015) reported the use of a shared Google Doc for note taking in college level political science and psychology classes. Students were presented the option to participate in collaborative note taking in groups of 3 or 4 or to take notes independently using any means they wanted. A control class that was never presented the option of collaborative digital note taking was used to compare any impact of the digital note taking.

Orndorff found that students who elected to take collaborative digital notes outperformed their peers by a full letter grade and the results were significant at the 0.01 level. Additionally, results from survey data indicated that students who elected to use digital notes used technology often, enjoyed using collaborative notes, and indicated that they were likely to use collaborative notes in future classes. Finally, the results from open ended questions indicated that the shared responsibility or division of labor ensured that no details were overlooked. Challenges that were noted were access to a laptop or tablet, the need to assign roles to each note taker, and difficulty recreating graphs in the notes.

Reading comprehension strategies. Once students better understand content-specific vocabulary and become more adept at taking and using notes, they can focus their attention on deepening their understanding of the content. While we have focused on literacy beyond merely reading and writing printed words, I use the phrase reading comprehension to encompass this expanded view of literacy. In some cases, students are reading and writing in the traditional sense, but in mathematics we also ask students to read and write equations, tables, and graphs. Reading comprehension strategies can be further categorized into reading to learn, writing to learn, anticipatory activities, graphic organizers, and reciprocal teaching. The manner in which these strategies are implemented determines if they are being used in a content area reading or disciplinary literacy framework.

Reading to learn. The connotation of literacy as reading and writing printed text provides us with a starting point for investigating literacy strategies. Traditional mathematics texts (textbooks, problem sets, formula lists) require students to not only comprehend words but simultaneously make sense of numerals and symbols (Adams, 2003) and mathematical signs and graphics (Barton, Heidema, and Jordan, 2002). Given the wide variety of texts in a mathematics class, we turn our attention to literacy strategies that will help students read and interpret the texts in order to promote learning.

Davey (1983) suggests "think alouds" as a way to model our cognitive processes. Teachers who use "think alouds" simply verbalize their thinking as they are reading a text. Davey suggests that teachers model this strategy regularly before asking students to tackle it in pairs and then eventually on their own. The "think aloud" strategy is easy to adopt in mathematics, because many teachers already do these things naturally. This content area strategy can be applied in mathematics when solving an equation, generating an outline for a proof, or tackling story problems. Highlighting the steps as you do them will help students transfer the process to their own thinking. Another modeling strategy to consider is a modified survey, question, read, recite, and review (SQ3R).

Kresse (1984) suggests modified SQ3R for use with word problems. Her primary modification is that the review step is replaced with reasoning and providing evidence, thus transforming this into a disciplinary literacy strategy. Similar to "think alouds," the teacher models the process and Kresse suggests backing off one step at a time until the entire process rests on the students. Much like Polya's (1945) problem solving strategy, the modified SQ3R strategy has students think about the problem and determine an appropriate plan of action before solving and reflecting on the solution. Kresse describes the survey, question, read, and recite parts of the process as modeling, a key component to the CCSS. While "think alouds" and the modified SQ3R strategies can be applied to specific content in mathematics, a useful strategy that applies broadly to mathematics class and traditional mathematics textbooks is the directed reading-thinking activity (DR-TA).

McIntosh and Bear (1993) offer DR-TA as a means to "help students to read, think, understand, and remember what they have read" (p. 40). McIntosh and Bear offer 3 examples of how this strategy can be applied in mathematics classes. The No Book DR-TA is a way to activate prior knowledge about the potential topics in the course. They suggest using this activity on the first day of a class, before students even have a copy of the textbook in their hands. There is also great value in doing this at the end of a semester to compare the students' growth over the course of the class. This DR-TA can also be modified for each unit of study rather than the entire course. The second and third variations are the Table of Contents DR-TA and the Whole Book DR-TA. McIntosh and Bear offer questions to model these DR-TAs which serve as a sort of textbook tour. Rather than a close and critical reading of the table of contents or the whole books, these DR-TAs provide students with the opportunity to see the textbook as more than a collection of homework problems. When students are asked to answer questions, knowing the type of question can help students better answer the questions.

McIntosh and Draper (1995) discuss the question-answer relationship (QAR) as a means to aid in student comprehension. Four categories of QARs allow students to consider questions in relationship to the text rather than insolation. Right There QARs are questions for which the answer is "right there" in the text. These are also referred to as textually explicit questions. An example of a Right There QAR in mathematics would be "State the Pythagorean Theorem." Think and Search QARs have answers that are right there in the text, but require students to think and search for them. An example in mathematics of a Think and Search QAR is a problem that is just like a worked out example, but the numbers have been changed. Students have the process available to them, but they need to apply the process to a new situation. The third QAR is the Author and Me QAR in which the answer is not in the text, nor is there anything like it in the text. These questions typically require an application of prior knowledge in conjunction with recent information in order to answer them. McIntosh and Draper humorously note that with Author and Me QARs "The author assumes that you have a brain and you use it" (p. 123). The final type of QAR is On My Own QAR which involves you putting all your experience together to answer a question whose answer is not at all in the text. An example in mathematics would be to describe real life situations in which negative numbers are used. McIntosh and Draper point out that students "need to be taught how to identify QARs and how to use that information to help them answer questions from their book and how to recognize the appropriate amount of effort needed when answering questions" (p. 123). The investment in time spent practicing and reinforcing this strategy has the potential to improve students' study habits. McIntosh and Draper used learning logs to gather the results of their investigation and found that students were more persistent when they had the wrong answer, they thought more about how much thinking they had to do, and they were more aware of their study habits.

Writing to learn. In the past, note taking may have been the typical form of writing in a mathematics class. Our expanded view of text in mathematics allows us to enhance our view of writing in a mathematics course. Expressing mathematics through writing includes creating equations, tables, and graphs. Just as we have conventions for written language such as capitalization and punctuation, we also have conventions for our written mathematical language such as using the equal sign correctly, including appropriate units of measure, and labelling the axes when graphing. While students are not creating traditional essays to persuade the reader, their writing in mathematics can have the same level of sophistication when they include their thinking and reasoning in addition to the symbol manipulation that is characteristic to mathematics.

Countryman (1992) offers suggestions for ways to use writing to help students learn mathematics. Her ideas include journals, free writes, learning logs, personal mathematics autobiographies, writing about mathematics problems, writing formal papers, and writing test questions. Andrews (1997) offers admit/exit slips, looping, and K-W-L (discussed in further detail in the anticipatory activities section) as additional writing strategies.

Chalk talks are another form of writing that can be successfully implemented in mathematics classes. Chalk talks are meant to be silent conversations among a small group. The conversation happens as students write (with words, graphs, symbols, etc.) in response to a central concept or question. Sliman (2013) discussed the use of chalk talks in mathematics as a way to “make connections between their own thinking and other students’ thinking” (p. 505). Chalk talks can be used as a means to activate prior knowledge at the beginning of a unit or to summarize learning at the end of a unit. In both cases, the classroom discussion that follows the silent conversation enhances students’ ability to make their thinking visible

Halpern and Halpern (2005/2006) suggested having students create their own fairy tale incorporating mathematical ideas they were focused on. Journals (Dougherty, 1996, Albert and Antos, 2000, Baxter, Woodward, Olson, and Robyns, 2002) and learning logs (McIntosh and Draper, 2001) are widely documented strategies, but again, very little empirical information exists about the effectiveness of such strategies in high school mathematics.

Norton, Rutledge, Hall, and Norton (2009/2010) discussed the benefits of a letter writing campaign between pre-service mathematics teachers and algebra 2 students. Their study was an extension of a similar project undertaken by Crespo (2003) with elementary students and pre-service teachers. Seventeen pre-service teachers were partnered with one or two algebra 2 students. The students began the letter writing project with an introductory letter describing their interests and mathematics background. Each week, for a ten-week period, the pre-service teachers provided the students with a mathematical task to be completed in pairs by the end of the week. The students and pre-service teachers had no other contact and used pseudonyms to maintain anonymity.

Two of the authors independently assessed the students’ responses to determine which NCTM Process Standards (communication, connections, problem solving, reasoning and proof, and representations) the students engaged in while completing the task. Their independent assessments were compared for reliability. The authors found that in the first four weeks, student pairs showed great improvement in the areas of communication, problem solving, and representation. There was a dip in all of the processes during weeks five and six which the authors attributed to the change in the semester and a change in students in the classes, some of whom were not engaged in the letter writing for the first four weeks. Problem solving was the only process to continue improving until the end of the ten-week period, while the others seemed to level off.

Pre-service teacher and student reactions to the letter writing campaign varied. Teachers were initially skeptical of the implementation of the letter writing because of the time it would take away from their curriculum. They were excited about the prospect of their students having individually tailored problems to complete. Students were initially unclear about the connection between mathematics and writing, and they expressed frustration at having to write about their mathematics. In the end, both students and pre-service teachers found the experience to be successful. Special considerations the authors mention for further implementation are to consider the gender of the pairings (so they match), to consider high school students who have a tendency for truancy, assigning the pre-service teachers to more than one student, and using more elaborate rubrics for the student work. The authors also point out the meaningful benefits to such a letter writing campaign include partnerships with local high schools and universities as well as between pre-college and college students.

Lesnak (1989) studied writing to learn in remedial algebra in college. Like most teachers, he was skeptical about the advantage of writing to learn in mathematics as well as whether it could have an impact on students' attitudes towards mathematics. Lesnak used an experimental design with four algebra classes of 26 students each. Two classes were taught as he had for more than 25 years and the other two were taught with writing to learn strategies throughout. He describes the students in the experimental group as "unimpressed" and "discouraged to the point of hostility" (p. 149).

One of the initial writing strategies that Lesnak implemented in his experimental group was to write the step-by-step procedure for order of operations problems. He encouraged students to use these when they were stuck on a problem. As an extension to this strategy, before his first exam, Lesnak required (of the experimental group) a written step-by-step procedure for every type of problem he announced would be on the test. These were to be turned in before receiving the exam. All students in the experimental group had completed this for the first exam. Lesnak reviewed the procedures and grouped them as either perfect or nearly so and other. Any student who earned a score of 80% or higher on the test just so happened to have procedures in the perfect or nearly so group. Lesnak presented this evidence to the students upon returning the exams and made no further mention of it. When the second exam rolled around and students inquired into the need to write a ticket, Lesnak realized that writing can have a place in mathematics.

Lesnak's primary goal was to increase academic achievement. He did find the course average in the control group was 74.5% and the experimental group was 77.7% and that the difference in the averages was statistically significant with $p = 0.046$. In the process, however, he “realized the qualitative benefits involving changes in attitude, confidence levels, and self-images might be taking place” (p. 149). Lesnak’s final writing assignment in the experimental group was an evaluation of the course and writing activities. There were 52 students in the experimental group, including eight that did not pass the course, and each one of them wrote a positive review and believed the writing activities helped them to do well. Lesnak notes “I would have been just as enthusiastic with the results of this experiment even if the quantitative statistical analysis had not indicated a significant increase in academic achievement” (p. 155).

These writing strategies provide a means to formatively assess student comprehension and are most often used during or after learning has occurred. Anticipatory activities, however, are designed to be implemented prior to learning in order to activate prior knowledge.

Anticipatory activities. Another literacy strategy that can be applied in mathematics is an anticipatory activity, also referred to as set induction (Schuck, 1969), anticipatory set (Hunter, 1982), or advance organizer (Ausubel, 1960). No matter what term you use, they all represent a brief activity designed to gain students’ attention. One of the pioneers of advance organizers, Ausubel (1968) emphasized that advance organizers were not merely overviews or summaries of what was going to be learned, “but rather are designed to bridge the gap between what the learner already knows and what he needs to know before he can successfully learn the task at hand” (p. 148). Fisher and Frey (2008) describe them as “activities that provoke interest, curiosity, and gain attention” (p. 251).

Examples of anticipatory activities include videos, articles, demonstrations, anticipation guides, and K-W-L (Know-Want-Learn).

Marzano, Pickering, and Pollock (2001) discuss four types of advance organizers: expository, narrative, skimming, and graphic. These are all intended to be used prior to reading or engaging in new materials. Expository advance organizers describe new content prior to student exposure while narrative advance organizers tell a story as a means to present new information. Skimming new materials with a specific focus can be used as an advance organizer as well as a visual display, sometimes called a graphic organizer. Marzano et al. found that all of them produce impressive gains, but expository advance organizers have the largest impact.

Ogle (1986) developed the K-W-L (Know-Want-Learn) strategy as a form of advance organizer for expository texts. The abbreviation represents what students *know*, what students *want* to learn, and what students have *learned*. Typically, students record this information in a chart with three columns. The first column addresses prior knowledge and provides students with a chance to brainstorm what they already know about a certain topic. The second column helps set the purpose for reading, usually to learn more about the topic. The final column is meant to be addressed after the reading and as a check to see if they learned what they wanted to learn. While it appears as though K-W-L requires the use of expository text, it is easily adapted for use prior to a discussion or project in mathematics classes. Such adaptations promote the use of K-W-L as a disciplinary literacy strategy. For example, one could use this when discussing the Pythagorean Theorem, the real number system, or the beginning of any unit that extends from a previous one.

Anticipation guides are typically true/false or agree/disagree statements that students respond to before reading or engaging in a learning activity. Similar to K-W-L, this activity will draw out prior knowledge; however, it forces students to make a decision based only on their preconceived notions of the topic. After reading, the student responses are revisited with a focus on providing evidence from the text to support any changes the students make. Adams and Pegg (2012) studied the ways that mathematics and science teachers implemented anticipation guides in secondary science and mathematics classes. Their classifications for implementation parallel the use of anticipation guides as a content area reading strategy or a disciplinary literacy strategy. Teachers who simply had students find the answers in their reading were implementing anticipation guides from a content area reading framework. But when teachers utilized anticipation guides "that elicited students' prior knowledge, engaged students in making inferences from the readings, and required them to justify responses with evidence from the text" (p. 156), the implementation became a disciplinary literacy strategy.

Adams, Pegg, and Case (2015) discuss the use of anticipation guides in mathematics to assist students in not just reading, but comprehending complex mathematical text. Their work in the Literacy Instruction in Math and Science for Secondary Teachers (LIMSST) project found that mathematics teachers valued anticipation guides as a means to encourage students to justify their thinking. In doing so, anticipation guides provide a venue for allowing for students to engage in the Standards for Mathematical Practice.

Additional work by Mayer (1983), Corkhill (1992), Sirhan and Reid (2002), and Domin, (2008) confirm the effectiveness of advance organizers; albeit at the collegiate level and in science rather than mathematics. Anticipatory activities are intended to draw out prior knowledge to help students connect previous learning with new learning. Another meaningful literacy strategy is graphic organizers which offer a visualization tool to support student learning.

Graphic organizers. Graphic organizers have their origins in the advance organizers described by Ausubel (1960) which were designed to help students make sense of written passages through pre-reading or anticipatory activities. In the time since then, graphic organizers have come to be a hybrid of visual displays and concise writing to organize concepts most similar to the graphic advance organizers described by Marzano, Pickering, and Pollock (2001). Graphic organizers can be used as a pre-reading strategy, often referred to as advance organizers, or as a summative strategy, often referred to as a post organizer. They can take on many forms including concept maps, Venn diagrams, Frayer model, verbal visual word association (VVWA), and K-W-L charts. The Frayer model and VVWA have many similarities. Both are graphic organizers that have been segmented into quadrants. In both organizers, two of the quadrants are a definition in your own words and characteristics of the topic. The Frayer model reserves the remaining quadrants for examples and non-examples and places the term in the center of the model. The VVWA allocates one quadrant for the term itself and the remaining quadrant is for a visualization of the word. These graphic organizers are particularly useful in mathematics, in particular for the introduction of parent functions in algebra.

Ives and Hoy (2003) and subsequently, Ives (2007) successfully utilized graphic organizers in high school mathematics with students with learning disabilities. Ives and Hoy present two graphic organizers for use in high school algebra. They refer to the first as a graphic organizer with no frame and use it to teach negative integer exponents. In conjunction with discussion, they complete the organizer to get at the pattern of both increasing and decreasing powers of 2. This is a technique that many teachers would use to present not just negative exponents, but also zero exponents. Presenting it in this manner helps students logically extend what they already know about positive exponents and in doing so, allows students to look for and make use of structure and express regularity in repeated reasoning, thus engaging the Standards for Mathematical Practice.

The second graphic organizer Ives and Hoy present is used for solving systems of three linear equations with three variables. The format and structure of the graphic organizer are intended to eliminate the common student error of not finding the values of all the variables to completely solve the system of equations. The layout of the organizer is a 2x3 array with the intent of having students start in the top left with all three equations. Working clockwise, students use the first row to eliminate variables and the second row to back-substitute to find the values of all the variables.

Ives (2007) reports results of the use of this second graphic organizer with students with learning disabilities. In his first study, Ives sought to determine if the use of the systems of equations graphic organizer for 2x2 systems helped students perform better immediately after instruction as well as on a posttest a few weeks later. The graphic organizer group had 14 students and the control group had 16 students. English was the first language for all students and just over two-thirds of each group had been diagnosed with language-related disabilities. Ives presented the lessons after having spent at least one week in the classes to allow the students to be accustomed to him. Ives used an alpha level of 0.10 rather than the customary 0.05 due to a lack of available research and the small sample size. The scores of the graphic organizer group were statistically significantly higher than the control group on a teacher designed test ($p = 0.087$), a researcher designed test taken immediately after instruction ($p = 0.009$), and a researcher designed test taken 2-3 weeks later ($p = 0.020$).

Ives followed up this study with a similar one to see if the results could be replicated in a 3x3 system. This study used a much smaller sample with five students in each of the treatment and control groups (none of whom had participated in the previous study). This study only included an immediate test following instruction for which the results were not statistically significant ($p = 0.327$). In addition to the small sample size, Ives suggests that an intervention provided by the usual classroom teacher may have altered the outcomes.

Graphic organizers provide a variety of visualization tools to assist students in comprehending mathematics. A final comprehension strategy is reciprocal teaching.

Reciprocal teaching. Reciprocal teaching is a strategy for collaborative groups to summarize brief expository passages. A student in the group acts as the teacher/leader and guides the group in four stages: summarizing, questioning, clarifying, and predicting. When students are beginning to use this strategy, each student takes on a role in which they focus on one of the four strategies. In subsequent reciprocal teaching activities, students will rotate roles. After they have practiced all roles, student groups are ready to use reciprocal teaching independent of the classroom teacher.

In mathematics, reciprocal teaching takes on a slightly different shape, thus classifying is as a disciplinary literacy strategy. VanGarderen (2004) suggests that reciprocal teaching can be modified to assist students in comprehending word problems in mathematics. Just as in traditional reciprocal teaching, the student leader in each group leads students in four stages. After all students in the group have read the word problem, the student leader seeks out any phrases or vocabulary that need to be clarified, uses questions to draw out the main idea of the word problem, and summarizes what needs to be solved. The final and only different stage is to create a plan to solve the problem.

Reciprocal teaching was first studied by Palincsar and Brown (1984) with seventh graders. Their study found that students who had received the reciprocal teaching intervention had improved questioning and main idea summaries that was not matched by students in the control group. Alfassi (2004), reported the use of reciprocal teaching in conjunction with direct instruction at the high school level. Her first study focused on two freshmen English language arts classes in a largely middle-class, suburban, Midwest high school. These students showed statistically significant ($p<.05$) improvement on reading assessments and standardized reading measures. In a follow up study to see if similar results can be obtained outside of English language arts classes, Alfassi (2004) investigated the use of reciprocal teaching in science, social studies, and mathematics classes. Participants were sophomores at a largely middle-class, suburban, Midwest high school. Students received 20 minutes daily of direct instruction using reciprocal teaching from readings within the current curriculum with a focus on informational texts such as textbooks, articles, or lab reports. Alfassi hypothesized that students would improve their achievement on textually implicit questions after receiving the intervention. Pre and post tests were used to compare the effects of the intervention. Alfassi found that students showed a significant ($p<.001$) improvement on textually implicit questions, but not on textually explicit questions.

Summary

The strategies implemented in my school were intended to improve our school top-to-bottom ranking by giving our students literacy skills to improve their scores on the state standardized test. Fisher et al. (2002, 2004) and Lai et al. (2014) provide evidence that school wide implementation of content area reading and disciplinary literacy strategies can improve the reading achievement of students and positively impact scores on standardized tests, but there is no evidence that school wide implementation of such strategies can improve student achievement in mathematics.

While we had no university involvement and our professional development was limited to short presentations during monthly staff meetings, our school made impressive gains. Over three school years, we moved from the fourth percentile to the 25th percentile on the state top-to-bottom ranking. Many in my school and district attribute these gains to the implementation of these literacy strategies. The purpose of this study is to explore the relationships between students' mathematics and reading achievement scores and the implementation of school wide literacy strategies to inform curriculum development and teaching strategies.

CHAPTER 3 METHODOLOGY

After being identified as a low achieving school on the state top-to-bottom ranking, my small, suburban high school implemented a school wide literacy initiative in an effort to improve the academic achievement of our students. National student assessment data over the last several testing cycles show little to no growth and yet, my school ranking changed significantly moving from the 4th percentile to the 25th percentile on the state top-to-bottom ranking in three years. A variety of data related to literacy strategies was gathered in preparation for our North Central Association (NCA) re-accreditation as well as to comply with requirements under the monitoring of the School Reform Office (SRO). In an effort to better understand the discrepancy between stagnant national standardized testing results and the positive gains made by my school in the state top-to-bottom ranking, the purpose of this study was to analyze local student assessment data to see how student achievement in mathematics and reading changed over the course of a two-year period.

Site

This study was done at a small, suburban, public high school in Michigan. The students who attend this school primarily live in the surrounding neighborhoods with a percentage of students attending through the school of choice program. The family structure varies and includes traditional two-parent homes, single-parent homes, and students who are living with other relatives or guardians. In the 2013-2014 school year, there were 480 students in grades nine through eleven and 504 in the following year. Students in twelfth grade were excluded from the study because the state ranking is based on standardized test scores of the eleventh grade cohort and the school does not target seniors in any of their intervention efforts. The school has four full time mathematics teachers and one special education mathematics teacher. We offer a traditional sequence of courses including Algebra 1, Geometry, and Algebra 2. Our advanced sequence of courses begins with Advanced Algebra 2 and students can progress to Precalculus, Advanced Placement (AP) Statistics, and AP Calculus AB. The special education teacher provides mathematics instruction in a collaborative setting as well as in a self-contained resource room.

As a small neighborhood school, it serves students who have a wide range of academic abilities. Across the school, Advanced Placement (AP) courses, honors/accelerated courses, as well as basic courses are offered. While students are not formally tracked, parents and students are free to select the levels that best suit them; they are placed in classes at the teacher's recommendation in conjunction with scores from standardized tests such as the Northwest Evaluation Association's (NWEA) Measure of Academic Progress (MAP). A variety of intervention courses in reading and mathematics, as well as academic test prep courses for English/Language Arts, mathematics, and science are also offered.

As noted earlier, my school was identified by the Michigan Department of Education as a Persistently Low Achieving (PLA) school after state mandated test scores in 2011 ranked our school in the bottom 5% in the state top-to-bottom ranking. Our school was also identified as having a large achievement gap between Caucasian and African American males. These factors prompted the implementation of literacy strategies as a school wide effort to improve our state ranking.

My role of teacher and researcher led to the selection of this site. As a teacher, I was invested in improving the academic achievement of my students as well as the state ranking of my school. As a researcher, I was interested in determining if changes in our teaching strategies had positive effects on the academic achievement of the students in our school.

Participants

Demographic data for the 2013-2014 and 2014-2015 school years are in Table 1. The state accountability system utilized for ranking schools considers the aggregate of the testing cohort as well as disaggregation of any subgroups of 30 students or more. In my school, our main subgroups are based on gender, race, and students receiving free or reduced-price lunches. For these reasons, I considered these categories when analyzing my data.

Racial data are only reported for Caucasians and African Americans as they make up the majority of our student population and no other racial group in our school has 30 or more students. In 2013-2014, 54.7% of our student body qualified for free or reduced-price lunches and in 2014-2015, 55.6% of our student body qualified. The graduation rate of our school over those two years was 90.4% and 93.5% respectively and we do not track how many students go to college. Finally, only students in grades nine through eleven were considered. The state top-to-bottom ranking is determined by the eleventh grade testing cohort and all intervention strategies were targeted at students in grades nine through eleven.

Table 1

Demographic Data for the 2013-2014 and 2014-2015 School Years

	2013-2014			2014-2015		
	9th	10th	11th	9th	10th	11th
Total	146	170	164	173	154	177
Male	53%	48%	53%	49%	49%	58%
Female	47%	52%	47%	51%	51%	42%
Caucasian	35%	31%	43%	32%	44%	49%
African American	59%	61%	50%	60%	50%	44%

While, the majority of our study body is stable, we experience some transient students. It is important to note the variance in the demographics from the 2013-2014 school year to the 2014-2015 school year. For example, the 9th grade cohort in 2013-2014 consisted of 146 students but when they advanced to 10th grade in the 2014-2015 school year, the class had 8 more students. Our school regularly sees students leave as well as students begin attending throughout every school year, so this net gain is not necessarily composed of new students. Additionally, the racial makeup is vastly different. For example, the 10th grade cohort in 2013-2014 was 61% African American, but when those students advanced to 11th grade in the following year, only 44% of the students were African American. This variance in the student population from year to year must be considered as we are not comparing perfectly matched groups.

Instruments

Once my school was identified as low achieving, several school wide measures were implemented to improve our school achievement. We were being monitored by the state's School Reform Office (SRO) and required to submit a plan for removal from state monitoring. We were also in the midst of renewing our North Central Association (NCA) accreditation. Both processes required data to support our interventions and provide evidence of student achievement.

As part of the ongoing school wide school improvement process, NCA accreditation process, and SRO monitoring, every student in a 9^{th}-11^{th} grade mathematics class participated in several activities that were also used for data collection. In the 2013-2014 school year, every student in a mathematics class completed a full-length practice Mathematics ACT test in the fall and spring of the school year. These test scores provide measures of students' achievement in mathematics. Additionally, all 9^{th} & 10^{th} grade students participated in NWEA testing three times per year. In the 2014-2015 school year, 11^{th} graders were added to the NWEA testing cycle and the practice Mathematics ACT tests were eliminated due to concerns of over testing students. NWEA testing in mathematics provided additional measures of student's achievement in mathematics while NWEA testing in reading provided measures of student's reading ability. Table 2 summarizes the instruments that were used each school year.

Table 2

Summary of Instruments for the 2013-2014 and 2014-2015 School Years

	2013-2014	2014-2015
9^{th} Grade	Practice ACT Mathematics NWEA Mathematics NWEA Reading	NWEA Mathematics NWEA Reading
10^{th} Grade	Practice ACT Mathematics NWEA Mathematics NWEA Reading	NWEA Mathematics NWEA Reading
11^{th} Grade	Practice ACT Mathematics	NWEA Mathematics NWEA Reading

Reliability and validity. My school used the NWEA MAP test to identify gaps in student learning so that teachers could differentiate instruction. Within the school, the results from these assessments helped identify students who could benefit from remediation in a support class. As a computer adaptive test that was utilized three times each school year, the reliability, or consistency, of the test is important. Brown & Coughlin (2007) reported the reliability of the NWEA MAP test as a range of correlation coefficients reflecting the reliability of the test across grade levels. The test-retest reliability of the NWEA MAP with the same form ranged from .79-.94. The test-retest with equivalent forms ranged from .89-.96. The internal consistency was .92-.95. Their overall conclusion was that the NWEA Map test was consistent and reliable.

NWEA also published reliability and validity estimates (NWEA, 2004) based on earlier versions of their assessments. The paper reports the test-retest reliability of the NWEA MAP test from 2002 but notes that it is a hybrid of traditional test-retest and parallel forms models due to the adaptive nature of the test. For test-retest from the Fall to the Spring in mathematics, the reliability for 9th graders was .90 and the reliability for 10th graders was .89 indicating that the test was indeed reliable. The internal consistency of the NWEA MAP test in mathematics was .95 for both 9th and 10th graders in the Fall and .96 and .95 respectively in the Spring. NWEA notes that rather than using Cronbach's alpha to determine the internal consistency, they use a marginal reliability coefficient which "yields results that are nearly identical to coefficient alpha" (p. 3).

The validity of an assessment is the degree to which it measures what it intends to. The NWEA paper asserts that “Content validity of NWEA tests is assured by carefully mapping existing content standards from a district or a state into a test blueprint” (p. 4). Their paper addresses concurrent validity of the NWEA MAP test with reference to several state level tests (Arizona, Washington, and Texas, for example) but there is no concurrent correlation coefficient for any Michigan assessments or the ACT. Brown & Coughlin (2007) acknowledged that while NWEA provides concurrent validity, there is no evidence of predictive validity.

Our school staff utilized the practice ACTs as a way to predict the likely scores for students when they took the state mandated test in the spring. Since our state ranking was based, in part, on the scores on this assessment, we utilized the scores to target our interventions. Within the mathematics courses, students participated in weekly ACT test preparation. The focus included re-teaching previous content as well as developing multiple choice test-taking strategies. Our school has an incentive program for students who earn a composite score of 18 or above on the ACT. Students who were below the target score were encouraged to participate in additional test prep activities including after school tutoring and online test prep. The ACT Technical Manual (2014) gives a median scale score reliability coefficient of .91 for the mathematics test on the six national administrations of the ACT in the 2011-2012 school year.

The ACT is a means for measuring academic achievement and predicting likely success in first-year college courses. The purpose of the test provides a framework for considering the validity. The ACT Technical Manual (2014) addresses content validity in three ways: test items are reviewed multiple times, test items aim to address high school and university curriculum, and careful reviews of different test forms. The predictive validity is based on defining success in a college-level course as having at least a 50% chance of earning a B or better. For example, earning a 22 on the mathematics portion of the ACT predicts that a student has at least a 50% chance of earning a B or better in College Algebra. ACT is careful to note that these benchmarks can be used to determine likelihood of collegiate success, but the presence of other factors contributes to success as well.

Procedures

Multiple sources of data across two years were analyzed. The 2013-2014 school year was the first year our school utilized NWEA and only 9th and 10th graders were tested. Additionally, 9th through 11th graders completed practice mathematics ACTs. At that time, all students had been exposed to literacy strategies in their core classes throughout their entire high school careers. Teachers had been utilizing literacy strategies for two full school years and had become more comfortable with their adaptation and implementation in their content areas. This was also the final year that the state was going to determine the top-to-bottom rankings due to forthcoming changes in the testing structure of students at the high school level. In the 2014-2015 school year, teachers were only required to implement two literacy strategies each semester, thus the practice of using literacy strategies was diminished in comparison to the previous years and the practice mathematics ACTs were abandoned due to a fear of over testing students.

Practice ACT mathematics. The administration of the practice ACT tests was part of the school improvement goals. The mathematics subcommittee of the school improvement team selected the tests from *McGraw-Hill's Conquering the ACT Math* book (Dulan, 2008). Classroom sets of the tests were created and remain housed in the mathematics department storage room. Students took the practice test on a predetermined day during the regular class period of 55 minutes. When formally administered, the test is allotted 60 minutes for completion; however, in this situation, students were asked to do their best in the 55 minutes allotted them. Students took this test using a bubble sheet to record answers while doing any written work on scrap paper which was discarded after the testing session. TI-84, TI Nspire, and TI Nspire CX calculators were used on a daily basis in classes and were available during the practice tests. The school staff uses Data Director, a web-based data warehouse, for most of their achievement data. Answer documents were created and scores were reported in Data Director. Raw scores were exported to Microsoft Excel and converted to an ACT score using the formula provided by the workbook.

At the end of the 2013-2014 school year, it was decided that we would no longer use practice ACTs for data collection in the mathematics department. The primary concern was that we were over testing our students and that they were over burdened with testing by the time the mandatory test was administered in the spring. As an alternative, the school staff held two mock test sessions in the 2014-2015 school year for juniors only. This provided them with an opportunity to experience actual timed testing conditions, including taking a full length test rather than just the mathematics portion.

NWEA mathematics and NWEA reading. In the 2013-2014 school year, all ninth and tenth grade students participated in NWEA testing three times per year. In the 2014-2015 school year, eleventh grade students were added to the testing cycle. Students were tested in Mathematics, Reading, Language Usage, Science-General Science, and Science-Concepts and Processes. During designated weeks, students were pulled from their classes to participate in NWEA testing. These tests are computer-based, adaptive, and untimed. During the mathematics testing window, teachers took their classes to a computer lab where the students logged in to a secure browser. Students were permitted to use scrap paper which was discarded at the end of the testing session. Students were not permitted to bring handheld calculators in during testing; rather the browser provided students with a calculator on screen for specified problems only. The on-screen calculator varied between a four-function calculator and a scientific calculator, but never a graphing calculator. Students completed as much of the test as they could in the 55-minute class period. Any student who did not complete the assessment in the class period was called out of class the following week to complete testing. All students had access to their scores upon finishing the assessment including an overall score as well as disaggregated scores for operations and algebraic thinking, the real and complex number systems, geometry, and statistics and probability.

Similarly, during the NWEA reading testing window, English teachers took their classes to the designated lab to complete their assessment. As with the mathematics test, the reading test was computer-based, adaptive, and untimed. During the reading assessment, students were not permitted any scrap paper or writing instruments. The testing program included features which allowed students to highlight, add virtual sticky notes, and a line guide to help them keep their place while reading. Students who did not complete the test during the 55-minute class period were called out of class at a later date to complete testing. When a student completed testing, they were immediately provided with their overall score as well as sub scores for literature, informational text, foundational skills and vocabulary, and a lexile score (a measure of reading ability).

Literacy strategies. Beginning in the 2011-2012 school year, teachers in all classes were required to implement two literacy strategies in every class in each marking period of the school year. The required strategies and brief descriptions are listed in Table 3. The strategies were determined by the high school reading teacher in consultation with the building principal. At each monthly staff meeting, the reading teacher modeled one of the required strategies and provided resources for its implementation across the curriculum. Teachers were required to document use of the literacy strategy in a Google Doc.

The implementation of these strategies within the mathematics department included adopting them as is (content area reading) as well as adapting them to meet the needs of the discipline (disciplinary literacy). The vocabulary strategies and note-taking strategies fall into the content area reading framework in that there was no modification required in order to implement in mathematics with fidelity. The reading comprehension strategies were utilized as both a content area reading strategy as well as a disciplinary literacy strategy. The differences between the strategies and the methods of implementation varied.

The initial vocabulary strategy that was implemented were word walls. A sample word wall is presented in Figure 1. In addition to utilizing word walls, other vocabulary strategies in our literacy initiative were to provide skills to assist students in decoding unfamiliar vocabulary by teaching root words, prefixes, and suffixes. This content area reading strategy was seamless to incorporate in mathematics due to the prevalence of Greek

Table 3

Required Literacy Strategies and Brief Descriptions

Term	Strategy	Description
2011-2012		
1st Quarter	Textbook Tour	Activity designed to highlight textbook features
	Talking to the Text	Annotating the text in a conversational style
2nd Quarter	Anticipation Guides	Questions before reading to anticipate learning outcomes
	Exit Tickets	Quick check for understanding done at the end of class
3rd Quarter	Tear & Share	Small groups answer the same questions on paper, tear them off into separate piles, each student reviews one question and synthesizes all the responses into a cohesive final answer
	Two Column Notes	Notes which highlight essential questions on the left side
4th Quarter	Jigsaw Summary	Division of reading so each student becomes an expert in one topic and shares it with their group
	Reciprocal Teaching	Shared responsibility in reading via scaffolded roles
2012-2013		
1st Quarter	Textbook Tour	Activity designed to highlight textbook features
	Talking to the Text	Annotating the text in a conversational style
2nd Quarter	Vocabulary Strategies	Techniques to help students decode unfamiliar vocabulary
	Paragraph Shrinking	Pairs of students take turns reading and summarizing small sections of a larger text
3rd Quarter	Reading Minute	Students read aloud for a minute to practice fluency
	Exit Ticket	Quick check for understanding done at the end of class
4th Quarter	Double Entry Journals	Students record meaningful parts of a text and their reactions
	Word Building	Understanding of roots, prefixes, and suffixes
2013-2014		
1st Quarter	Exit & Entrance Tickets	Quick check for understanding done at the end or beginning of class
	Annotating Text	Writing on the text to highlight key details
2nd Quarter	Graphic Organizers	Visual displays to organize information
	Reading Minute	Students read aloud for a minute to practice fluency
3rd Quarter	Retell-Paraphrasing & Summarizing	Targeted summaries to identify key ideas, claims, and supporting evidence
	Digital Note-Taking & Note-Taking	Alternate note-taking strategies including Cornell notes, Google docs, foldables, and two-column notes
4th Quarter	Scrambled Sentences	Activity designed to properly sequence a story or procedure
	Chalk Talk	Silent conversation written on chart paper

Figure 1. Sample word walls.

and Latin roots in mathematics. The implementation of these strategies included verbal and visual representations and they were used in all mathematics classes from our self-contained special education classes to our Advanced Placement classes. Teachers were required to document compliance by completing a Google Doc. Our special education teacher worked with his class as a whole group to advance their understanding of necessary mathematics vocabulary. This teacher commented “I noticed that when purposeful explicit instruction of math vocabulary occurred, along with providing things such as visual representations and examples/non-examples (Frayer model), students had a greater mastery of the word and could use the technical math words in class discussions” (Reading Strategies Log, Line 41). Our AP Statistics teacher had her students work independently and use their textbooks to acquire necessary vocabulary. She commented “Focus on vocabulary lists in chunks based on sections of their book. Students are expected to use vocabulary appropriately and regularly in their responses. Articulating ideas or arguments in writing is a key component of the course" (Reading Strategy Log, Line 43). Within my classroom, I displayed key roots, prefixes, and suffixes as a part of my word wall and referenced them in whole group discussions as we attempted to decode unfamiliar terms.

The note taking strategies that we were required to implement included two column notes/Cornell notes, double entry journals, general note taking strategies, and digital note taking. These were also content area reading strategies that required no specific modification in order to be authentically utilized in mathematics classes. The Cornell notes template that I utilized had a grid in order to make graphing easy, but I do not believe that modification qualifies this as a disciplinary literacy strategy. The same grid template could be used in science or social studies when students would need to create a graph and the portability from one discipline to another is the main characteristic of content area reading strategies. See Figure 2 for a sample grid Cornell notes template.

Within the mathematics department, many teachers implemented guided notes and interactive foldables. With guided notes, a handout is provided to students to follow along with the teacher through the lesson. Students are required to fill in missing parts of the notes throughout the lesson. One teacher was very adept at creating these to follow along with a video lesson she would stream to the whole class. She commented that this "Help students engage in their guided notes packet (chapter). The students like that they can use these notes for quizzes, it has increased their work with and on the packets. I found that I have to model the interaction with their text - most are getting better at using the notes as

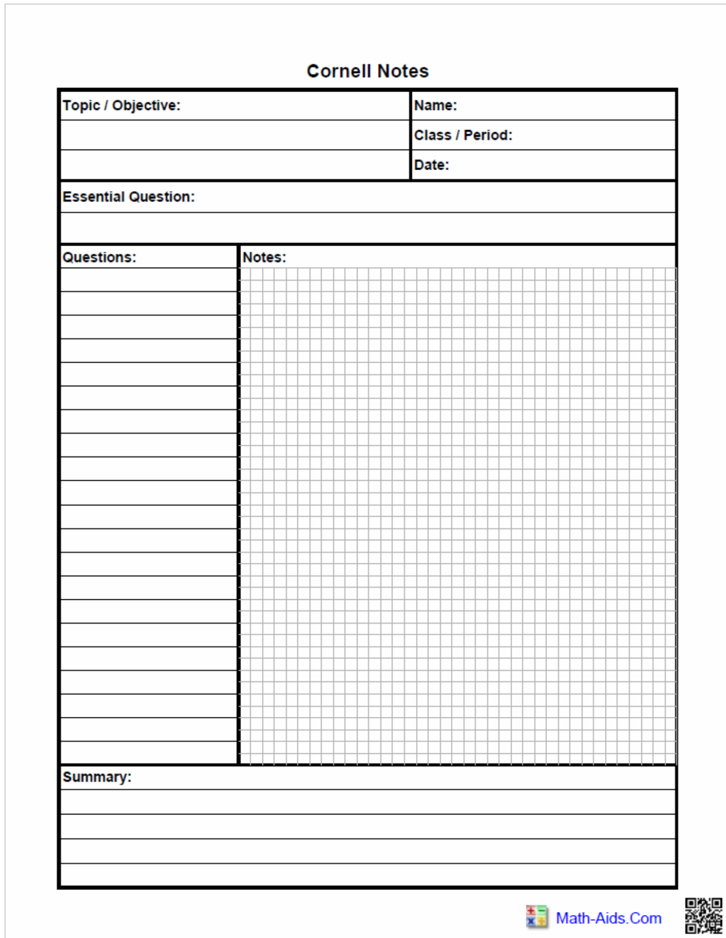

Cornell Notes
Topic / Objective:
Name:
Class / Period:
Date:
Essential Question:
Questions:
Notes:
Summary:
Math-Aids.Com

Figure 2. Cornell Notes. Sample grid Cornell notes (Source: www.math-aids.com)

the guide that they are intended to be" (Reading Strategy Log, Line 34). Another teacher commented "The students need this help at this level (low 9th graders). We also don't have a text book, so creating useful notes is crucial" (Reading Strategy Log, Line 31).

Another note taking strategy that was used by many mathematics teachers were interactive foldables. An Algebra 1 teacher commented "As for notes, we use interactive foldables and notebooks where students put and tape documents into their notebooks and we take notes on them...makes it a little more interesting and engaging then just continuously writing down words....students enjoyed the note taking and find it more helpful as well...however students didn't review these notes for the unit test because scores were very low..need to refer back to notebooks and foldables more often when students struggle” (Reading Strategy Log, Line 30).

As part of our transition to online standardized testing for state accountability, the online math portion required students to be able to use an equation editor to type math font. I recall taking my students to the computer lab once to practice doing this before our online testing began. This was the only use of digital note taking documented by a mathematics teacher. I found that students struggled with using the editor and now that the online math portion has been removed, I would not have my students do this again.

Many of the literacy strategies that were required were reading comprehension strategies that were designed to be used with traditional paragraphs of text. In the Talking to the Text, Annotating Text, Paragraph Shrinking, Reading Minute, Jigsaw, and Reciprocal Teaching strategies, students read traditional passages and interact with them in various ways. The mathematics teachers who engaged in these strategies used them as content area teaching strategies and did not modify them in any way.

The Talking to the Text (T4) strategy has students take notes in the margin of the text in a conversational tone, as if they were talking to it. Many times, the notes would be connections to the content (I’ve heard of that before, I know that person/place, etc.). Annotating the Text is less structured in that students can circle/underline key ideas, terms, people, or vocabulary. Paragraph shrinking has students make a short two- or three-word summary of each paragraph that is read. Reading Minute has students practice their reading fluency by reading aloud for one minute. Jigsaws have students read short parts of a larger whole and come together to share the big ideas. Reciprocal Teaching has students work in a small group and take on a specific role (summarizing, questioning, clarifying, predicting) during the shared reading.

Since we only had textbooks in our advanced classes, these were the only classes that attempted to utilize these strategies using our textbooks. Our AP Statistics teacher often describes her class as a combination of math and reading, so it was no surprise that she utilized these strategies. In each section summary, she utilized Talking to the Text (T4) and commented "kids were somewhat engaged, being an upper class group, opinions abut [*sic*] the usefulness of T4 are formed. Either they like it or they don't" (Reading Strategy Log, Line 36). I was the only other teacher to document the use of these reading comprehension strategies. Since I had no textbook, I used the American Mathematical Society's Mathematical Moments Series for the Reading Minute in my Algebra 1 classes. At the end of every class, I had a volunteer read the one page summaries aloud. Some students found them interesting as they addressed real world applications of mathematics. I found math related articles online to use for the other reading strategies. While I found the articles to be interesting applications of mathematics, the students did not feel the same way. In many cases, my attempts to lead whole class discussions afterward were met with silence. After a few attempts, I gave up on using these traditional text-based literacy strategies. No other mathematics teachers documented the use of these strategies.

The Textbook Tour strategy also posed a problem for the mathematics teachers as only our Precalculus and AP Statistics classes had textbooks at the time. The purpose of this strategy is so that become familiar with standard textbook features such as the index, table of contents, and glossary but also to help students identify the text structures that are specific to their textbooks. Text structures such as highlighting and bold faced words, section introductions and summaries, as well as worked out examples are key things that we want students to identify and use. I consider this to be a content area reading strategy as it can be applied without modification in any content area. Within the mathematics department, the implementation of this strategy was straightforward and continues to be used by the department to this day. Figure 3 shows an excerpt from my Precalculus textbook tour.

Precalculus Textbook Tour

Name: ______________________________

Use your textbook to find the answers to these questions.

1. What is the title of your textbook?
2. Who are the authors?
3. How many chapters are in your book?
4. How many sections are in Chapter 9?
5. On what page does the homework for section 12.1 begin?
6. On what page do the answers for odd-numbered problems begin?
7. On what page can you find information about Kepler's Laws?

Figure 3. Excerpt of a Textbook Tour.

The remaining strategies represent disciplinary literacy strategies in that they needed to be modified in order to be authentically implemented in our mathematics classes. Exit Tickets, Tear & Share, Graphic Organizers, Scrambled Sentences, and Chalk Talks were utilized in the mathematics departments, but exit tickets and graphic organizers were implemented far beyond the required use.

I believe exit tickets became the most used strategy in the mathematics department, not as its use as a literacy strategy, but rather as its use as a formative assessment tool. We used them at the end of class (exit ticket) to assess understanding of the lesson as well as at the beginning of class (entrance ticket) to assess understanding of the homework. One mathematics teacher noted "I either use this as a ticket to start class and gauge whether or not students remember the material from the day before or use at the end of the hour to determine the effectiveness of my lesson and student learning (to guide the next teaching steps)" (Reading Strategy Log, Line 9). The mathematics department determined that their use was so critical, that we created a template to organize the level of student understanding so we can better plan our subsequent instruction. We continue to use exit tickets and are currently working to create common exit tickets for Algebra 1, Geometry, and Algebra 2.

Graphic Organizers were the next most commonly used strategy within the mathematics department. Most of the graphic organizers were used in a content area reading framework—the visual display was not specific to math and it was easily adopted in our classes. The Frayer Model was especially easy to use with each new parent function that was discussed in our Algebra classes. See Figure 4 for a sample templates of the Frayer

Model and Verbal Visual Word Association (VVWA) graphic organizers. One teacher commented "we used a frayer model to explain and go over the basics of a linear functions

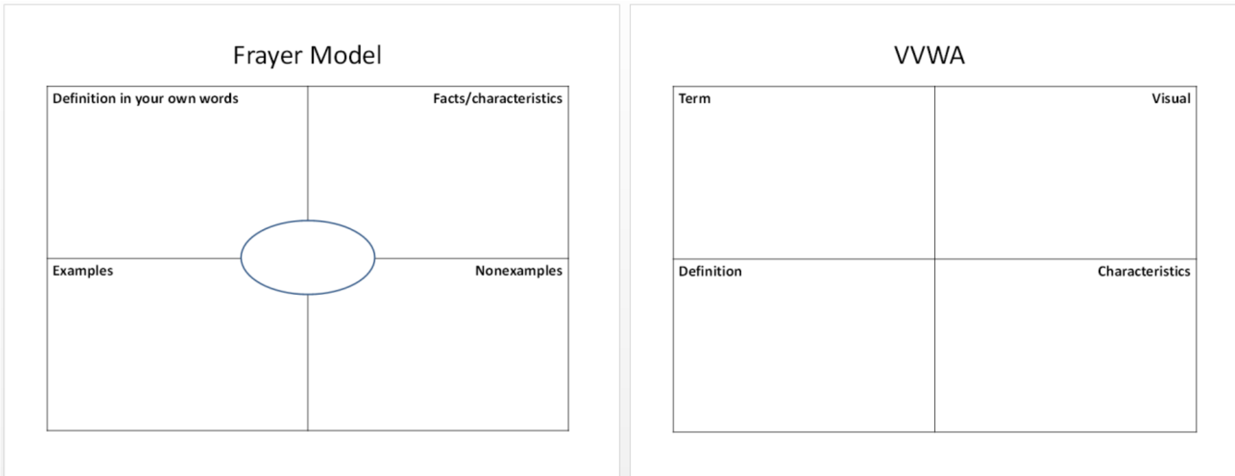


Figure 4. Frayer Model & VVWA. Template of the Frayer Model and Verbal Visual Word Association Graphic Organizers.

and it's characteristics...students also pasted this into their notebooks to make it more 'interactive'" (NCA Strategy Log, Line 9). Flowchart graphic organizers were also widely used in the mathematics department to help students with procedural work. I recall one student in particular who struggled with a factoring flowchart that I had used in precalculus. The flowchart began by having students factor out any greatest common factor and then broke off into three branches. Depending on the number of terms, each branch suggested a factoring technique. This student was frustrated to the point of tears because she couldn't figure out how to use the flowchart. However, when I worked with her independently and verbally asked the questions that the flowchart modeled she was able to successfully factor. For her, the visual display impeded her success where the verbal questioning techniques is what she needed to be successful.

I was the only teacher in the mathematics department to utilize the remaining strategies: Chalk Talk, Scrambled Sentences, Anticipation Guides, and Tear & Share. During a Chalk Talk, small groups of students respond to a central topic or question on chart paper. The goal is for students to engage in a silent conversation about the topic or question by writing on the chart paper rather than talking. The Scrambled Sentence strategy is designed to have students arrange sentences in the correct order. Anticipation Guides are designed to have students activate their prior knowledge about a topic by responding to questions prior to reading and then adjust their misconceptions after reading. Tear & Share has all students in a group respond to several questions and then tear them apart. Like a Jigsaw, one student becomes an expert on one part and then they come back together to share summaries of each question. These strategies were designed to be used with traditional text, but were adapted to be used in mathematics classes, thus I consider them to be disciplinary literacy strategies.

I first used Chalk Talks to review for a unit test. I posed broad questions on the chart paper such as “What do you know about the Unit Circle?” When I first tried Chalk Talks, I found that students struggled with having a silent conversation and using their writing instead. I used exit tickets with my students the first few times I had used Chalk Talks to get feedback from them. A common theme among them was that they weren’t accustomed to writing about mathematics and doing it in the Chalk Talk was a challenge for them. I also struggled with students who didn’t take them seriously. In response to a “What do you know about…” question on the chart paper, I had multiple students write “nothing.” In another instance, I had posed a question about transformations of the sine and cosine curves and I had someone write a joke about the movie Transformers. I was discouraged by the level of regard my students had for this strategy, but I was not ready to give up on it. I sought suggestions from a colleague who had utilized Chalk Talks frequently and her primary suggestion was that I participate in the Chalk Talk as well. She suggested that this would help students take it seriously and allow me to engage in the silent conversations and redirect them as necessary. Since then, I have always participated in the Chalk Talks with my students and I rarely have this issues anymore. See Figure 5 for a sample chalk talk from my Algebra 2 class.

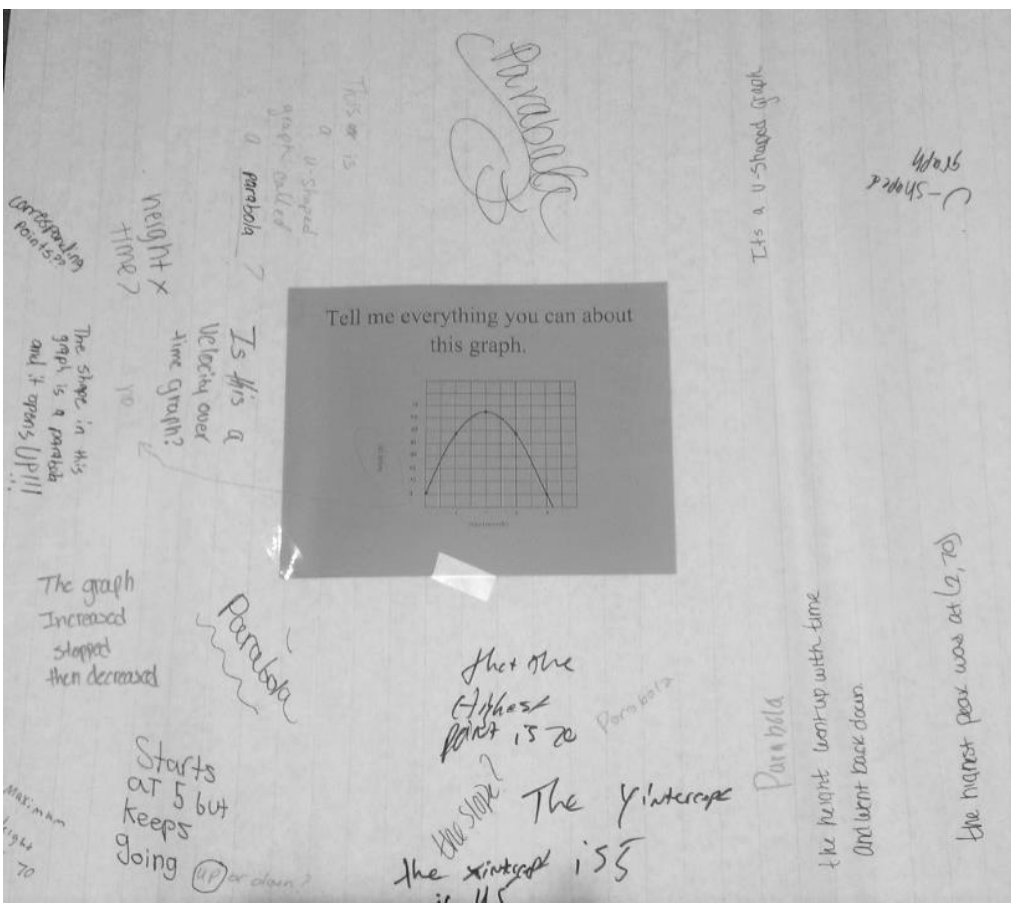


Figure 5. Chalk Talk sample eliciting prior knowledge of key features of the graph of a quadratic function.

I only used the remaining strategies the one time that they were required and since I was the only mathematics teacher to have implemented them, I can only provide my adaptations. The Scrambled Sentence strategy was designed for students to properly order the main ideas of a passage. I adapted this strategy to order the correct mathematical procedure for solving systems of linear equations. I wrote the steps on large, colored sentence strips and had the students work on pairs to unscramble them. I found that most students were able to quickly unscramble the procedure. Anticipation Guides were designed for students to respond to a few questions prior to reading about an unknown topic and then alter their responses, if necessary, after reading. I adapted this strategy so that the reading piece was replaced with instruction and I used entrance and exit tickets as my anticipation guides.

The Tear & Share strategy was designed to have groups of four students answer four questions about a piece of reading. Then each student reviews all the responses to one particular question and synthesizes them into one response. I adapted this to practice a variety of SohCahToa story problems in my precalculus class. See Figure 6 for the sample problems. Each group of four students had four different types of right triangle

1. From a horizontal distance of 80 m the angle of elevation to the top of a flagpole is 18°. What is the height of the flagpole to the nearest tenth?

2. The angle of elevation of the sun is 68° when a tree casts a shadow 14.3 m long. How tall is the tree to the nearest tenth?

3. A 9 m ladder leans against the side of a building. The bottom of the ladder is 1.5 m from the base of the wall. What is the measure of the angle between the ladder and the ground to the nearest degree?

4. A wheelchair ramp is 4.2 m long. It rises 0.7 m. What is the angle of inclination to the nearest degree?

Figure 6. Sample Tear and Share Trigonometry Problems.

trigonometry problems. I gave students time to complete all four problems and then asked them to tear them apart and share them in their group so that one person had all of problem one, one person had all of problem two, and so on. I asked each person now to review all four solutions to the same problem and identify the correct solution. In addition, I wanted students to categorize errors that led to the wrong solution. In particular, I was interested in finding out if there were algebra errors, trigonometry errors, or calculation errors (including calculator in radian mode).

This was one of those lessons that I was very excited about trying and then it was a total flop. I couldn't have any of the rich discussions about student errors because most of the students couldn't do the problems. In retrospect, I had planned this as a review of content that they learned in their previous mathematics class and I had provided no review. I made the mistake of assuming students would remember how to do these types of problems and it backfired miserably.

From the 2011-2012 to 2013-2014 school years, all teachers were required to implement a variety of literacy strategies once in each marking period. The mathematics department did not implement all the required strategies. The limited instances of fidelity of the required strategies poses a concern about the potential impact of these strategies. However, in the last year, all mathematics teachers did fully participate in the literacy initiative.

In the 2014-2015 school year, each teacher was required to utilize only two strategies throughout the year at least once per marking period. The principal and the reading teacher had decided that all teachers had been exposed to a variety of literacy strategies so that they could choose for themselves which strategies fit best into their classes. Within the mathematics department, all teachers were using exit and entrance tickets as one of our strategies, but the second strategy varied amongst the mathematics teachers. Note-taking strategies were utilized by three of the four regular education mathematics teachers and included guided notes, Cornell notes, and interactive foldables. A typical foldable is taped into a student's notebook and includes flaps that are folded to strategically reveal definitions, examples, characteristics, notation, or other relevant content. The sole special education math teacher utilized vocabulary strategies as his second literacy strategy and I utilized chalk talks as my second literacy strategy.

Data Analysis

My school utilizes Data Director, a web-based data warehouse for our student achievement data. At my request, the Director of Instruction and Assessment for my school district provided me with the retroactive data. All data was provided in a Microsoft Excel spreadsheet and student names were redacted prior to my receiving the data. I uploaded the data into SPSS (IBM, 2015) and completed all the analyses using SPSS.

Data analysis was completed by grade level cohort, since the state utilizes the results of the eleventh grade cohort in the state top-to-bottom ranking. Within each cohort, data were also disaggregated by gender, race, and socioeconomic status as determined by students who qualify for free and reduced-price lunches. These subgroups were considered because they are the only subgroups that the state utilizes to determine achievement gaps in my school.

Practice ACT mathematics. Students participated in practice mathematics ACT tests throughout the year and scores on the mathematics ACT range from zero to 36. We were interested in knowing if there was a difference within our group from the beginning of the year to the end of the year. Non-parametric tests were used due to a lack of normally distributed scores. The Wilcoxon signed-rank test was used to determine if there was a significant change from the beginning of the year to the end of the year in students' mathematics achievement. The data were disaggregated based on gender, race, and SES.

NWEA Mathematics and NWEA reading. Students participated in NWEA testing in the Fall, Winter, and Spring. This nationally normed test does not have a maximum score, rather national benchmarks exist for each grade-level and testing cycle. While the national data is normally distributed, it was not likely that our school data would be. For this reason, the Wilcoxon signed-rank test was used to determine if there is a significant change from the beginning of the year to the end of the year in students' mathematics & reading achievement. These data were also disaggregated based on gender, race, and SES.

Summary

The purpose of this study was to analyze local student assessment data to see how student achievement in mathematics and reading changed over the course of a two-year period. Student achievement data was gathered on practice mathematics ACT tests and NWEA tests of reading and mathematics. After the implementation of literacy strategies across the school, these measures were analyzed to better understand the discrepancy between stagnant national standardized testing results and the positive gains made by my school in the state top-to-bottom ranking.

CHAPTER 4 RESULTS

Though national standardized assessments show little to no growth in reading and mathematics over multiple testing cycles, a small, suburban high school has shown consistent growth over several years on the state top-to-bottom ranking. The state top-to-bottom ranking is created every year based on student achievement in core academic subjects, school improvement, and achievement gaps between the top and bottom 30% of students. Having moved from the 4^{th} percentile on the state top-to-bottom ranking to the 25^{th} percentile in three short years, district administration attributes this growth to the school wide implementation of literacy strategies. In this study, I reviewed data gathered for the SRO and NCA processes to see how mathematics and reading were impacted over a two-year span. More specifically, I sought to answer two questions:

1. How was student achievement in mathematics affected by the school wide implementation of literacy strategies?
2. How was student achievement in reading affected by the school wide implementation of literacy strategies?

The state accountability system utilized for ranking schools considers the aggregate of the eleventh grade testing cohort as well as the disaggregation of any subgroup of 30 students or more. In my high school, the only subgroups we have are based on gender, race, and socioeconomic status. For these reasons, I consider these categories in my results. The results will include aggregated grade level data for grades nine, ten, and eleven as well as within grade level disaggregation by gender, race, and socioeconomic status (SES) as determined by students receiving free or reduced price lunches.

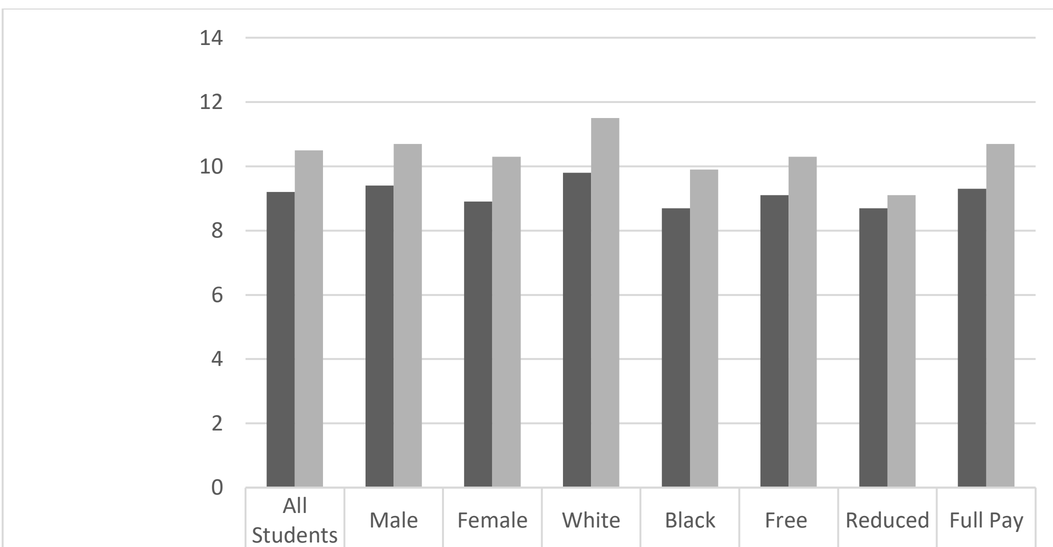
The analysis was completed using SPSS (IBM, 2015). General descriptive statistics were calculated and the means from the fall semester were compared to the means from the spring semester. Additionally, data from the fall semester was compared to data from the spring semester using the Wilcoxon signed-ranks test in order to determine if the changes over the course of the year were statistically significant. This non-parametric test was utilized as the population was not necessarily normally distributed. In performing the Wilcoxon signed-ranks test, SPSS uses the median of the differences to determine significance. In all tests, the null hypothesis was that the median difference between the fall and spring data was zero and $\alpha=.05$.

Research Question 1: How was student achievement in mathematics affected?

Measure # 1: ACT Mathematics. In the 2013-2014 school year, students participated in several practice ACT Mathematics tests. Tests were given via paper and pencil in individual classrooms in 55 minutes, though the test is allotted 60 minutes under standard time conditions. The mathematics section of the ACT is scored as an integer with a maximum value of 36. The following results are separated by grade level and within each grade level, the subcategories or gender, race, and SES are presented.

Ninth Grade Results. This group of students had the most limited exposure to the literacy strategies we had been implementing. At the time they completed their fall ACT Mathematics test, they had only been exposed to exit/entrance tickets and annotating the text strategies. When they completed their spring testing, they had been exposed to graphic organizers, reading minute, paraphrasing and summarizing, and note taking strategies.

The ninth grade cohort in the 2013-2014 school year showed improvement on the ACT Mathematics test as a whole and within every subgroup of interest. Figure 7 shows the mean scores of the ninth grade cohort as well as the mean scores of each subgroup on the fall and spring practice ACT mathematics test. The increased scores were statistically significant for the entire ninth grade cohort, with p=0.013. When considering gender, the increased scores by the males were statistically significant with p=0.042 while the increased scores for females were not statistically significant. African Americans showed statistically significant increases with p=0.047 whiles whites did not show a statistically significant increase. Students who qualify for free and reduced-price lunches both showed statistically significant increases with p=0.049 and p=0.027 respectively. Students who pay full price for lunch did not show a statistically significant increase.



	All Students	Male	Female	White	Black	Free	Reduced	Full Pay
ACT Math Fall	9.2	9.4	8.9	9.8	8.7	9.1	8.7	9.3
ACT Math Spring	10.5	10.7	10.3	11.5	9.9	10.3	9.1	10.7

Figure 7. 2013-2014 9th Grade ACT Mathematics.

Tenth Grade Results. These students had been exposed to the same literacy strategies as the ninth grade cohort in the 2013-2014 school year, but they had also experienced an entire year of strategies in the preceding school year. As freshmen, these students had been exposed to textbook tours, talking to the text, vocabulary strategies, paragraph shrinking, reading minute, double entry journals, and word building strategies. For all the additional exposure to literacy strategies, there was no increase in the mathematics achievement of these students.

The tenth grade cohort in the 2013-2014 school year decreased on the ACT Mathematics test as a whole and within every subgroup of interest except students qualifying for a reduced-price lunch. Figure 8 shows the mean scores of the tenth grade cohort as well as the mean scores of each subgroup on the fall and spring practice ACT mathematics test. The decreased scores were statistically significant for the entire tenth

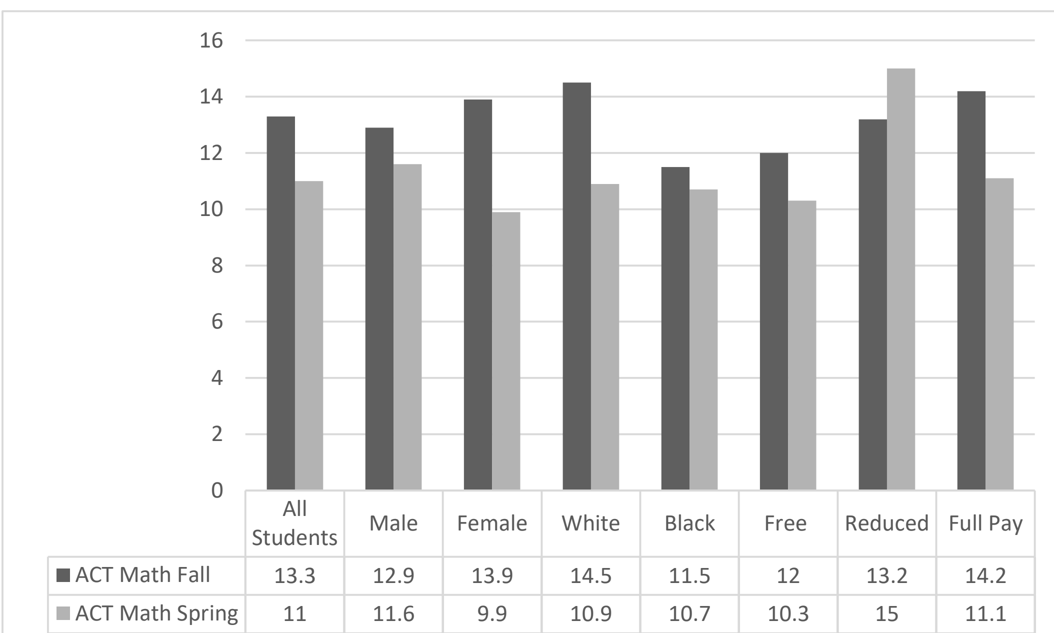
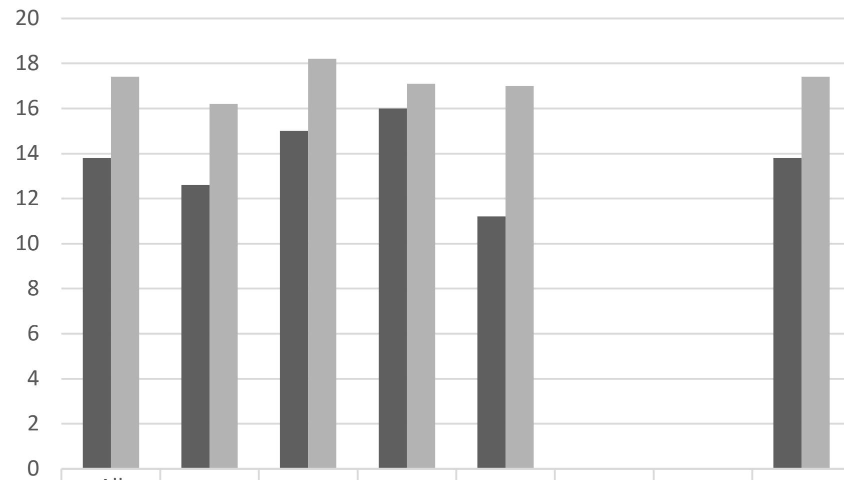


Figure 8. 2013-2014 10th Grade ACT Mathematics.

grade cohort, with p=0.023. The decreased scores by the males were statistically significant with p=0.038 while the decreased scores for females were not statistically significant. Among African Americans and Whites, the decreased scores were not statistically significant. The decrease in scores of students who qualify for free lunch was not statistically significant. Students who pay full price showed a statistically significant decrease with p=0.035. The only group to have their scores increase were those students who qualify for reduced-price lunches and their increase was not statistically significant.

Eleventh Grade Results. This group of students had the broadest exposure to literacy strategies over the course of their high school education. The year that this group of students were freshmen corresponded with the year that my school began our school wide implementation of literacy strategies. The eleventh grade cohort had been exposed to all the same strategies as the ninth grade cohort in the 2013-2014 school year and like the tenth grade cohort, had been exposed to the same literacy strategies in their previous year of school. Additionally, in their freshman year, they had also been exposed to anticipation guides, tear and share, two column notes, jigsaw summary, and reciprocal teaching.

The eleventh grade cohort increased their scores as a whole. However, this was the only set of data for which all subcategories were not represented. There was no valid data for students who qualify for free or reduced-price lunch. In all other subcategories, the students showed improvement on their practice ACT Mathematics scores. Figure 9 shows the mean scores of the eleventh grade cohort as well as the mean scores of each valid subgroup on the fall and spring practice ACT mathematics test. The aggregate of the eleventh grade cohort showed a statistically significant increase with p=0.017. In



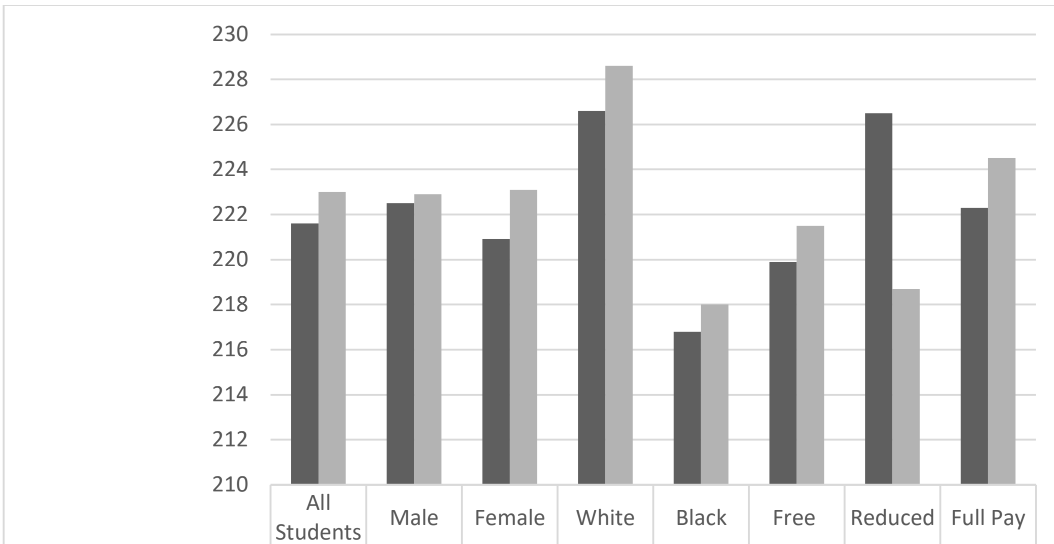
	All Students	Male	Female	White	Black	Free	Reduced	Full Pay
ACT Math Fall	13.8	12.6	15	16	11.2			13.8
ACT Math Spring	17.4	16.2	18.2	17.1	17			17.4

Figure 9. 2013-2014 11th Grade ACT Mathematics.

considering gender, only the increased scores by males was statistically significant with p=0.023. White students showed a statistically significant increase with p=0.006 while African American students did not have a statistically significant increase in their scores. The only valid SES data available was for students who paid full price for their lunches and their increased scores were statistically significant with p=0.017.

Measure # 2: NWEA Mathematics. Students participated in NWEA testing three times per year. These tests are computer based, adaptive, and untimed. Classroom teachers took students to computer labs during designated time windows to participate in testing. Any student who did not complete the test during the allotted testing window was pulled from class at a later date in order to finish testing. Since the NWEA tests are adaptive, a maximum score does not exist. The national mean for high school students in the beginning of grade 9 is 233.8 and at the end of grade 11 is 238.3.

Ninth Grade Results. In the 2013-2014 school year, ninth grade students increased their NWEA Mathematics scores as a whole and across all subgroups except among students who qualify for reduced-price lunch. Figure 10 shows the mean scores of the ninth grade cohort as well as the mean scores of each subgroup on the fall and spring NWEA Mathematics test.



	All Students	Male	Female	White	Black	Free	Reduced	Full Pay
NWEA Math Fall	221.6	222.5	220.9	226.6	216.8	219.9	226.5	222.3
NWEA Math Spring	223	222.9	223.1	228.6	218	221.5	218.7	224.5

Figure 10. 2013-2014 9th Grade NWEA Mathematics.

The increased scores of the ninth grade cohort were statistically significant with p=0.004. By gender, only the increased scores of females were statistically significant with p=0.014. By race, only the increased scores of whites were statistically significant with p=0.022. By SES, students who qualify for free lunch and students who pay full price for lunch both showed statistically significant increases with p=0.041 and p=0.015 respectively. The decreased scores of students who qualify for reduced-priced lunches were not statistically significant.

While the literacy strategies implemented in the 2013-2014 school year were consistent throughout the school, in the 2014-2015 school year, teachers were finally given he autonomy to select the strategies that they wished to implement. All teachers were required to implement two strategies throughout the school year (at least once in each marking period). The mathematics department elected to utilize exit/entrance tickets throughout the year in all of our math classes. The second strategy varied amongst the mathematics teachers. Note-taking strategies were utilized by three of the four regular education mathematics teachers and included guided notes, Cornell notes, and interactive foldables. A typical foldable is taped into a student's notebook and includes flaps that are folded to strategically reveal definitions, examples, characteristics, notation, or other relevant content. The sole special education math teacher utilized vocabulary strategies as his second literacy strategy and I utilized chalk talks as my second literacy strategy.

In 2014-2015, the NWEA Mathematics scores for ninth graders increased as a cohort. The subgroups of females, whites, students who qualify for free lunch and students who pay full price for lunch all saw increased scores on the NWEA Mathematics test. Figure 11 shows the mean scores of the ninth grade cohort as well as the mean scores of each subgroup on the fall and spring NWEA Mathematics test.

The scores of the ninth grade cohort showed a statistically significant increase with $p=0.028$. Only the increased scores for females and white students showed a statistically significant increase with $p=0.021$ and $p=0.028$ respectively. The increases by students who qualify for free lunch and students who pay full price for lunch were not statistically

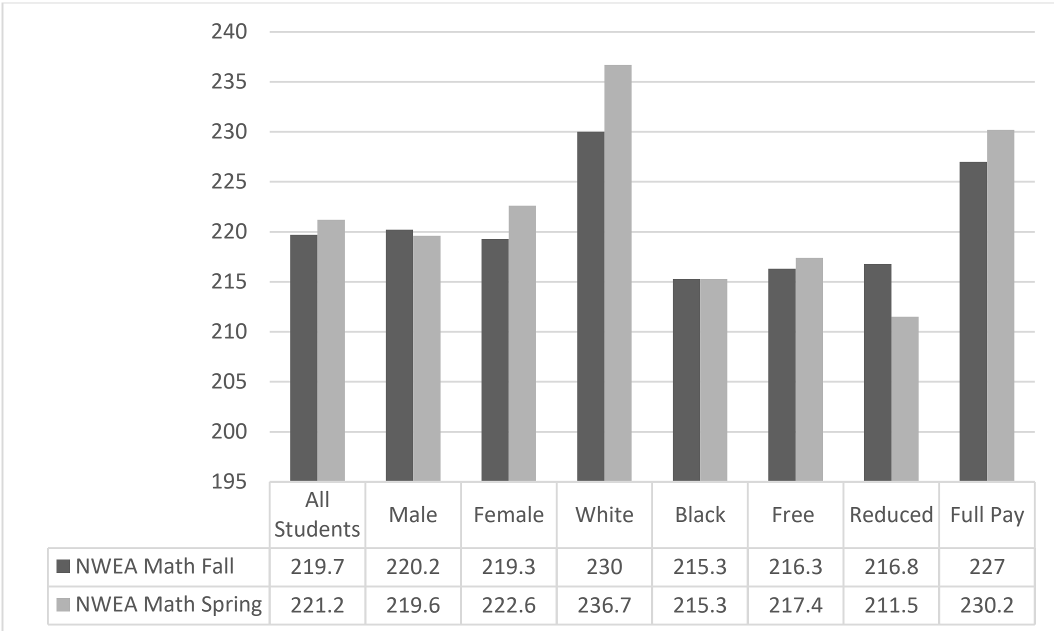
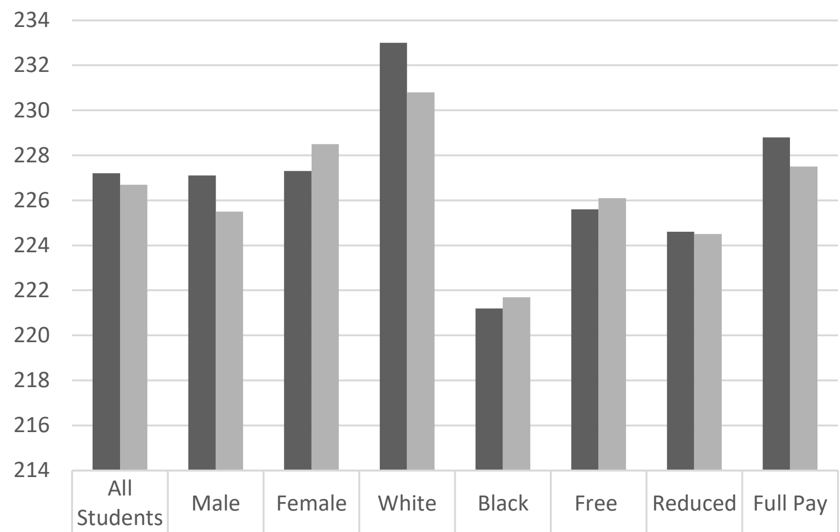


Figure 11. 2014-2015 9th Grade NWEA Mathematics.

significant. The decreased scores by males, African Americans, and students who qualify for reduced-price lunches were not statistically significant.

Tenth Grade Results. In the 2013-2014 school year, the tenth grade NWEA mathematics scores increased among females, African Americans, and students who qualify for free lunch. All other subgroups saw decreases on their NWEA mathematics scores. Figure 12 shows the mean scores of the tenth grade cohort as well as the mean scores of each subgroup on the fall and spring NWEA Mathematics test. Among the tenth grade cohort as well as in each subgroup, none of the increases or decreases were statistically significant.

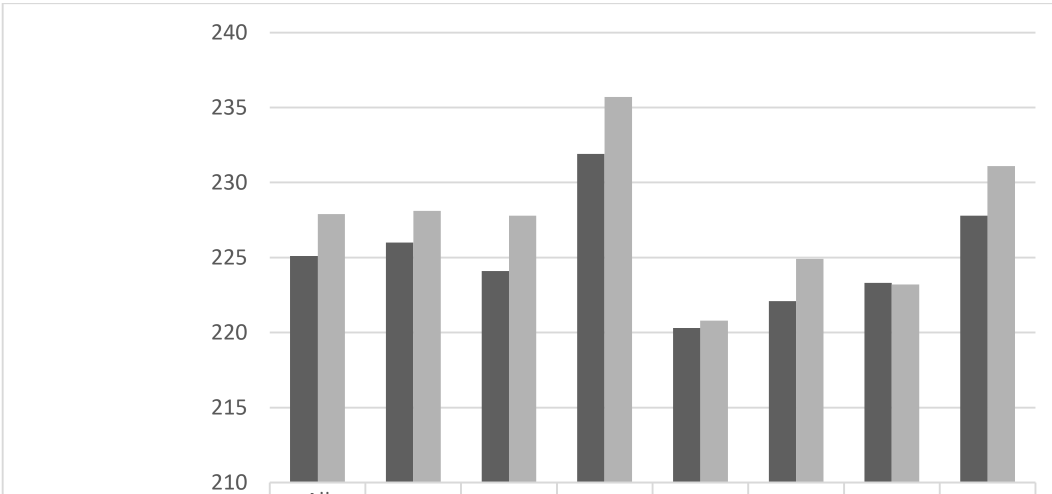


	All Students	Male	Female	White	Black	Free	Reduced	Full Pay
NWEA Math Fall	227.2	227.1	227.3	233	221.2	225.6	224.6	228.8
NWEA Math Spring	226.7	225.5	228.5	230.8	221.7	226.1	224.5	227.5

Figure 12. 2013-2014 10th Grade NWEA Mathematics.

In the 2014-2015 school year, the tenth grade NWEA mathematics scores increased as a whole as wells as in each subgroup except among those students who qualify for reduced-price lunches. Figure 13 shows the mean scores of the tenth grade cohort as well as the mean scores of each subgroup on the fall and spring NWEA Mathematics test. The increase in scores among the tenth grade cohort was statistically significant with p=0.001. In considering gender, the increase in females was statistically significant with p=0.001 while the increase among males was not statistically significant. In considering race, the increase in scores among whites was statistically significant with p<0.001, while the increase among African Americans was not statistically significant. In considering SES, the increased scores among students who qualify for free lunch and the students who pay full price for lunch both saw statistically significant increases with p=0.008 and p=0.024

respectively. The decrease among students who qualify for reduced-price lunches was not statistically significant.



	All Students	Male	Female	White	Black	Free	Reduced	Full Pay
NWEA Math Fall	225.1	226	224.1	231.9	220.3	222.1	223.3	227.8
NWEA Math Spring	227.9	228.1	227.8	235.7	220.8	224.9	223.2	231.1

Figure 13. 2014-2015 10th Grade NWEA Mathematics.

Eleventh Grade Results. The only available NWEA Mathematics results for eleventh grades is from the 2014-2015 school year. The cohort did not see an improvement in their scores from fall to spring, but the subgroups of white students and those students who qualify for free lunch saw increases in their scores. Figure 14 shows the mean scores of the eleventh grade cohort as well as the mean scores of each subgroup on the fall and spring NWEA Mathematics test. None of the increased scores or decreased scores from fall to spring were statistically significant.

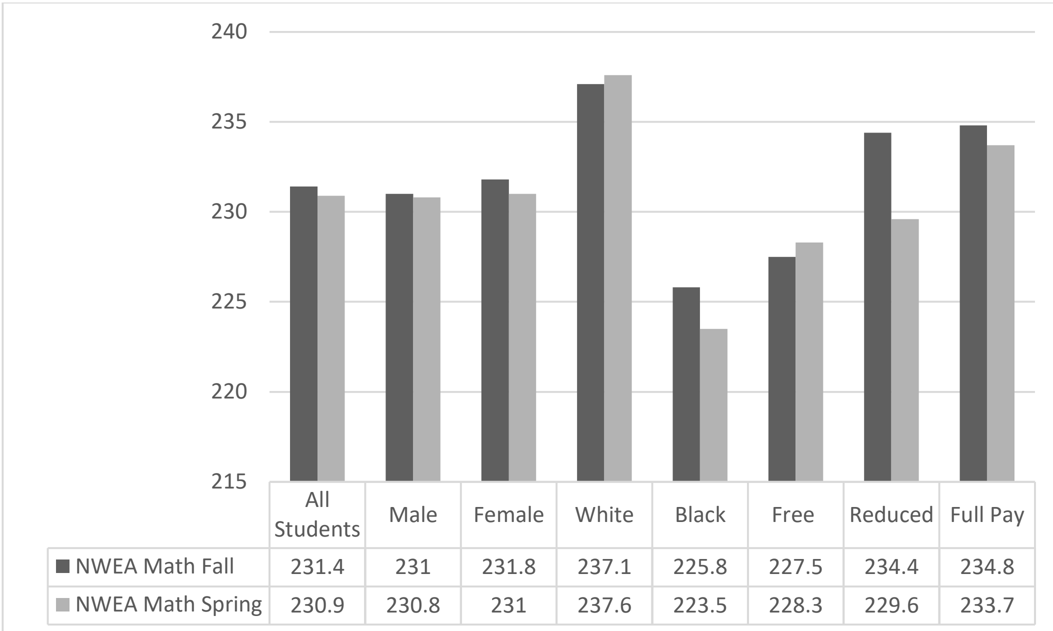


Figure 14. 2014-2015 11th Grade NWEA Mathematics.

Research Question 2: How was student achievement in reading affected?

NWEA Reading. As with NWEA Mathematics, the NWEA Reading test was completed three times per year. Individual classroom teachers took students to a computer lab and any students who did not complete the test in the class period were pulled from class at a later date to finish testing. Similar to the NWEA Mathematics test, the reading test is adaptive and does not have a maximum score. The national mean for a student in the fall of their 9th grade year is 221.4 and at the end of their 11th grade year is 223.7. The means from the fall and spring semesters were compared to determine if any statistically significant changes occurred.

The strategies that were utilized in the 2013-2014 school year, as well as the two prior years, were uniform throughout the school. As previously mentioned, the ninth grade cohort had limited exposure to the literacy strategies while the eleventh grade cohort had the broadest exposure. In the 2014-2015 school year, teachers were afforded the opportunity to self-select the strategies to be implemented in their classrooms. Unlike the mathematics department, the ELA department did not select a uniform strategy for use in their department. Each teacher utilized a wide range of strategies, in many cases, documenting far beyond the required two strategies. We have one special education ELA teacher who teaches both self-contained ELA classes and works with a general education ELA teacher in a collaborative setting. The special education ELA teacher reported utilizing exit tickets, graphic organizers, and talking to the text in her self-contained classes in the 2014-2015 school year. We had two full time reading specialists teaching our decoding and comprehension classes. These teachers reported utilizing Cornell notes, graphic organizers, talking to the text, vocabulary, summarizing, exit tickets, and note-taking strategies throughout the year. The remaining four full time ELA teachers reported using reading minute, digital note-taking, exit tickets, graphic organizers, summarization, talking to the text, and vocabulary strategies throughout the 2014-2015 school year.

Ninth Grade Results. In 2013-2014, the ninth grade cohort had decreases in the NWEA Reading test as well as in every subgroup of interest. Figure 15 shows the mean scores of the ninth grade cohort as well as the mean scores of each subgroup on the fall and spring NWEA Reading test. None of the decreases were statistically significant.

In 2014-2015, the ninth grade cohort had increases in the NWEA Reading test as well as in every subgroup of interest. Figure 16 shows the mean scores of the ninth grade cohort as well as the mean scores of each subgroup on the fall and spring NWEA Reading test. The increased scores for the cohort was statistically significant with $p<.001$. Both

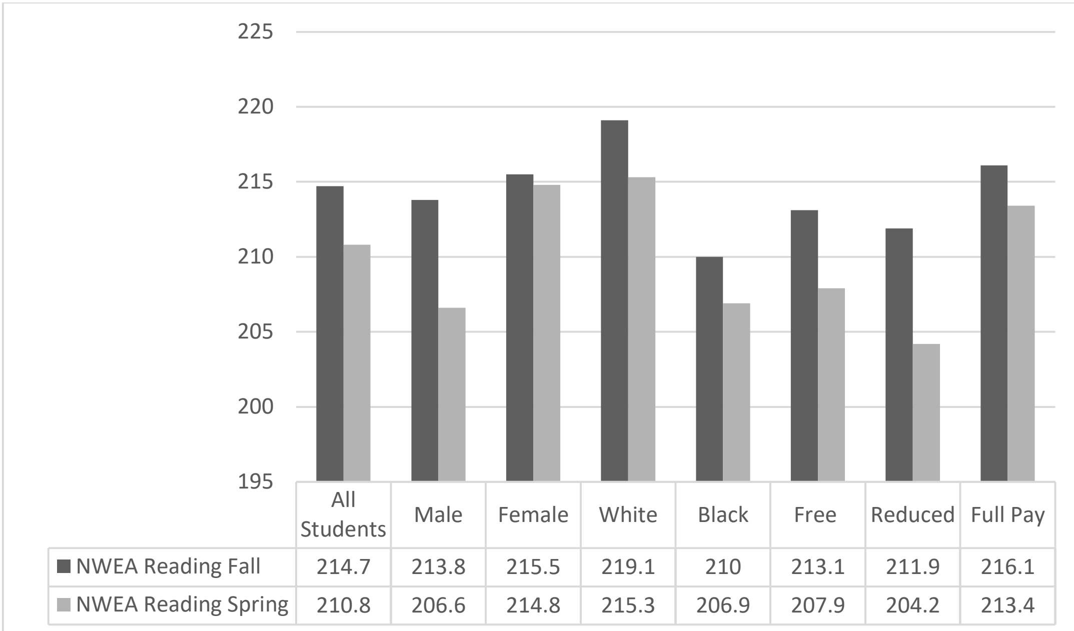
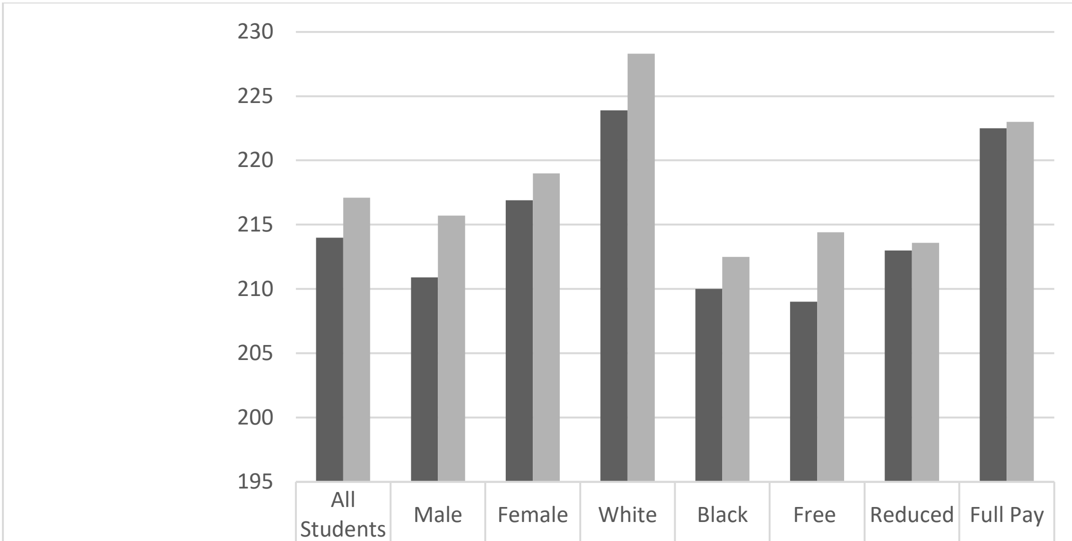


Figure 15. 2013-2014 9th Grade NWEA Reading.

genders saw statistically significant increases with p=0.001 for males and p=0.002 for females. In considering race, whites saw a statistically significant increase with p=0.002 and African Americans saw a statistically significant increase with p=0.007. Based on SES, the only group to see a statistically significant increase were students who qualify for free lunch with p<0.001.

Both ninth grade cohorts had limited exposure to literacy strategies, and yet the 2014-2015 cohort saw significant improvement. One possible reason for this was the addition of a second full time reading specialist in the 2014-2015 school year. The reading specialists taught decoding and comprehension classes aimed at improving the reading skills of our students. In comparison with the 2013-2014 school year, we likely had twice as many students enrolled in these intervention classes which could have contributed to the significant increase in students' NWEA Reading scores.



	All Students	Male	Female	White	Black	Free	Reduced	Full Pay
NWEA Reading Fall	214	210.9	216.9	223.9	210	209	213	222.5
NWEA Reading Spring	217.1	215.7	219	228.3	212.5	214.4	213.6	223

Figure 16. 2014-2015 9th Grade NWEA Reading.

Tenth Grade Results. In 2013-2014, the tenth grade cohort had decreases in the NWEA Reading test as well as in every subgroup of interest. Figure 17 shows the mean scores of the ninth grade cohort as well as the mean scores of each subgroup on the fall and spring NWEA Reading test. None of the decreases were statistically significant.

In 2014-2015, the tenth grade cohort had increases in the NWEA Reading test as well as in every subgroup of interest. Figure 18 shows the mean scores the ninth grade cohort as well as the mean scores of each subgroup on the fall and spring NWEA Reading test. The increased scores for the cohort was statistically significant with p<.001. Both genders saw statistically significant increases with p=0.009 for males and p=0.007 for females. In considering race, whites saw a statistically significant increase with p=0.001 and African Americans saw a statistically significant increase with p=0.047. Based on

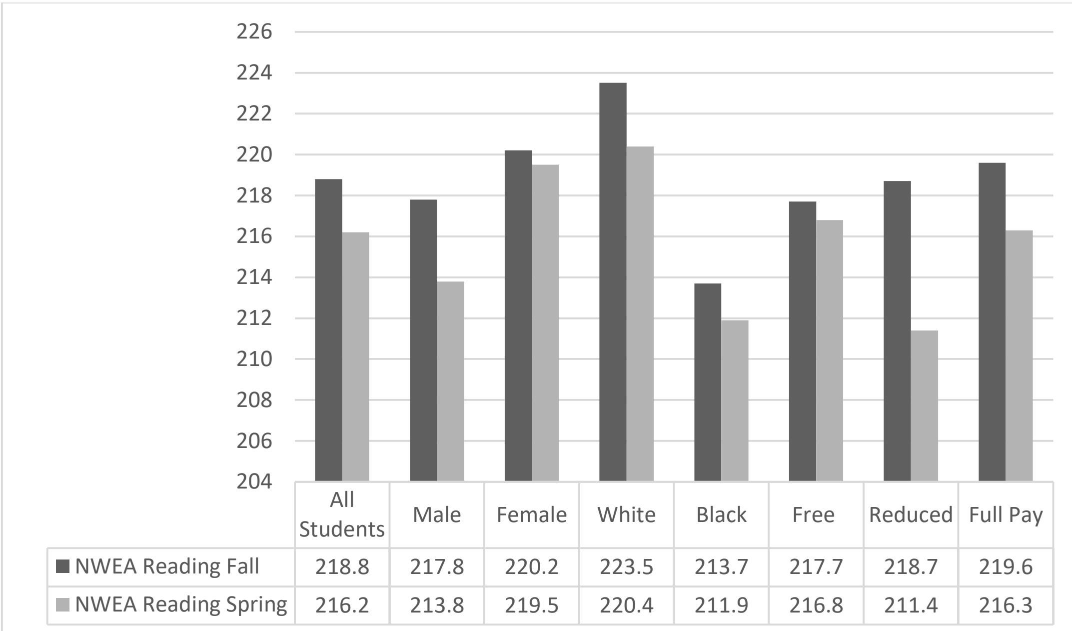
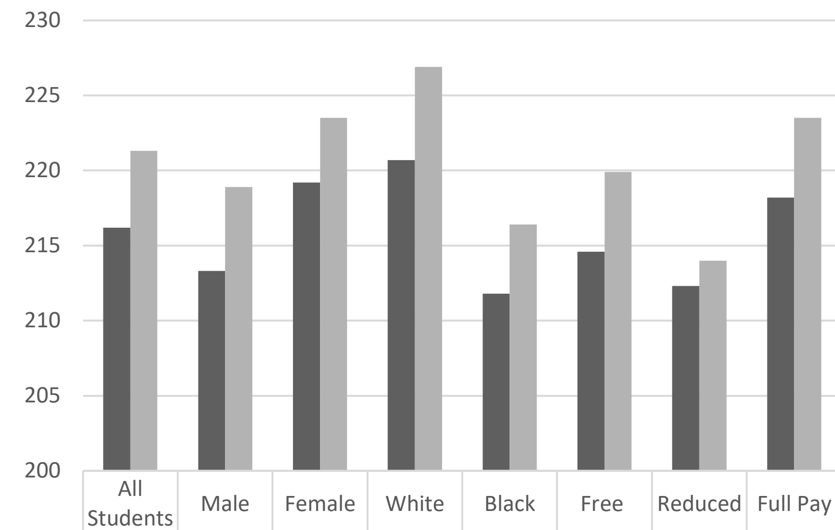


Figure 17. 2013-2014 10th Grade NWEA Reading.

SES, students who qualify for free lunch saw a statistically significant increase with p=0.009. Students who pay full price also had a statistically significant increase with p=0.004. The increase for students who qualify for reduced-price lunches was not statistically significant.

Eleventh Grade Results. The only available NWEA Reading results for eleventh grades is from the 2014-2015 school year. The cohort did not see an improvement in their scores from fall to spring, and the only subgroup to see an increase was among students who qualify for free lunch. While we had increased the number of reading support classes in 2014-2015, we target the underclassmen in them so that they have improved their decoding and comprehension skills prior to their junior year—the year of the state mandated testing. This may have contributed to the lack of growth in the eleventh grade cohort. Figure 19 shows the mean scores of the eleventh grade cohort as well as the mean



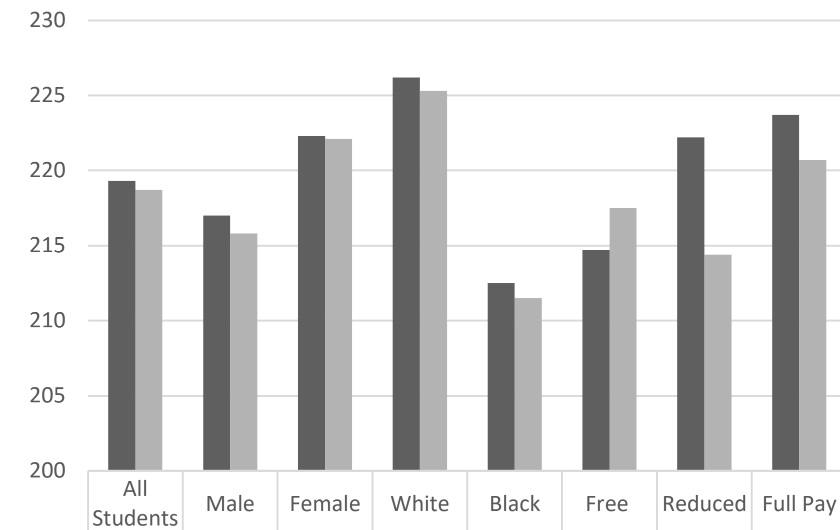
	All Students	Male	Female	White	Black	Free	Reduced	Full Pay
NWEA Reading Fall	216.2	213.3	219.2	220.7	211.8	214.6	212.3	218.2
NWEA Reading Spring	221.3	218.9	223.5	226.9	216.4	219.9	214	223.5

Figure 18. 2014-2015 10th Grade NWEA Reading.

scores of each subgroup on the fall and spring NWEA Reading test. The increase among students who qualify for free lunches was not statistically significant. The decrease in scores among students who pay full price was statistically significant with p=0.018. None of the other decreases was statistically significant.

Summary

The state determines our adequate yearly progress based on the scores of the eleventh grade cohort. This investigation focused on the mathematics and reading scores of the 9th through 11th grades and considered gender, race, and SES subgroups in determining growth. The 2013-14 school year began with our school ranked at the 18th percentile on the state top-to-bottom ranking and the 2014-15 school year began with us at the 25th percentile. We will not be ranked again until the 2016-17 school year due to



	All Students	Male	Female	White	Black	Free	Reduced	Full Pay
NWEA Reading Fall	219.3	217	222.3	226.2	212.5	214.7	222.2	223.7
NWEA Reading Spring	218.7	215.8	222.1	225.3	211.5	217.5	214.4	220.7

Figure 19. 2014-2015 11th Grade NWEA Reading.

changes in the state testing products. Our state ranking shows overall growth and the results of this investigation over the last two years of state monitoring shows statistically significant growth was attained among many different groups of students in both mathematics and reading.

The practice ACT Mathematics test was only administered in the 2013-2014 school year. The ninth grade cohort saw statistically significant increases among the entire cohort, males, African Americans, and students who qualify for free and reduced price lunches. The tenth grade cohort saw statistically significant decreases among the entire cohort, males, and students who pay full price for lunch. The eleventh grade cohort saw statistically significant increases among the entire cohort, males, whites, and students who pay full price for lunch. We no longer expose students to individual subject tests throughout the year. Instead, we have adopted an actual full length test for students twice per year. In this way, students are exposed to actual timed testing conditions as well as the length of the overall actual test.

The inconsistency of these results does not provide any conclusive evidence that mathematics achievement was impacted through the implementation of literacy strategies. The improvement of the 11th graders on the practice Mathematics ACT is more likely attributed to the importance the teachers and school places on the actual ACT. Juniors tend to take their standardized testing more seriously than the underclassmen and this may have impacted their motivation to be successful. It may also explain why the 10th graders saw decreases on their practice Mathematics ACT—they aren't as concerned about their post-secondary plans and don't see the practice test as important in their sophomore year. Additionally, freshmen may have seen improvements on their scores just by virtue of being in an algebra class and learning some of the material that was assessed on the practice Mathematics ACT.

The NWEA Mathematics test was administered in 2013-2014 to students in grades nine and ten and in 2014-2015 to students in grades nine, ten, and eleven. In the 2013-2014 school year, the ninth grade cohort showed statistically significant increases among the entire cohort, females, whites, students who qualify for free lunch, and students who pay full price. In the ninth grade cohort in 2014-2015, the entire cohort, females, and whites showed statistically significant increases. In 2013-1014, the tenth grade cohort and every subgroup saw no statistically significant increases. In 2014-2015, the tenth grade cohort saw statistically significant increases among the entire cohort, females, whites, students who qualify for free lunch, and students who pay full price for lunch. The NWEA

Mathematics test was only administered to the eleventh grade in the 2014-2015 school year. The eleventh grade cohort and each subgroup saw no statistically significant increases in that year.

The NWEA tests saw more consistent increases in mathematics achievement compared to the practice Mathematics ACT. It may be that the adaptive nature of the NWEA tests allowed for more accurate representations of what students know and are able to do. The use of the computer for the test may have been a better format for testing digital natives. The stagnant achievement among the 11^{th} graders may be due to the fact that those students know that the ACT is the test that matters and perhaps they did not put forth as much effort on the NWEA test.

The NWEA Reading test was administered in 2013-2014 to students in grades nine and ten and in 2014-2015 to students in grades nine, ten, and eleven. The ninth grade cohort in 2013-2015 had no statistically significant increases as a whole or in any subgroup. In the 2014-2015 school year, the ninth grade cohort had statistically significant increases as a whole, among both genders, among both races, and among students who qualify for free lunches. The tenth grade cohort in 2014-2015 saw no statistically significant gains as a whole or in any subgroup. In the 2014-2015 school year, the tenth grade cohort had statistically significant increases as a whole and in every subgroup except among students who qualify for reduced price lunches. Eleventh graders were only included in NWEA testing in 2014-2015. As a whole, the cohort did not have any statistically significant increases. Students who pay full price for lunch had a statistically significant decrease.

The lack of increase in reading achievement in the first year surprised me. I expected that the implementation of literacy strategies would naturally lead to increases in reading comprehension. Such an increase would be consistent with the work of Fisher et al. (2002, 2004) and Lai et al. (2014). One of the key differences in the literacy initiative of those studies and my school is the lack of professional development. The strategies that we were required to implement were presented in short segments at our monthly staff meetings. We did not engage in any cycle of use, modify, re-use and we were not provided any time to meet with the reading specialist to discuss how to adapt the strategies for our mathematics classes. Additionally, the literacy strategies were practiced via paper and pencil in the classroom and the computer based NWEA assessments may not have allowed for the transfer of those strategies.

However, the second year did see increases in reading achievement. The lack of consistency across the two years leads me to believe that something else was at play here. I believe it was the addition of a second reading teacher in the second year. This led to a much larger group of students enrolled in remedial decoding and reading comprehension classes, which may have impacted our reading scores.

It is not possible to know how these results impacted our overall school achievement in the state ranking or how these results impacted our removal from state monitoring by the SRO. What we do know is that some groups increased their achievement on some measures. As this was not a randomized control trial, we cannot conclude that the use of literacy strategies in and of themselves were the cause of those changes.

Reflections

Anecdotally, I can share my personal narratives regarding the implementation of literacy strategies in high school mathematics and how they have transformed my practice. I began this journey as a skeptic and I was convinced that literacy strategies had no place in my mathematics classroom. I utilized the required strategy, documented my compliance, and did a fair amount of complaining about it with my colleagues who felt the same way. In one school year, my school moved from the 4th percentile to the 15th percentile on the state top-to-bottom ranking. It was at this point that I began to more seriously consider the possibility of what the literacy strategies could do for me in my mathematics classes.

Vocabulary strategies were the easiest for me to implement because they are truly content area reading strategies. They can be adopted into any content area without need for modification based on the discipline. I realized that I already used word building strategies involving root words and affixes. The multiple Greek and Latin roots in many mathematics terms made this a seamless transition for me. In addition, I created word walls for each unit and posted them so that all students in the room could see them. I would change them with each unit so we could focus our attention on the most relevant vocabulary. I remember students working in groups and they would turn and point to the word wall while engaging in authentic mathematical discourse. This was not isolated to one class or a particular student. From my Algebra students to my AP Calculus students, they saw our vocabulary on our word wall and used it. When students would say “I can’t remember what it’s called” it was very easy for me to follow up with “Can you find that word on our word wall?” One year, as we prepared for our exams at the end of the first semester, I had a student look to the word wall to find the term she was looking for. Since I change the walls with each unit, it wasn't there, but she could remember exactly where the term in particular that she was looking for was on the word wall when it was posted. I have since allowed students to take a picture of our word walls with their cell phones so that they always have access to all of our vocabulary.

Note-taking strategies were also fairly easy for me to implement. I would consider these to be content area reading strategies as well. There were not any modifications that I needed to make in order to use them to teach mathematics. I have textbooks for my precalculus and AP Calculus classes, but our department did not have textbooks for our Algebra 1, Geometry, or Algebra 2 classes. Cornell notes and foldables quickly became my primary means for notes in these classes. I purchased a number of algebra foldables from www.teacherspayteachers.com and when I could not find one to suit my needs, I used a Cornell notes template. I prefer to use a Cornell notes template that has grids on it, even when I don't need to graph anything. The grids alone do not, in my opinion, make this a disciplinary literacy strategy. I also copied my foldables and Cornell notes on colored paper. This allowed me to reference them by color and also helped the less organized students find them more quickly in the sea of white notebook paper in their backpacks.

It was the reading comprehension strategies that were the most challenging for me to implement. The connotation of text as paragraphs of words and literacy as the ability to read such text clouded my initial views of reading comprehension strategies. The expanded view of literacy and text presented in the literature review helped me see the possibility of using these strategies in my mathematics classes. This is also what makes reading comprehension strategies truly disciplinary literacy strategies. In order for me to authentically implement them in my mathematics classes, I had to truly assess my needs as a mathematics teacher and make sure that I adapted the strategy to meet those needs. This is what caused the most challenges for me. I was only obligated to use a strategy once and early on, I had no interest is adapting the strategy and trying it again. Once I decided to implement strategies with fidelity, I found that my cycle of use, modify, re-use and my willingness to collaborate with the reading specialist allowed me to find the best, most disciplinary way to utilize many of these strategies.

The literacy strategy that had the most impact on my practice were exit tickets. However, it is the use of exit tickets as a formative assessment tool that has altered my practice. This quick check for understanding has become the primary way that I plan my lessons. I use a stoplight system for grading them. A green mark indicates a student who ready to move forward, a yellow mark indicates the need to slow down and check something, and a red mark indicates the need to come to a full stop. When students get their tickets back, they know that the color on it is an indication of where they stand and can work with others to find and correct their errors. I also keep track of student errors and have used erroneous solutions on summative assessments where students need to find and correct the error.

The graphic organizers I use have many different forms. I prefer to use the Frayer Model when introducing new parent functions. It provides a one-page summary for students with all the important information in one place. I have several flow charts that I use with my students from year-to-year. The factoring flowchart offers students suggestions on how to factor polynomials given the number of terms. The conic section flowchart helps students classify a conic section in general form by considering the sign and coefficient of the squared terms. The integration flowchart offers suggestions for finding anti-derivatives based on key features of the functions.

Chalk talks have become my favorite literacy strategy. I have used them to check for prior knowledge, but I prefer to use them as a review prior to unit assessments. What I like best about using them is that it forces students to communicate mathematics in a way that they are unaccustomed to. I find that as the year progresses, students write more, both individually as well as conversationally, as the strategy is intended. I continue to use chalk talks in the first week of school to establish classroom norms. This gives me a chance to introduce the format of chalk talks separate from content, but begins to set the foundation for how I will use it throughout the year.

I have found that scrambled sentences work particularly well with procedural mathematics. I have used scrambled sentences with order of operations, solving multistep equations, solving systems of equations, and completing the square. I typically ask students to unscramble the procedure and once they think they have it correct, I ask them to solve a problem using the procedure that they have established. This follow up allows for many of the students to self-correct any errors they have made in unscrambling the procedures.

Anticipation guides are designed to be used as a pre-reading strategy to determine the prior knowledge of students. Without textbooks, I found using this strategy to be a challenge so I modified it to fit my needs. I use the same format and ask students a few questions, but instead of having students read and see if the reading changed their answers, I show students a video. After the video, I ask students to revisit the questions and see if anything changed. In this way, I have truly adapted anticipation guides to be a disciplinary literacy strategy.

The tear and share strategy was a challenge for me to implement. It is designed for groups of four students to complete four questions, typically based on a reading passage. Then students tear their four responses apart and share them with others in their group. One person is responsible for reading all the responses to one question and synthesizing them into one, concise response. I've tried doing this by having groups of four students complete four similar math problems and then tear and share them so that one person has four solutions to the same question. I then asked the students to correct the problems and identify the types of errors that students made and share back with their group. The main problem I have encountered with this is students who are unable to do the questions correctly. When this happens, the group doesn't always get the feedback they need. I have attempted to fix this by using ability grouping and differentiating the problems within the groups, but I just haven't been able to get it right, yet. Most of the time, the group can work it out together, but it is not a seamless as I would like it to be.

Digital note-taking and Reciprocal teaching are the only strategies that I have used when required and not looked at retrying. My problem with digital note-taking is the challenge with typing math font. I am confident my students could get to use the equation editor, but it is not easy to do as you are simultaneously listening, watching, and typing. Reciprocal teaching was among one of the first strategies I used. I think that my implementation was not authentic and as such, I did not see the value in using it in my mathematics class. It remains in the back of my mind as something to consider in the future.

While we are no longer required to utilize any literacy strategies I continue to try and find ways to use them. In befriending the reading teacher, I have found an ally who is willing to help me continue on this journey. She listens to my ideas, offers suggestions, and has observed my implementations of these strategies in my mathematics classes. This collaborative effort was only possible once I realized that literacy strategies can have a place in high school mathematics.

CHAPTER 5 CONCLUSION

The first goal of this final chapter is to summarize the research project. Next, I will draw conclusions from, and implications of, the results. Finally, I will discuss the limitations of the study, connect the study to previous research, and offer suggestions for future research.

Summary

In the current educational era of standardized testing, positive results have become the end game. Being labelled as a low achieving school meant that we needed to make improvements and do so quickly in order to avoid being taken over by an emergency manager. District administration brought in a motivational young principal to help turn the school around. The first item our principal enacted was the required use of literacy strategies in all classes, across all disciplines. This school wide initiative was based on a similarly low achieving local school that had made impressive gains in the first year following their implementation of literacy strategies.

Researchers such as Hall (2005), Ness (2009), and Meyer (2013) find that content area teachers often resist the addition of literacy strategies in their class, and I was no different. As a mathematics teacher, I was skeptical about how these strategies would give my students additional success on the mathematics portions of these standardized tests. Aside from reading word problems, the literacy skills I imagined my students needed were limited. I questioned how literacy strategies would deepen the mathematical reasoning skills and algebraic symbol manipulation that I viewed as necessary for success on the mathematics portions of standardized tests.

I begrudgingly implemented the required quarterly strategies and documented my compliance. Over the next four years, our school moved from the 4th percentile to the 25th percentile on the state top-to-bottom rankings and our progress was largely attributed to the implementation of literacy strategies. Many argued that the standardized tests used for the state rankings were truly reading tests and our strategies better prepared our students to read the tests. This, in turn, positively impacted their success on those standardized tests.

Collectively, the scores of our students improved enough to raise our state ranking significantly. I began to wonder what impact those literacy strategies had in mathematics. Was my skepticism justified or did the literacy strategies make a difference in mathematics? My school was being monitored by the SRO while simultaneously renewing our national accreditation through NCA. Both processes required the collection and analysis of data to determine the effectiveness of our educational strategies. The reports prepared by central office administration and classroom teachers simply looked at descriptive statistics across the school, across grade levels, and across race. I was not directly a part of preparing those reports, but I know that they were prepared in a way to "sell" ourselves as a "good" school—worthy of removal from state monitoring and worthy of NCA accreditation. They served their purpose. In February of 2015, we received word that our renewal for NCA accreditation was approved and in August of 2015, we were formally removed from state monitoring and no longer on a watch list of low performing schools.

From the district and building point of view, the literacy strategies used over a four-year period appeared to have served their purpose. I was interested in looking more closely at the data to see how mathematics and reading scores were impacted. I selected data from the last two years of the monitoring process to use in my study. I had access to one year's worth of practice ACT mathematics scores and two years' worth of NWEA mathematics and reading scores. These data allowed me to consider changes in the mathematics and reading achievement of the ninth through eleventh graders in my school.

Discussion and Implications

The purpose of this study was to analyze data that was gathered for the SRO and NCA processes. For four years, all students in all content areas were exposed to specific literacy strategies in an attempt to improve scores on standardized testing and improve our ranking on the state top-to-bottom list. During the final two-years, students in grades 9 through 11 were subjected to a battery of assessments designed to measure their achievement in mathematics and reading. My school sought to use data from these assessments as justification for the implementation of a school-wide literacy initiative. I sought to address two specific research questions.

Research question 1: How was student achievement in mathematics affected? Student achievement in mathematics was measured by practice ACT mathematics tests and by NWEA Mathematics tests. The practice ACT Mathematics test was only administered in the 2013-2014 school year. The ninth grade cohort saw statistically significant increases among the entire cohort, males, African Americans, and students who qualify for free and reduced price lunches. The tenth grade cohort saw statistically significant decreases among the entire cohort, males, and students who pay full price for lunch. The eleventh grade cohort saw statistically significant increases among the entire cohort, males, whites, and students who pay full price for lunch. We no longer expose students to individual subject tests throughout the year. Instead, we have adopted an actual full length test for students twice per year. In this way, students are exposed to actual timed testing conditions as well as the length of the overall actual test.

The NWEA Mathematics test was administered in 2013-2014 to students in grades nine and ten and in 2014-2015 to students in grades nine, ten, and eleven. In the 2013-2014 school year, the ninth grade cohort showed statistically significant increases among the entire cohort, females, whites, students who qualify for free lunch, and students who pay full price. In the ninth grade cohort in 2014-2015, the entire cohort, females, and whites showed statistically significant increases. In 2013-1014, the tenth grade cohort and every subgroup saw no statistically significant increases. In 2014-2015, the tenth grade cohort saw statistically significant increases among the entire cohort, females, whites, students who qualify for free lunch, and students who pay full price for lunch. The NWEA Mathematics test was only administered to the eleventh grade in the 2014-2015 school year. The eleventh grade cohort and each subgroup saw no statistically significant increases in that year.

The differences in formats of the test and the testing environments played a key role in the results. The practice ACT mathematics was a static, timed test covering high school mathematics content. In contrast, the NWEA mathematics test was a dynamic, untimed test which adapted to the strengths and weaknesses of each individual student. I expected that the paper and pencil practice ACT mathematics test would give students a chance to utilize the annotating text strategies that were implemented and that the inability to do so on the computer-adaptive NWEA mathematics test would inhibit students' achievement. Alternatively, I predicted that the untimed nature of the NWEA mathematics test would improve student achievement while the time limit of the practice ACT mathematics would impede student achievement. Finally, I thought that the focus on high school mathematics content on the practice ACT mathematics would more accurately reflect the current mathematics achievement of students. As most students score at the 6th grade level on the NWEA mathematics test, it adapts to that level. I anticipated little achievement on the NWEA mathematics test since it would adapt to content that was taught three to five years prior to the assessment.

The mathematics achievement of students in my school was measured by practice ACT mathematics tests and the NWEA mathematics tests. The only groups that saw statistically significant increases on both measures across both school years were the ninth grade cohort and ninth grade females. I had anticipated that the upperclassmen would have made significant improvements on these assessments. I find that eleventh grade students generally focus on college admissions and show a more concentrated effort in their overall education in junior year. For the freshmen to show such gains across both assessments and both years contradicts my experiences.

There is no research to indicate that school wide implementation of literacy strategies can have an impact on student achievement in mathematics. This study was not designed to contribute such research, but rather, informally see if such research could be warranted. The inconsistent results indicate that it is not likely that the school wide implementation of literacy strategies can have an impact on student achievement in mathematics.

However, research does show that small scale implementation of some strategies can impact student achievement in mathematics (Ives & Hoy, 2003; Fisher, 2007; Ives, 2007). It is worth considering and implementing more specific, targeted strategies in high school mathematics, rather than using a school wide approach. It may be that the disciplinary literacy strategies will produce more meaningful outcomes than the more general content area reading strategies.

Regardless of the school wide results, my teaching of mathematics was transformed through the required use of literacy strategies. Once I embarked on a collaboration with the reading teacher to modify the literacy strategies for authentic use in mathematics and implement them with fidelity, I found that my teacher tool kit expanded in ways that were unlikely just a few years ago. I regularly use exit tickets, chalk talks, graphic organizers, and Cornell notes in all of my mathematics classes. This unintended consequence has made me a better teacher and allows me greater flexibility in reaching my students. I am now a staunch advocate for utilizing literacy strategies in mathematics and I continue to seek out multidisciplinary collaboration among my colleagues in order to continue to expand my tool kit.

Research question 2: How was student achievement in reading affected? The NWEA Reading test was administered in 2013-2014 to students in grades nine and ten and in 2014-2015 to students in grades nine, ten, and eleven. I had anticipated that the reading achievement would show more significant increases than the mathematics achievement since the literacy strategies were designed to be used in the traditional sense of literacy. This would support the previous research from Fisher et al. (2002, 2004) and Lai et al. (2104) which saw increases in reading comprehension and standardized testing after a multi-year implementation of literacy strategies. The results here are not consistent with those outcomes. The ninth grade cohort in 2013-2015 had no statistically significant increases as a whole or in any subgroup. In the 2014-2015 school year, the ninth grade cohort had statistically significant increases as a whole, among both genders, among both races, and among students who qualify for free lunches. The tenth grade cohort in 2013-2014 saw no statistically significant gains as a whole or in any subgroup. In the 2014-2015 school year, the tenth grade cohort had statistically significant increases as a whole and in every subgroup except among students who qualify for reduced price lunches. Eleventh graders were only included in NWEA testing in 2014-2015. As a whole, the cohort did not have any statistically significant increases. Students who pay full price for lunch had a statistically significant decrease.

The same measures were used in each year, so there was no variation in the assessments as there was in identifying mathematics achievement. On the NWEA reading assessment, students had the ability to digitally annotate the text by using a highlighter or adding a virtual sticky note. But these literacy strategies were utilized with paper and pencil in the classroom and I did not expect them to transfer without practice. I suspect that the main reason we saw improvements in reading achievement in the second year was the addition of a second full time reading teacher in the high school that year. That addition nearly doubled the number of students in decoding and reading comprehension classes.

The significant increases in reading achievement may be due to the participation of so many students in reading support classes.

Additionally, the reading support classes utilized the same literacy strategies that were being employed elsewhere in the building. They may have provided more traditional reading and writing opportunities which may have solidified the strategies for those students allowing it to transfer more readily to the NWEA Reading assessment. I suspect that the English teachers' tool kit is far more expansive than mine and that may have aided in improving the reading achievement of students.

Limitations

It is important to note that the nature of this study does not allow for any causal inferences because the school wide implementation of these strategies did not allow for a control vs. treatment comparison or a random selection of students in utilizing literacy strategies. Nevertheless, the results of my analyses indicate that some groups of students showed statistically significant increases on both mathematics and reading. It is not possible to attribute these changes solely to the implementation of literacy strategies. While these were the primary instructional strategies implemented school wide, there are far too many additional factors which could have impacted student growth. For example, teaching to the test, interventions for targeted groups of students, minimal teacher professional development, and inconsistent fidelity in implementation may have also impacted results. I have organized these factors into two categories: confounding variables and teacher training and implementation.

Confounding variables. Student growth over the course of a school year is an expectation of our educational system. Several different groups in this study showed increases on various measure of academic achievement. Two of the measures utilized in this study were the NWEA Mathematics and Reading tests. The 2011 NWEA RIT Scale Norms Study (NWEA, 2011) describes the expected annual growth across tests and grade levels. The means of the ninth grades students in this study place them at the middle of sixth grade on both mathematics and reading based on the nationally normed data. The tenth graders in this study are on par with students in the middle of seventh grade on both tests. The scores of the eleventh graders are about the middle of eighth grade on both tests. Mean national annual growth on the NWEA Mathematics test for 6^{th} grade is 6 points and our ninth grade students grew by 1.7 and 1.5 points in each of the two years of this study. For the NWEA Reading test, mean national annual growth for 6^{th} grade is 4.1 points and our ninth grade students decreased by 3.9 points in the first year and increased by 3.1 points in the second year. Similar gains were made by the tenth and eleventh grade cohorts and like the ninth grade, they were below national norms. Such growth could be expected by virtue of completing another year of formal schooling. However, for students who are so far behind grade level, the growth could also be somewhat unexpected.

As part of our monitoring by the state, a school reform officer was assigned to our school and visited on a monthly basis. Her visits included classroom walk-throughs and were met with anxiety and tension by most teachers and students. During her first few visits, it became clear that mathematics and science classrooms were her targets, and it may have prompted those teachers to raise the expectations in their classrooms. Those higher expectations could have led to the increases on the standardized assessments.

Our individual teacher evaluations and our school ranking are based on the results of standardized tests. Thus, it seems plausible that teachers have moved away from their content and have begun teaching to the test. In my district, the outcome of your annual teaching evaluation results in each teacher being identified with a number from 1-3. When it comes to teacher layoffs, the teacher with the lowest number is laid off first. When your job security depends on showing student growth on standardized tests, it is plausible that some teachers spend disproportionate amounts of class time on test preparation, not all of which is content-related. On one hand, some teachers spend time teaching test-taking skills such as narrowing choices on multiple choice questions, eliminating wrong answers, plugging in the answers, and working backwards. On the other hand, some teachers avoid content that is not likely to be tested in order to help students be successful on more common topics. For example, it is not uncommon for an Algebra 2 class to review foundational work on linear and quadratic functions and skip exponential and logarithmic functions altogether. Such possibilities could have contributed to the increase in students' scores.

The main Response to Intervention (RtI) program in our school is our Corrective Reading program. This multi-tiered program assesses the reading ability of our students and tracks those who need an intervention into a decoding or comprehension class. These semester long classes aim to bring the reading and comprehension levels of our students up to grade level. It is possible that students enrolled in these courses showed significant growth, especially on the NWEA reading test. This would have confounded our data.

In addition to the implementation of literacy strategies, our school implemented several additional school wide strategies. Other instructional strategies included the posting and referencing of daily objectives, the use of feedback on student work, recognition of student effort, and the incorporation of collaborative learning. Affective strategies were also utilized. These included holding students accountable, ensuring students knew that they mattered, and providing students opportunities for reflection and growth. These strategies may have also impacted student achievement.

There was a great deal of change within a short time in my school. Without controlling for these additional variables, we cannot make any claims on the effectiveness of the literacy strategies as they were utilized in this setting. Any future studies can correct for this by using a more targeted approach. For example, select one specific strategy and plan the implementation in a certain unit of study. Use pre- and post-assessments to determine the understanding and retention of specific concepts. I believe our school tried to do too much at once. It seems to me that we gathered excessive data in order to provide ample evidence that we were modifying instruction based on the data available to us. We succeeded in providing more data than was likely necessary and we were successfully granted reaccreditation and removed from state monitoring. Unfortunately, we did not carefully reflect on that data to determine what strategies were the most impactful for our students.

Teacher training and implementation. The small amount of training in a short period of time that teachers received regarding literacy strategies is a significant limitation to this study. Fisher et al. (2002, 2004), Hall (2005), Ness (2009), and Reed (2009) all discuss the importance of ample, high quality professional development on the implementation of literacy strategies. Our school provided teachers with 15-20 minute presentations at monthly staff meetings on the various literacy strategies we were required to utilize. While this provided us with job-embedded professional development, the structure lacked the opportunity for collaboration, coaching, or self-reflection that Reed (2009) suggested as influential in the implementation of literacy strategies. Hall (2005) also suggested that coming back and discussing the implementation was a critical component of the professional development cycle. Palincsar & Brown (1984) provided the teachers in their study three days of professional development on reciprocal teaching. When compared to the 15-20 minutes our teachers received, it is hardly possible to compare the outcomes.

While the primary focus has been on the literacy strategies that were implemented school wide, each teacher, each classroom, and each student in our school is unique. Theoretically, students saw each literacy strategy in each of their 6 classes at least once per quarter. Our goal was for students to see the multiple utility of these strategies. However, there were cases of limited fidelity within the mathematics department and within the school. Some teachers simply refused to do more in their classrooms. Some teachers made attempts early on, but then stopped utilizing the strategies. There were two teachers who completely fabricated their compliance of the strategies. Such a large scale initiative without buy-in from teachers leads to these complications. Reed (2009) discussed the need for teachers to embrace all the strategies rather than cherry picking the ones that seemed a best fit for their classrooms. Alternatively, several teachers had grown in their appreciation and implementation of literacy strategies in their classes. The entire social studies department restructured their courses around the use of literacy strategies with primary documents. I had regularly implemented vocabulary strategies, note taking strategies, graphic organizers, chalk talks, and exit tickets in my mathematics classes. Myself and the social studies department had embraced the disciplinary nature of these literacy strategies. But the inconsistent exposure to literacy strategies throughout the school adds another limitation to this study.

The top-down style of leadership in schools may have limited the outcomes of this study. Our school wide initiative was designed after our principal spoke with the principal at a similarly low achieving school. In consultation with the reading teacher, the two of them designed the school wide literacy implementation plan. Each year, the plan was expanded slightly with little consultation from teachers or students. Fisher & Frey (2008) reported the disparity between students and teachers on the usefulness of various literacy strategies. They suggest providing students with a voice in the educational decisions that impact them.

Looking at our state rankings to determine our success can be misleading. While we have moved from the 4^{th} percentile to the 25^{th} percentile, this does not actually tell us how we have grown. Even if every school in the state met the required benchmarks, there will always be schools in the bottom five percent. Similarly, if every school in the state did not meet the required benchmarks, there would still be schools identified in the top 5 percent, earning the status of a reward school. This is exactly what ranking is meant to do. It allows for comparison, but does little to highlight specific details about a school. It seems to me that school ranking is merely a divisive tactic pitting local schools against one another as they compete for students and in turn, revenue. A colleague pointed out at a staff meeting that we just need to hope other schools do worse than us. This can very well be the case. We may not have improved much at all; other schools may have simply done worse on their testing allowing us to move up in the ranking.

In order to avoid such ambiguity, it is prudent to compare our school to itself across years rather than compare ourselves to other schools. While this allows for some consistency such as a similar learning environment and a similar SES among students, comparing our school to itself has inherent limitations in that the students who were tested have changed. The state provides detailed information regarding our school's performance from year to year on the MI School Data website (www.mischooldata.org). A review of the College Readiness Trend Report from the 2011-2012 to the 2014-2015 school years shows that the percent of our students who have met or exceeded the college readiness benchmarks in mathematics and reading have remained relatively constant.

Using the state top-to-bottom ranking, our school appears to have made great strides in improving the academic achievement of our students, yet the percent of students who are college ready has remained stagnant throughout this literacy initiative. The inconsistency in these results calls into question how meaningful school rankings can be if they are not truly a reflection of academic achievement.

Suggestions for Future Research

The use of literacy strategies within mathematics classes is a viable means to enhance the mathematical achievement of high school students. This study looked at quantitative data to determine that student achievement was impacted in several categories, though not necessarily due to the implementation of literacy strategies. This retrospective study was incredibly broad in what was implemented. In order to enhance the findings, I offer the following suggestions for further research:

1. I believe my school attempted to do too much at once. Further studies that target a single literacy strategy in a single group of students seem to be the most evident follow up study. For example, after using the chalk talk strategy the first time, I have since used it almost exclusively as a means for test review. A possible study would compare the outcomes of students' scores on a unit test with one group of students using chalk talks as a review and another group using a traditional set of practice problems as a review.
2. If such large scale studies are done, corrections for confounding variables need to be considered. For example, students who were in the Corrective Reading class should not have had their scores considered. The very nature of the course is to improve their decoding and comprehension skills. By virtue of being in the class, their NWEA reading scores could have shown improvement and potentially skewed the data.
3. Future randomized control trial studies can be designed to determine if the literacy strategies were the cause of the increased student achievement. The school wide nature of the implementation of literacy strategies prevented such causal inference in this study.

4. Future studies can focus on student perception of the usefulness of literacy strategies in mathematics. What strategies did students find most/least helpful? Which strategies were easiest to implement? Did any strategies transfer from one class to another? Did students find themselves using a strategy even when it was not explicitly demanded?

5. How does the frequency of use impact the usefulness of the strategy? For example, if students are required to write the procedural steps for solving a certain type of problem before a quiz, but need not do so before a test or final exam, is their retention of that procedure different in the short- and long-term?

6. Does the explicit use of a strategy lead students to naturally select the strategy when given the choice? For example, does using Cornell notes in the beginning of the year promote student use when they are given no demands on how to take notes?

7. As a school improvement strategy, our use of literacy strategies was selected and designed exclusively by the principal and the reading teacher. Future school improvement strategies should have input and buy-in from teachers and students in order to minimize inconsistent implementation.

8. Future studies can focus on a professional development cycle for teachers implementing literacy strategies. Such a cycle would include learning to use a strategy experientially, implementing it in their classrooms, coming back for discussion and modification. Similar to a lesson study, but it would be centered on specific literacy strategies.

Empirical studies on the use of literacy strategies in high school mathematics are very limited. These suggestions for further research begin to form a foundation for the possibilities when literacy and text are expanded to mean more than reading and writing printed words. It begins with collaboration between literacy and content area teachers. The potential to impact student achievement in mathematics should not be underestimated. Readin', writin', an' 'rithmetic can form a symbiotic relationship in high school mathematics.

I began this journey as a literacy skeptic. I doubted the utility of literacy strategies in high school mathematics viewing them as unnecessary and unhelpful intrusions into my content. As I end this journey on the implementation of literacy strategies in high school mathematics classes, I am reminded of the words of Lesnak (1989): "I would have been just as enthusiastic with the results of this experiment even if the quantitative statistical analysis had not indicated a significant increase in academic achievement" (p. 155).

REFERENCES

ACT. (2014). Technical Manual: The ACT. Retrieved from https://www.act.org/content/dam/act/unsecured/documents/ACT_Technical_Manual.pdf

Adams, A. E., & Pegg, J. (2012). Teachers' enactment of content literacy strategies in secondary science and mathematics classes. *Journal of Adolescent & Adult Literacy, 56*(2), 151-161. doi:10.1002/JAAL.00116

Adams, A. E., Pegg, J., & Case. M. (2015). Anticipation Guides: Reading for mathematics understanding. *The Mathematics Teacher, 108*(7), 498-504.

Adams, T. L. (2003). Reading mathematics: More than words can say. *The Reading Teacher, 56*(8), 786-795. Retrieved from http://www.jstor.org/stable/20205297

Albert, L. R., & Antos, J. (2000). Daily journals connect mathematics to real life. *Mathematics Teaching in the Middle School, 5*(8), 526-531. Retrieved from http://www.jstor.org/stable/41180878

Alfassi, M. (2004). Reading to learn: Effects of combined strategy instruction on high school students. *The Journal of Educational Research, 97*(4), 171-184. doi:10.3200/JOER.97.4.171-185

Andrews, S. E. (1997). Writing to learn in content area reading class. *Journal of Adolescent & Adult Literacy*, *41*(2), 141-142. Retrieved from http://www.jstor.org/stable/40013497

Ausubel, D. P. (1960). The use of advance organizers in the learning and retention of meaningful verbal material. *Journal of Educational Psychology, 51*(5), 267-272.

doi: 10.1037/h0046669

Ausubel, D. P. (1968). *Educational psychology: A cognitive view*. New York: Holt, Rinehart & Winston.

Barton, M. L., Heidema, C., & Jordan, D. (2002). Teaching reading in mathematics and science. *Educational Leadership, 60*(3), 24-28. Retrieved from http://www.ascd.org/publications/educational-leadership/nov02/vol60/num03/Teaching-Reading-in-Mathematics-and-Science.aspx

Baxter, S., & Reddy, L. (2007). *What content-area teachers should know about adolescent literacy*. Jessup, MD: National Institute for Literacy.

Baxter, J. A., Woodward, J., Olson, D., & Robyns, J. (2002). Blueprint for writing in middle school. *Mathematics Teaching in the Middle School, 8*(1), 52-56. Retrieved from http://www.jstor.org/stable/41181228

Borasi, R., & Siegel, M. (2000). *Reading Counts: Expanding the role of reading in mathematics classrooms*. New York: Teachers College Press.

Brown, P. L., & Concannon, J. P. (2016). Students' perceptions of vocabulary knowledge and learning in a middle school science classroom. *International Journal of Science Education, 38*(3), 391-408. doi:10.1080/09500693.2016.01143571

Brown, R. S., & E. Coughlin. (2007). The predictive validity of selected benchmark assessments used in the Mid-Atlantic Region (Issues & Answers Report, REL 2007–No. 017). Washington, DC: U.S. Department of Education, Institute of

Education Sciences, National Center for Education Evaluation and Regional Assistance, Regional Educational Laboratory MidAtlantic. Retrieved from http://ies.ed.gov/ncee/edlabs

Brozo, W. G., Moorman, G., Meyer, C., & Stewart, T. (2013). Content area reading and disciplinary literacy: A case for the radical center. *Journal of Adolescent & Adult Literacy 56*(5), 353-357. doi: 10.1002/jaal.153

Chall, J. S. (1983). *Stages of reading development.* New York: McGraw Hill.

Chall, J. S., Jacobs, V. A., and Baldwin, L. E. (1990). *The reading crisis: Why poor children fall behind*. Cambridge, Mass.: Harvard University Press.

Conley, M. W. (2008). Cognitive strategy instruction for adolescents: What we know about the promise, what we don't know about the potential. *Harvard Educational Review, 78*(1), 84-106.

Corkill, A. J. (1992). Advance organizers: Facilitators of recall. *Educational Psychology Review, 4*(1), 33-67.

Countryman, J. (1992). Writing to learn mathematics: Strategies that work, K-12. New Hampshire: Heinemann.

Coxhead, A. (2000). A new academic word list. TESOL Quarterly, 34(2), 213-238.

Crespo, S. (2003). Learning to pose mathematical problems: Exploring changes in preservice teachers' practices. Educational Studies in Mathematics, 52(3), 243-270.

Davey, B. (1983). Think aloud: Modeling the cognitive processes of reading comprehension. *Journal of Reading, 27*(1), 44-47. Retrieved from http://www.jstor.org/stable/40029295

De La Paz, S., & Felton, M. K. (2010). Reading and writing from multiple source documents in history: Effects of strategy instruction with low to average high school writers. *Contemporary Educational Psychology*, 35, 174-192.

Domin, D. S. (2008). Using an advance organizer to facilitate change in students' conceptualization of the role of creativity in science. *Chemistry Education Research and Practice*, 9, 291-300. doi: 10.1039/b818463c

Donohoo, J. (2010). Learning how to learn: Cornell notes as an example. *Journal of Adolescent & Adult Literacy, 54*(3), 224-227.

Doughterty, B. J. (1996). The write way: A look at journal writing in first-year algebra. *The Mathematics Teacher, 89*(7), 556-560. Retrieved from http://www.jstor.org/stable/27969907

Draper, R. J., & Siebert, D. (2010). Rethinking texts, literacies, and literacy across the curriculum. In R. Draper (Ed.), *(Re)Imagining content-area literacy instruction* (pp. 20-39). New York: Teachers College Press.

Dulan, S. W. (2008). *McGraw Hill's conquering the ACT math.* New York: McGraw Hill.

Dunkerly-Bean, J., & Bean, T. W. (2016). Missing the *savoir* for the *connaissance*: Disciplinary and content area literacy as regimes of truth. *Journal of Literacy Research, 48*(4), 448-475. doi:10.1177/1086296x16674988

Faggella-Luby, M., Graner, P., Deshler, D., & Drew, S. (2012). Building a house on sand: Why disciplinary literacy is not sufficient to replace general strategies for adolescent learners who struggle. *Topics in Language Disorders, 32*(1), 69-84.

Fisher, D. (2007). Creating a schoolwide vocabulary initiative in an urban high school. *Journal of Education for students Placed at Risk*, *12*(3), 337-351. doi:10.1080/10824660701601308

Fisher, D. & Frey, N. (2008). Student and teacher perspectives on the usefulness of content literacy strategies. *Literacy Research and Instruction, 47*, 246-263. doi: 10.1080/19388070802300330

Fisher, D., Frey, N., & Williams, D. (2002). Seven literacy strategies that work. *Educational Leadership, 60*(3), 70-73. Retrieved from http://eric.ed.gov/?id=EJ655420

Fisher, D., Frey, N., & Williams, D. (2004). Five years later: The outcomes of schoolwide approach to increasing achievement in an urban high school. In Strickland, D. S., & Alvermann, D. E. (Eds.), *Bridging the Literacy Achievement Gap*. New York: Teachers College Press.

Friedland, E. S., McMillen, S. E., & del Prado Hill, P. (2011). Collaborating to cross the mathematics-literacy divide: An annotated bibliography of literacy strategies for mathematics classrooms. *Journal of Adolescent & Adult Literacy, 55*(1), 57-66. doi:10.1598/JAAL.55.1.6

Gabig, C. S. & Zaretsky, E. (2013). Promoting morphological awareness in children with language needs: Do the common core state standards pave the way? *Topics in Language Disorders, 33*(1), 7-26. doi: 10.1097/TLD.0b013e318280f592

Guzzetti, B. J, & Bang, E. (2011). The influence of literacy-based science instruction on adolescents' interest, participation, and achievement in science. *Literacy Research and Instruction, 50*(1), 44-67. doi:10.108019388070903447774

Hall, L. (2002). Social studies standards, benchmarks, and assessments: An analysis of an eighth-grade exam. *The Social Studies, 93*(5), 213-217.

Hall, L.A. (2005). Teachers and content area reading: Attitudes, beliefs and change. *Teaching and Teacher Education*, 21, 403-414. doi:10.1016/j.tate.2005.01.009

Halladay, J. L. & Neumann, M. D. (2012). Connecting reading and mathematical strategies. *The Reading Teacher 65*(7), 471-476. doi:10.1002/TRTR.01070

Halpern, C. M., & Halpern, P. A. (2005/6). Using creative writing and literature in mathematics classes. *Mathematics Teaching in the Middle School, 11*(5), 226-230. Retrieved from http://www.jstor.org/stable/41182872

Hamilton, S. I., Seibert, M. A., Gardner, R., III, & Talbert-Johnson, C. (2000). Using guided notes to improve the academic achievement of incarcerated adolescents with learning and behavior problems. *Remedial and Special Education, 21*, 133-140.

Heller, R. (2010). In praise of amateurism: A friendly critique of Moje's "Call for Change" in secondary literacy. *Journal of Adolescent & Adult Literacy, 54*(4), 267–273. doi:10.1598/JAAL.54.4.4

Hillman, A. (2014). A review on disciplinary literacy: How do secondary teachers apprentice students into mathematical literacy? *Journal of Adolescent & Adult Literacy, 57*(5), 397-406. doi: 10.1002/jaal.256

Houseal, A., Gillis, V., Helmsing, M., & Hutchinson, L. (2016). Disciplinary literacy through the lens of the next generation science standards. *Journal of Adolescent & Adult Literacy, 59*(4), 377-384. doi:10.1002/jaal.497

Hunsader, P.D. (2004). Mathematics trade books: Establishing their value and assessing their quality. *The Reading Teacher, 57*(7), 618-629. Retrieved from http://www.jstor.org/stable/20205408

Hunter (1982). *Mastery Teaching*. El Segundo, CA: TIP Publications.

IBM Corp. Released 2015. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

Ippolito, J, Dobbs, C. L., Charner-Laird, M., & Lawrence, J. F. (2016). Delicate layers of learning: Achieving disciplinary literacy requires continuous, collaborative adjustment. *Journal of Staff Development, 37*(2), 34-38.

Ives, B. (2007). Graphic organizers applied to secondary algebra instruction for students with learning disorders. *Learning Disabilities Research & Practice, 22*(2), 110-118. doi: 10.1111/j.1540-5826.2007.00235.x

Ives, B., & Hoy, C. (2003). Graphic organizers applied to higher-level secondary mathematics. *Learning Disabilities Research & Practice, 18*(1), 36-51. doi: 10.1111/1540-5826.00056

Kieffer, M. J. & Lesaux, N. K. (2010). Morphing into adolescents: Active word learning for English-language learners and their classmates in middle school. *Journal of Adolescent & Adult Literacy*, *54*(1), 47–56. doi:10.1598/JAAL.54.1.5

Kresse, E. C. (1984). Using reading as a thinking process to solve math story problems. *Journal of Reading, 27*(7), 598-601. Retrieved from http://www.jstor.org/stable/40029394

Lai, M. K., Wilson, A., McNaughton, S., & Hsiao, S. (2014). Improving achievement in secondary schools: Impact of a literacy project on reading comprehension and secondary school qualifications. *Reading Research Quarterly, 49*(3), 305-334. doi:10.1002/rrq.73

Lazarus, B. D. (1991). Guided notes, review, and achievement of secondary students with learning disabilities in mainstream content courses. *Education & Treatment of Children, 14*, 112-127.

Lee, C. D., & Spratley, A. (2010). *Reading in the disciplines: The challenges of adolescent literacy*. New York, NY: Carnegie Corporation of New York.

Lesnak, R. (1989). Writing to learn: An experiment in remedial algebra. In Connolly, P., & Vilardi, T. (Eds.), *Writing to Learn Mathematics and Science* (pp. 147-156). New York: Teachers College Press.

Marzano, R. J., Pickering, D. J., & Pollock, J. E. (2001). *Classroom instruction that works: Research-based strategies for increasing student achievement*. Alexandria, VA: ACSD.

Mayer, R. E. (1983). Can you repeat that? Qualitative effects of repetition and advance organizers on learning from science prose. *Journal of Educational Psychology, 75*(1), 40-49. doi: 10.1037/0022-0663.75.1.40

McIntosh, M. E., & Bear, D. R. (1993). Directed reading-thinking activities to promote learning through reading in mathematics. *The Clearing House, 67*(1), 40-44. Retrieved from http://www.jstor.org/stable/30188737

McIntosh, M. E., & Draper, R. J. (1995). Applying the questions-answer relationship strategy in mathematics. *Journal of Adolescent & Adult Literacy*, *39*(2), 120-131. Retrieved from http://www.jstor.org/stable/40034520

McIntosh, M. E., & Draper, R. J. (2001). Using learning logs in mathematics: Writing to learn. *The Mathematics Teacher*, *94*(7), 554-557. Retrieved from http://www.jstor.org/stable/20870796

Meyer, C. K. (2013). The literacy needs of adolescents: What do content-area teachers know? *Action in Teacher Education*, *35*, 56-71. doi: 10.1080/01626620.2012.743441

Michigan School Data. (n.d.). Retrieved from https://www.mischooldata.org/Default.aspx

Moje, E. B. (2008). Foregrounding the disciplines in secondary literacy teaching and learning: A call for change. *Journal of Adolescent & Adult Literacy, 52*(2), 96-107. doi: 10.1598/JAAL.52.2.1

Mraz, M., Rickelman, R. J., & Vacca, R. T. (2009). Content-area reading: Past, present, and future. In Wood, K. D. & Blanton, W. E. (Eds.) *Literacy instruction for adolescents: Research-based practice* (pp. 77-91). New York: The Guilford Press.

Nagy, W., Berninger, V. W., & Abbott, R. D. (2006). Contributions of morphology beyond phonology to literacy outcomes of upper elementary and middle-school students. *Journal of Educational Psychology, 98*(1), 134-147. doi:10.1037/0022-0663.98.1.134

Nagy, W., & Townsend, D. (2012). Words as tools: Learning academic vocabulary as language acquisition. *Reading Research Quarterly, 47*(1), 91–108. doi:10.1002/rrq.011

National Council of Teachers of Mathematics. (2014). *Principles to actions: Ensuring mathematical success for all*. Reston, VA: Author.

National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010a). *Common Core State Standards*. Washington, DC: Authors.

National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010b). *Common Core State Standards for English language arts and literacy in history/social studies, science, and technical subjects*. Washington, DC: Authors.

Ness, M. K. (2009). Reading comprehension strategies in secondary content area classrooms: Teachers use of and attitudes towards reading comprehension instruction. *Reading Horizons, 49*(2), 143-166.

Northwest Evaluation Association. (2004). Reliability and validity estimates: NWEA Achievement Level Tests and Measures of Academic Progress. Lake Oswego, OR: Author.

Northwest Evaluation Association. (2011). 2011 Normative data. Retrieved from https://support.nwea.org/sites/www.nwea.org/files/resources/2011_Normative_Data_Overview.pdf

Norton, A., Rutledge, Z., Hall, K., & Norton, R. (2009/2010). Mathematical letter writing. *The Mathematics Teacher, 103*(5), 340-346. Retrieved from http://www.jstor.org/stable/20876631

Ogle, D. M. (1986). K-W-L: A teaching model that develops active reading of expository text. *The Reading Teacher, 39*(6), 564-570. Retrieved from http://www.jstor.org/stable/20199156

Orndorff, H. N., III. (2015). Collaborative note-taking: The impact of cloud computing on classroom performance. *International Journal of Teaching and Learning in Higher Education*, *27*(3), 340-351.

Pacheco, M. B. & Goodwin, A. P. (2013). Putting two and two together: Middle school students' morphological problem-solving strategies for unknown words. *Journal of Adolescent and Adult Literacy*, *56*(7), 541-553. doi: 10.1002/JAAL.181

Palincsar, A. S., & Brown, A. L. (1984). Reciprocal teaching of comprehension-fostering and comprehension-monitoring activities. *Cognition and Instruction, 1*(2), 117-175. doi:10.1207/s1532690xci0102_1

Polya, G. (1945). *How to solve it: A new aspect of mathematical method*. Princeton University Press.

Reed, D. K. (2009). A synthesis of professional development on the literacy strategies of middle school content area teachers. *Research in Middle Level Edcuation Online,* *32*(10). Retrieved from http://www.amle.org/portals/0/pdf/rmle/rmle_vol32_no10.pdf

Roepke, T. L, & Gallagher, D. K. (2015). Using literacy strategies to teach precalculus and calculus. *The Mathematics Teacher, 108*(9), 672-678.

Schroll, R. (2014, October 8). Reading Strategy Log. Retrieved from https://docs.google.com/spreadsheets/d/1sYGl0btDaQfD8asCfQgyy7GxIueWm6I574DyKFo6AOw/edit#gid=888064666

Schuck, R. F. (1969). The effects of set induction upon pupil achievement, retention, and assessment of effective teaching in a unit on respiration in the BSCS curricula. *Educational Leadership, 2*(5), 785-793.

Shanahan, T., & Shanahan C. (2008). Teaching disciplinary literacy to adolescents: Rethinking content-area literacy. *Harvard Educational Review, 78*(1), 40-59.

Siebert, D. & Draper, R. (2012). Reconceptualizing literacy and instruction for mathematics classrooms. In T. Jetton & C. Shanahan (Eds.), *Adolescent literacy in the academic disciplines: General principles and practical strategies* (pp. 172-198). New York: The Guilford Press.

Siebert, D. & Hendrickson, S. (2010). (Re)imagining literacies for mathematics classrooms. In R. Draper (Ed.), *(Re)Imagining content-area literacy instruction* (pp. 40-53). New York: Teachers College Press.

Sirhan, G. & Reid, N. (2002). An approach in supporting university chemistry teaching. *Chemistry Education: Research and Practice in Europe, 3*(1), 65-75.

Sliman, E. (2013). Visible thinking in high school mathematics. *The Mathematics Teacher, 106*(7), 502-507.

Snow, C. E., Barnes, W. S., Chandler, J., Goodman, I. F., & Hemphill, L. (1991). *Unfulfilled expectations: Home and school influences on literacy*. Harvard University Press.

Snow, C. E., & Biancarosa, G. (2003). *Adolescent literacy and the achievement gap: What do we know and where do we go from here?*. New York: Carnegie Corporation.

Spires, H. A., Kerkhoff, S. N., & Graham, A. C. K. (2016). Disciplinary literacy and inquiry: Teaching for deeper content learning. *Journal of Adolescent & Adult Literacy, 60*(2), 151-161. doi:10.1002/JAAL.577

Vacca, R. T., & Vacca, J. A. L. (2008). *Content area reading*. Boston: Allyn & Bacon.

vanGarderen, D. (2004). Focus on inclusion: Reciprocal teaching as a comprehension strategy for understanding mathematical word problems. *Reading & Writing Quarterly, 20*(2), 225-229. doi: 10.1080/10573560490272702

Vintinner, J. P., Harmon, J., Wood, K., & Stover, K. (2015). Inquiry into the efficacy of interactive word walls with older adolescent learners. *The High School Journal, 98*(3), 250–261. doi:10.1353/hsj.2015.0007

Welles, B. (2014, August 14). NCA Strategy Log. Retrieved from https://docs.google.com/spreadsheets/d/1N40fxwyVNUedAKmSRZwqTrnUt3aaOPLp8kIwhk2jp94/edit

Yates, P. H., Cuthrell, K., & Rose, M. (2010). Out of the room and into the hall: Making content word walls work. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 84*(1), 31–36. doi:10.1080/00098655.2010.496810

ABSTRACT

READIN', WRITIN', AN' 'RITHMETIC:
LITERACY STRATEGIES IN HIGH SCHOOL MATHEMATICS

by

ANGELA M. PRINCIPATO

August 2017

Advisor: Dr. Thomas G. Edwards

Major: Curriculum & Instruction

Degree: Doctor of Philosophy

Stagnant growth on national standardized tests in mathematics and reading and a focus on disciplinary literacy in the Common Core State Standards in ELA, history/social studies, science, and technical subjects has prompted a resurgence in utilizing literacy strategies in the content areas in high school. While literacy standards in mathematics are not explicitly identified in the Common Core State Standards, there may be a place for the use of literacy strategies in high school mathematics. This study explored the relationships between students' mathematics and reading achievement scores at a small, suburban high school and the implementation of a school wide literacy program to inform curriculum development and instructional strategies.

The reading and mathematics achievement of students in ninth through eleventh grade was retroactively analyzed to identify changes in student achievement over a two-year period. In the first year, the ninth grade cohort showed statistically significant improvement on both measures of mathematics achievement. Within this ninth grade cohort, students who qualified for free lunches also saw statistically significant

improvement in mathematics. None of the other groups showed improvement on both measures of mathematics achievement or reading achievement. In the second year, both the ninth and tenth grade cohorts showed statistically significant increases on both mathematics and reading achievement. Within each of these grade level cohorts, females and white students also saw statistically significant increases in both mathematics and reading. The eleventh grade cohort did not have any significant increases on either measure.

While national standardized tests have shown little to no improvement over the last several administrations, this small, suburban high school has seen continued growth over the last several years. On the state top-to-bottom ranking, this high school has moved from the 4th percentile to the 25th percentile during the implementation of the school wide literacy program. Though the results of this study cannot be used to determine a causal relationship between the implementation of literacy strategies and the academic achievement of students in either mathematics or reading, it does provide a case for further investigation into such a relationship.

AUTOBIOGRAPHICAL STATEMENT

I had no grandiose plans when I entered Wayne State University right out of high school. My parents had merely suggested that I try college based on my above-average success in high school. I quickly found a passion for mathematics through my participation in the Emerging Scholars Program, the Undergraduate Research Group in Mathematics, and working in the Mathematics Tutoring Center. I earned my Bachelor of Science in Mathematics in 1999 and my Master of Arts in Mathematics in 2002 from Wayne State University. In pursuing my Master's degree, I was awarded a Graduate Teaching Assistantship. It was during this time that I discovered my passion for teaching. I consider myself both a mathematician and a mathematics educator and together, my passion for mathematics and my passion for teaching drive me.

I earned my teaching certificate in 2003 and I have been teaching at South Lake High School in St. Clair Shores, Michigan since then. My students continue to ask me if I will leave them once I complete my doctorate and I continue to reassure them that my passion for teaching and doing mathematics will keep me in the classroom for years to come. I believe that learning is a life-long endeavor and I hope to pass that on to my students.

I am happily married to Antonio and we have two beautiful children, Sophia and Victor. In my free time, I enjoy reading, scrapbooking, cooking, and baking.