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Implementing Literacy Strategies and Activities to Help Math Students in Geometry

By

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Submitted in partial fulfillment of the requirements for the degree M.S. Literacy Education

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Abstract

This study examines how literacy strategies and activates help math students learn geometry concepts and solve problems. Three literacy activities were implemented in a 10th grade geometry classroom, and three students of different math abilities were interviewed. Student work was also analyzed and presented as part of the findings. The data collected revealed the following three themes: the helpfulness of literacy strategies differs for high and low achieving students, using visual representations led to more successful problem solving, and content area vocabulary was essential to know for achievement. The results from this study suggest that math teachers need to balance conceptual understanding and procedural fluency. Using differentiated content area literacy strategies is a suggested way to emphasize conceptual learning.
Implementing Literacy Strategies to Help Struggling
Math Students in Geometry

Math, English Language Arts, Science and Social Studies are considered separate subjects, although each discipline requires similar skills to master. Even so, mathematics is sometimes seen as the odd one out. Prior to 1950, most mathematics that was taught before high school involved computations, with whole numbers and fractions, such as finding the area or converting units of measure (Findell, 1996). Students in higher grade levels learned Algebra, namely how to write equations to represent problem situations and then solve these equations. Sometimes the solutions involved long division or finding the square root of a number, but not up to the rigor of what high school students are seeing today (Findell, 1996). In the past, if a student struggled with literacy, math class was a place where reading and writing could be avoided. Only the best students were in higher-level math courses and according to Findell, about 30 percent of students could write an equation for “Find two numbers whose sum is 100 and whose difference is 28,” compared to the current expectation that all ninth grade Algebra students should be able to write and solve this equation with ease. By the 1960s, “new math” was put in place in response to the launching of Sputnik satellites in an attempt to speed up our space program (Klein, 2003). The focus of new math took students away from the basics and teachers were using materials developed by mathematicians, similar to the development of the current New York State math modules. Although these materials do math justice, they were not, and are not aligned to how children learn. Findell shares that the general public saw new math as a failure because students no longer knew the basic facts of arithmetic. Thus was born the “back-to-basics” movement of the 1970s. Students would not be given other mathematical tasks until they had mastered the facts and could compute quickly and accurately. Findell recognizes
that although students learned how to add, subtract multiple and divide, they did not learn when and how to apply those mathematical operations. By the end of the decade, teachers concluded that the basics were not enough and an emphasis on problem solving and mathematical application was the new initiative. The new approach called for more interdisciplinary learning. Historically, math education has been changing every decade and this pattern has continued right into the current Common Core State Standards Initiative (CCSSI).

The goal of the CCSSI is to prepare America’s students for college and careers. Part of the preparation is the need for strong literacy skills in every discipline, including mathematics. College level math courses involve daily reading assignments from textbooks and other sources, as well as major writing assignments where synthesis of material is required. Even if students are not planning on going to college, their high school diploma depends on the ability to use literacy across subject areas. New York State has identified fluency, deep understanding, application and dual intensity as four of six the major instructional shifts in mathematics with the implementation of the CCSSI (Engage NY, 2012). The shifts in math instruction call for a balance of the reforms adopted in the past. Engage NY emphasizes that students are expected to have speed and accuracy with simple calculations (math fluency), as well as deeply understand math concepts before moving on (conceptual understanding). Both of these aspects to math teaching and learning will be focused on intensely. Students will see the shifts in rigor through the math questions being asked. The problems students encounter are multi-step and often involve written responses to demonstrate and communicate understanding. Students are expected to choose appropriate concepts to apply without being prompted. This is difficult when and if students have a misunderstanding, do not remember all concepts learned, or if they struggle to read and understand what the question is asking in the first place. With the CCSSI,
the list of skills necessary to excel in math is longer than ever. Students who excel in math today are able to do the following: memorize the facts and procedures, and understand why the procedures work; read and use mathematical language and symbols; analyze and interpret diagrams and word problems; justify and explain their thought process; have and utilize background knowledge; choose the most efficient process to solve a problem; and have a conceptual understanding of mathematics. Every item on this list requires some form of literacy.

The changes to include more literacy in math are very evident in high school geometry courses. In elementary school, geometry problems involve simple formulas and math calculations such as “calculate the area/perimeter of a triangle.” High school geometry is vocabulary heavy. Nearly all of the terms and symbols are new to adolescents in high school. What students know as shapes should be called polygons: closed plane figures with at least three sides. A line is infinite, and the term regular actually has a very specific meaning. Many words used in the high school geometry curriculum have a different name than what students have seen in earlier grade levels and some words are contradictory to their everyday meaning. In addition to vocabulary, students must be able to read and interpret complex word problems. For example, a square pyramid has a square base ABCD, and lateral faces that are isosceles triangles. Median $EF$ bisects $AD$. If $m\angle FED = 25$, find $m\angle ECD$. After reading the question, one should be able to see the issue facing geometry teachers. Many students will shut down at first glance of this question or after reading through it, not knowing where to start. One major skill emphasized in geometry is being able to take the language and translate it into a diagram. Creating a visual representation requires conceptual knowledge as well as metacognition (Adbdullah, Halim & Zakaria, 2013). In addition to creating a model and knowing what the figure looks like, students then have to identify what the question is asking and choose the correct theorem or concept to
apply; often times the applied concept requires algebra. If students can get to the solving part of the problem, it should be smooth sailing considering algebra is a pre-requisite for geometry. Many people who struggle in geometry cannot get past the initial step of reading and interpreting the content or problem. Educators should question if challenges in geometry are math issues or if students struggling due to inadequacies in literacy. Students placed in geometry support classes will then need literacy intervention as well as math intervention. Exploring the use of specific literacy strategies and activities to help students in geometry is beneficial for developing student understanding and supporting academic success in mathematics. If the topic of using literacy in geometry is not explored, students and teachers will both suffer. Students need to be prepared for further math courses as well as other disciplines that require mathematical literacy. Korpershoek, Kuyper and Van Der Werf (2015) found math and reading ability to be positively related on examination grades in math, physics and chemistry. Students in upper level math courses are expected to comprehend and answer rigorous problems and unfortunately many high school graduates continue their education without the necessary skills for college credit-bearing math courses (Schornick, 2010). Even in high school, New York state teachers and students are being measured by the Common Core Math Assessments, which consist of 36 rigorous questions with similar or more difficult language than the example question stated previously. Math teachers must make sure students are fully equipped to master the high school assessments and also be prepared for college level courses that require math.

This action research project was designed to investigate how math students find literacy strategies and activities helpful in understanding geometry concepts and problems. A small group of geometry students participated in literacy activities in a geometry classroom. Three different literacy activities were implemented on the following literacy aspects, reading
comprehension word problems, vocabulary, and written explanations. Students were observed in the classroom while using literacy in geometry, their work was analyzed, and three students of different abilities were interviewed after each activity. Within the data collected, some reoccurring themes emerged and these themes revealed that the effectiveness of literacy strategies and activities in math differs for students of varying math ability. Strong math students are able to self-monitor their comprehension of word problems, as well as instinctively transfer literacy skills such as re-reading or using vocabulary, and thus do not find explicitly taught literacy strategies in math to be helpful. Weaker math students need even more support than just literacy strategies and activities to understand geometry concepts. The literacy strategies and activities were the most helpful when used as a supplement for understanding concepts with average level math students. Furthermore, visualization and drawing a diagram was identified to be the most helpful strategy used by all students to solve word problems and understand vocabulary. The findings and data imply that math teachers should not force the use of literacy strategies and activities in math lessons, and instead should integrate literacy in math lessons when appropriate and necessary for learners. Students should be offered many strategies as optional supplemental tools. Although the use of literacy strategies is helpful for some students, weak math students will need more explicit re-teaching of math concepts and procedures to be successful.

**Theoretical Framework**

Literacy skills have become essential for understanding mathematics. Therefore, math educators need to look at what literacy is and what theories inform the implementation of literacy strategies in math classes. Gee (1989) interprets literacy as “control of secondary uses of
language” (p. 23). A secondary discourse is any discourse involving social institutions beyond the family. People belong to multiple groups outside of their primary discourse, and they could potentially use different types of literacy within each group; exhibiting that literacy is multimodal. For example, adolescents use different literacies throughout the school day such as interpreting a diagram in a math discourse, writing an essay in another academic discourse, and using text messaging in social peer groups. In order to develop a secondary discourse, a person must have experience and exposure to different social situations. Although math is taught in lower grade levels students do not experience the discourse of geometry until high school. It is safe to assume that geometry is not a topic discussed regularly at home by students, so the opportunity for them to become proficient in the geometry discourse is limited to time in math class. For students struggling to develop mathematical literacy, more opportunities should be provided to participate in the discourse throughout the school day/week.

Gee (1989) asserts that mastering any discourse (and thus literacy) is done through acquisition, not learning. To acquire literacy is to gain knowledge without cognitively knowing you are, through experiences and observations about the surroundings and the group (Gee). This is different than being explicitly taught something, which is often the teaching style seen in math classes and perhaps a reason why students have difficulty acquiring mathematical literacy. Furthermore, Lanksher and Knobel (2007) recognize that a person must be socially and culturally invested in a discourse in order to become literate in that discourse. Getting students invested in mathematical discourses can be a challenge for teachers. Teachers must find strategies to help students feel comfortable in math classrooms and become active participants. It is important to recognize that in any discourse, especially math, literacy is not a solitary act; literacy is a social practice that people participate in with others (Freebody and Luke, 1990).
Whether the participants are a group of 25 students or a small group of six students, mathematical literacy is best developed through working and communicating with others.

Many instructional strategies that could help students with the literacy in math courses including geometry are informed by sociocultural theory. Kucer (2014) explains “a sociocultural examination of literacy shifts our attention from decontextualized texts, skills and individuals to literacy events, literacy practices and literacy performances” (p. 230). Following the sociocultural theory means that students would partake in literacy learning together, sharing experiences and engaging in conversations about literacy. One instructional approach that follows the sociocultural theory is collaborative learning (Larson & Marsh, 2005, Moll & Gonzalez, 1994). Literacy strategies taught in math classrooms should be of a collaborative nature. Students can work together with the guidance of the teacher to problem solve and identify the key parts or steps to problems. Sociocultural theory is supported by the Principles and Standard of The National Council of Teachers of Mathematics (2000) where it is stated “students who have opportunities, encouragement, and support for speaking, writing, reading and listening in mathematics classes reap dual benefits: they communicate to learn mathematics, and they learn to communicate mathematically” (p. 60). Another aspect of sociocultural theory is connecting in and out of school literacies (Larson & Marsh, 2006, Moll & Gonzalez, 1994, Kucer, 2012). Teachers can use literacy to make math relevant and connect math concepts to students’ prior knowledge from other subjects and out-of school.

In response to educational reforms, many math educators have advocated for a constructivist approach to teaching and learning (Draper, 2002). Constructivists rely on teaching practices that are rich in conversation and constructivists understand that experience, environment and language all play important roles in learning. Similar to sociocultural theory,
constructivism is the philosophy that learners create their own knowledge based on interaction with other people (Draper, 2002). Findell (1996) expresses that if math classrooms are to become student-centered, the teacher must act as a questioner and problem poser, so students can make sense out of what they are learning. Utilizing a constructivist approach does not mean every mathematical process and concept must be discovered by students individually. Successful teachers explore and acquire a variety of methods, including literacy methods, and know when and which students to use each method with (Findell, 1996). The end goal is for students to understand mathematics and solve problems independently, but students will not be able to achieve this goal without the mathematical literacy acquired through social practices.

**Research Question**

Literacy strategies implemented in math classrooms should reflect sociocultural theory and constructivism in order to meet student needs. Teachers should be guiding students in interpreting questions and problem solving. Given that literacy is a necessary aspect of math instruction, this action research project asks, how can utilizing literacy strategies and activities in math class help math students understand geometry content and problems?

**Literature Review**

In order to further inform the action research that will take place, relevant literature was reviewed on the topic of content area literacy, specifically mathematics. By analyzing what has been explored in the past, current researchers can gain knowledge on the topic being studied, become familiar with successful research and pedagogical practices and have an idea of how to implement the research in the classroom. Three themes will be discussed in this literature review. The first theme will present evidence of the cross circular connection between literacy
and mathematics as it appears in multiple grade levels. Once a correlation between the subjects has been established, it is necessary to look deeper at how teachers are using literacy to teach math content and problem solving. Accordingly, the second theme will examine research on applied literacy strategies as they are used in math classrooms. The final theme will highlight and address one of the biggest literacy challenges math students encounter, word problems. In addition to investigating the struggles with word problems, some successful strategies will be explained.

**Establishing the Connection between Literacy and Math**

Literacy is a major foundational key to success in academic content areas, including mathematics. Learning mathematics and solving math problems requires more than computational skills. Today’s students need to have strong reading abilities in order to achieve at high levels in math. The connection between literacy and math is largely discussed at the middle and secondary levels, even though the relationship begins before children enter school. The knowledge children gain in math and literacy at a young age is necessary for the acquisition of knowledge in other subjects. Purpura, Hume, Sims and Lonigan (2011) further discovered that early literacy and early numeracy are important in the development of each other. Early in their development, children start to differentiate letters and numbers. Basic understanding and identification of visual symbols is necessary for children to develop emergent numeracy and literacy skills (Munn, 1994). Early numeracy incorporates a child’s ability to recognize numbers, count numbers, compare amounts and understand changes in quantities. These skills may develop through meaningful social and print interactions in a child’s primary discourse and are certainly further developed when children experience schooling; as mathematics and literacy are the two dominant areas of children’s early academic learning. After studying a group of
preschoolers, Purpura et al. (2011) found that early numeracy skills are related to and impacted by vocabulary and print knowledge. In order to develop numeracy skills, children have to be able to read numbers, symbols and understand math related vocabulary such as “more” and “how many.” Betts, Pickart, and Heistad (2009) found that letter recognition is related to finding patterns, number sense, and measurement. These findings suggest that understanding of numbers and letters in preschool provides a strong foundation for the development of more advanced mathematics and reading.

The use of language and symbols in math becomes more demanding with each increasing grade level. By secondary school, reading skills are even more of a powerful predictor for math performance (Korhonen, Linnanmäki & Aunio, 2012). The literacy abilities a student brings with them to math class will set the stage for their success in math. The understanding of certain language is inherently necessary for the completion of mathematical tasks (Purpura, Hume, Sims & Lonigan, 2011). Another factor connected to reading that contributes to math performance are teacher expectations. Schronick (2010) reported some high school graduates attributed their mathematical shortcomings to the low expectations of their high school math teachers. Teachers must challenge students and work to ensure that there is a high level of rigor in math lessons. Higher expectations could include requiring students to use sophisticated math language in discussions and in writing. Teachers could also incorporate more reading assignments to model what math courses look like in college. When teachers do not integrate such literacy-involved activities in secondary math courses, students could be blindsided when they get to a college level course. In addition to low teacher expectations having a negative impact on math learning, if student’s literacy skills are weak, then their ability to learn mathematics will greatly suffer. High school mathematics involves learning and comprehending a considerable number of
concepts. Students with a history of low performance in math and literacy are struggling to learn these concepts (Korhonen et al., 2012). Certain mathematics tasks such as performing basic math operations are often embedded in complex text, necessitating strong reading abilities, socialization skills and adequate language development to comprehend. Purpura et al. (2011) recognized that some children were able to conceptually grasp the informal vocabulary used in math class, but without a deeper knowledge of mathematical language and symbolism, it proved to be unlikely that the students could apply their knowledge in a formal mathematical context. Korhonen et al. (2012) discovered the relation between math and literacy by comparing performance of high school students in both math and reading. The group comparisons showed that students with low mathematical performance had low scores in word and reading comprehension as well. Simply, research has shown that literacy impacts mathematics learning and problem solving form pre-school all the way up to the college level.

The way math text and problems are written also has an impact on students’ understanding and performance in math. In a comparison of two different math texts, one with mathematical symbols the other only using natural language, Österholm (2006) reveals that mathematical words are not the most dominant aspect affecting the reading comprehension process, but the use of symbols in the text is a more relevant factor. When symbols and content area vocabulary are used, math texts become more challenging to comprehend. In agreement, mathematicians acknowledged reading vocabulary, notation and symbols as potentially problematic for high school students (Shaananan & Shanahan, 2008). Although math text is a challenge for adolescents, being able to read it and write it is curtail for their understanding of math content. Regarding vocabulary, mathematicians noted the challenge of some words having both general and specific meanings. For example, students must know a “factor” is a number
that when multiplied with another produces a given number. A factor could also be an influence on a certain result. In this instance, the nonmathematical meaning will not aid in understanding the mathematical meaning. For other words, definitions may be related in and out of the context of math and prefixes and suffixes may give students clues to help identify meaning. Keeping track of vocabulary words and which words have familiar meaning is yet another challenge for high school math learners. If students already have a deficiency in reading comprehension then they are at an even greater disadvantage when it comes to reading math text with symbols and vocabulary. Pimperton and Nation (2010) investigated the mathematical abilities of children with specific reading comprehension difficulties and found that poor comprehenders performed significantly low on mathematical reasoning questions and showed significant weaknesses relative to vocabulary knowledge. Just because students with weak comprehension perform lower in math does not automatically mean that students with good general reading comprehension skills will necessarily be able to understand math texts better. Österholm (2006) concluded that mathematical texts seem to demand a special type of skill for reading comprehension, especially if the text has symbols. His findings highlight the need for explicit teaching of content-specific literacy skills, in this case, direct practice reading symbolic texts. Similarly, Pyke (2003) researched the role of reading in spatial abilities and results showed that students’ use of symbols, words, and diagrams to communicate about their ideas each contribute in different ways to solving tasks and reflect different kinds of cognitive processes invested in problem solving. The presented evidence proves that there is more involved in solving math problems than just math. Even students with strong procedural skills in math can struggle with reading comprehension of math problems focused on conceptual understanding. Pimperton and Nation (2010) tested procedural mathematical skills along with mathematical reasoning skills
and the results showed that good computational ability is no guarantee for adequate understanding of math concepts and problem solving; just as good decoding does not always lead students to understanding what they have read. Another important part of math aside from procedural fluency and conceptual understanding is being able to represent situations in multiple ways, for example algebraically, graphically or with diagrams. Pyke (2003) suggests there is an association between general text literacy skills and representational proficiency: “It was demonstrated that strategies for representation develop in coordination with the development of prior knowledge and skill associated with reading and spatial ability” (p. 427). Although there is a link between mathematical ability and reading comprehension, what causes the link is unclear. Österholm (2006) argues “the reading process of the mathematical text with symbols is a special kind of comprehension process” (p. 340), and thus wonders if perhaps the results would be different if students were asked to read a different type of math text, formatted in a different way such as a list of steps or a procedural description. Even though students might be able to fluently read math text, some may still struggle in knowing the meaning of it. Pimperton and Nation (2010) suggest that students’ underlying mathematical reasoning competencies could be masked by linguistic comprehension weaknesses and that language proficiency is necessary to be able to reason mathematically.

In summary, mathematics learning cannot occur without a strong literacy background. Early recognition of written and spoken letters and numbers are important stepping-stones for later development of math abilities. Content area vocabulary knowledge and symbol representation become key factors in the understanding of math at the middle and secondary levels. In addition to mathematical language fluency, reading comprehension is a major factor in the process of mastering a math discourse.
How Teachers are Using Literacy Strategies to Teach Math Content and Problem Solving

Providing math teachers with literacy strategies and suggesting the implementation of them is purely not enough for the strategies to be used effectively. Content area teachers need to understand the purpose of using literacy strategies in their classroom and the strategies must match their routines, philosophies and view of how they think the subject should be learned. Enforcing that all teachers should be “teachers of reading” can frustrate content area teachers because each subject area has its own unique disciplinary literacy skills. Teaching mathematical literacy will look different than literacy in social studies or science etc. Phillips, Bardsley, Bach and Gibb-Brown (2009) report hesitation from teachers involved in a professional development (PD) project designed to encourage middle school teachers to explore the integration of literacy strategies into math classrooms. Once teachers were given the opportunity to discuss student concerns and learning needs with each other, they realized that the literacy strategies and resources being delivered at the PD would be helpful to their instruction. In a similar PD study with math teachers, Adams and Pegg (2012) observed that if similar instructional goals are not already in place, considerable learning and rethinking may be necessary before a teacher can effectively incorporate content literacy strategies. However, the shift for some teachers is necessary in order to meet the needs of the students who are faced with disciplinary literacy challenges. Teachers interviewed by Phillips et al. (2009) expressed the want for lessons to be useful, not in addition to. In other words, teachers want strategies they can incorporate with existing curriculum instead of doing it separately. Shanahan and Shanahan (2008) encountered the same teacher concerns when asking for middle and high school disciplinary teams input about strategy use. The team of teachers advocated for strategies that mirrored the kinds of
thinking and analytic practices common to their discipline. While politely acknowledging the value of more general strategies such as the KWL, they did not discuss using these strategies in teaching content (Shanahan & Shanahan, 2008). Strategy use should fit naturally into math lessons and not be forced. Although there is some push back from teachers about adding literacy strategies, many math educators inherently instruct students in reading and writing without being prompted to do so at PD meetings (Carter & Dean, 2006). Whether literacy is new to math teachers or innate, the way in which math teachers enact literacy strategies is varied. Adams (2010) argues that “teachers’ views of learning and understanding mathematics proved a powerful influence both on which literacy strategies they chose to use and on how they used these strategies” (p. 386). Ultimately, teachers will adapt strategies to best fit the content and the needs of their student. In a summer math clinic for grades five through eleven, Carter and Dean (2006) analyzed instruction for the use of spontaneous reading strategies. The teachers incorporated 101 separate cases of literacy instruction, the most centered around vocabulary. The fact that teachers used for vocabulary strategies instinctively indicates that math educators understand the importance of vocabulary knowledge in understanding math content and problems. All teachers involved used the strategies inherently and all in different ways (Carter & Dean, 2006). Some vocabulary was taught in context, while others taught it directly by providing formal academic definitions. Disciplinary experts are adamant that precise mathematical definitions need to be learned by high school students in order to differentiate math meaning from every day meaning (Shanahan & Shanahan, 2008). Vocabulary instruction is not the only way strategy use can differ. Adams and Pegg (2012) observed teachers modifying literacy strategies to help students rehearse and remember knowledge rather than using strategies to support the development of conceptual understanding. Such as the common technique for
remember the order of operations: PEMDAS, which is turned into the mnemonic phrase “please, excuse my dear Aunt Sally.” It stands for parentheses, exponents, multiplication and division, and addition and subtraction. Adams (2010) observed the same two patterns of procedural vs. conceptual strategy use in a case study with math teachers. One teacher used strategies such as writing summaries, as a rehearsal tool to provide students multiple opportunities to review and memorize facts, concepts and procedures. While other teachers were observed using thinking tools to support understanding of mathematical ideas and procedures, such as asking students to describe their understanding of a mathematical relationship in writing and make connections between new knowledge and prior knowledge. The studies presented do not specify if one way of using a strategy proved to be more effective than the other in terms of student performance. However, a comparison should be made. Procedural strategies are necessary, but they should be supplemented with authentic disciplinary activities that focus on sense making. Strategies used for rehearsal purposes only do not encourage students to make their own meaning or understand math concepts for themselves. It is now crucial to look at some examples of instructional approaches put in place by teachers and discuss the effects on student understanding.

Halpern and Halpern (2005) designed a creative writing activity for secondary geometry students, in which stories were written involving polygons and their distinct characteristics. As a creative writing assignment, students can demonstrate their understanding of geometry shapes through the use of mathematical language, and also through illustrations. Another example of using visuals for mathematical literacy instruction is through the use of a Frayer model for vocabulary. Diaz and Dykes (2015) observed that middle school students who learned vocabulary through the Frayer model were drawing visual clues on test questions to remind themselves what the questions were asking them to do. Teaching using accurate drawings and
diagrams can help students fully comprehend mathematical concepts and terminology, especially in the subject of geometry. When students were interviewed about the creative writing process, they noted the importance of the pictures: “when pictures were inaccurate, the mathematics did not make sense and information was not communicated to the reader clearly” (Halpren & Halpren, 2005, p. 229). Having learners create their own visual display of mathematical concepts is an example of an authentic experience where students can make meaning. The visual representation emphasized in the Frayer model proved to help students answer math problems correctly, similar to students using a problem solving strategy described by Reilly, Parsons and Bortolot (2009) as the reciprocal teaching strategy. The reciprocal teaching method consists of four stages to solving math problems: predicting, clarifying, solving and summarizing. Groups of students using the reciprocal teaching strategy were encouraged to use pictures or manipulatives to visualize a solution and in doing so were able to answer math questions successfully, in comparison to a group of students who did not use visuals and were unsuccessful. With higher-level math assignments, students will need to be able to do more than draw a diagram to help comprehend the mathematics. A prime example would be in secondary geometry courses, where adolescents need to be able to write clear, concise proofs of mathematical theorems. Yang and Lin (2010) developed a reading-oriented activity that proved to help reading comprehension and writing of geometry proofs. High school geometry is most likely the first time students encounter the tasks of writing proofs, so as a completely new, difficult task, strategy development is key. In a control group, teachers jumped right into guiding students through the proof writing process where as in the experimental group students were given a full proof to read, discuss and answer comprehension questions about (Yang & Lin, 2010). Reading a proof can be equally as challenging as writing one, so it is good that the
reading was accompanied by clarifying questions and group discussions. The discussions were a major literacy factor that helped students comprehend written proofs. Bruun et al. (2015) also studied the results of journal writing with peer teaching in comparison with the Frayer model as a strategy for vocabulary. Journal writing gave the teacher an opportunity to see what students were thinking, and peer discussions motivated students to make sure they knew the correct definitions to share with each other. Any time visualizing problem situations and mathematical discussions are implemented as strategies will particularly help students who struggle with reading, writing and language.

Perhaps one of the most important aspects of literacy in math is how teachers and students communicate. There is much debate whether or not the use of formal versus informal mathematical language makes a difference with student understanding and achievement. Firmender, Gavin and McCoach (2014) assert that significant positive relationships existed between teachers’ implementation of mathematical language practices and student achievement at early grade levels. A strong language foundation is important in math because of its cumulative, recursive nature. Also, most students enjoy feeling smart and showing off their understanding by using sophisticated content language to enhance their communication. On the other hand, Staats and Batteen (2009) argue how an informal speech style can extend the communicative capacity in high school classrooms and allow for more participation by all students. Using informal language instead of precise mathematical language can be a trade off for more student involvement. Teachers will need to decide when it is appropriate to allow informal language. Substituting words like “drop” and “slide” when describing the solution to an algebraic equation still explicates the direction of a student’s problem solve pathway (Staats & Batteen, 2010). Although motion verbs help students describe mathematical procedures, using
math terms will address the conceptual understanding behind equation solving. The reason we are able to “slide” numbers to the other side of an equation is because of inverse operations. The debate over the use of mathematical language goes back to the two different viewpoints presented by Adams (2010) and Adams and Pegg (2012): content area literacy instruction can have a procedural emphasis according to some teachers’ methods, or focus on developing conceptual understanding. Many math teachers teach short cuts to help students with procedural skills, for example memorizing SOH CAH TOA for the trigonometric ratios, Sine, Cosine and Tangent. However, skipping over conceptual understanding can cause more confusion for students. Firmender et al. (2014) saw great gains in student achievement when focusing on a conceptual understanding approach by implementing mathematical language as an instructional practice and requiring students to use appropriate math vocabulary in their verbal and written communication. Using the language of math is a main part of developing the math discourse and acquiring mathematical literacy. It is understood that participation is also a key element of being in a discourse, but teachers need to help students get to a point where they are able to do both, participate using content language. Herbal-Eisenmann (2002) suggests being flexible and allowing students to move between official math language and transitional math language. A teacher could start off a new topic using transitional vocabulary, for example “steepness” and then eventually as the lesson or unit progresses introduce the mathematical term “slope.” In a case study, Herbal-Eisenmann observed that using multiple ways of talking about math ideas enhanced students’ learning and helped make ideas accessible to every student in the classroom. Also, the introduction of the math language was more natural to the flow of conversation instead of simply writing a list of vocabulary words and defining each on day one of a unit. However, starting a unit with an informal math terms may mislead or confuse students. Carter and Dean
(2006) found learning vocabulary through context is an important skill, but direct vocabulary instruction greatly improves vocabulary knowledge and comprehension. Direct vocabulary instruction is specifically important in math classes because the precision of math definitions often distinguishes words from their non-mathematical meanings and also plays a role in clearing up vague understandings.

The research presented provides evidence that teachers are implementing literacy strategies in the classrooms, mainly for two different purposes. Given the current educational reform of the Common Core Learning Standards, content area literacy strategies geared towards developing conceptual understanding are preferred. Students required to predict, clarify, question and summarize for each math question completed two questions correctly while non-strategy using students completed four questions partially correct it the same amount of time (Reilly, Parsons, & Bortolot, 2009). Although these conceptual strategies take more time to teach and more time for students to implement, a deeper understanding of mathematics will have long effects and support achievement across grade levels. Teachers who utilize sophisticated math language will influence students to acquire that language and develop the math discourse.

**Literacy Challenges in Math Word Problems**

Reading and comprehensions strategies are particularly necessary when it comes to solving mathematical word problems. Written word problems require students to transition between everyday language, math language and math symbols. Some word problems require students to bring in background knowledge, as they could be math problems written in real-world contexts. While managing the words, students need to identify relevant details and connect concepts (sometimes across subject areas). In order to come up with the solution to a
LITERACY STRATEGIES HELPING MATH STUDENTS

Word problem, students must decide which meaningful, computational procedure is needed and apply it correctly. Kyttala and Bjorn (2014) proclaim that “one has to have both linguistic and mathematical knowledge, and one has to flexibly operate between these different knowledge types to be able to solve mathematical word problems” (p. 59). Math skills and literacy skills should be interchangeable during the process of solving word problems. This theme will present studies that have targeted specific literacy skills and explain how the abilities play an important role in problem solving.

Word problems are an important part of math curriculum beginning in elementary school. At this level word problems are utilized to connect in and out of school mathematics, providing students with real-world applications of math. Problems about spending money at stores are classic examples of elementary word problems. When students are just beginning to learn formal mathematics in school, it is important they find what they are learning to be relevant and engaging. Fuchs et. al (2006) report that during elementary school, reading fluency and site word efficiency significantly predict the performance in solving mathematical word problems. Knowledge of everyday language in addition to simple mathematics language is key for children who are at the beginning stages of learning math. Kyttala and Bjorn (2014) argue if a student has developed average language skills, he or she will find it easier to use context and prior knowledge to support the problem solving process. Fluency is In combination with fluency and site word knowledge, Bjork and Bowyer-Crane (2013) tested reading comprehension to be the greatest variable in predicting performance on mathematical word problems in six and seven year olds. The result of both studies together is consistent with literacy education and assessment in that fluency plays a role in a reader’s ability to comprehend texts. So, it makes sense that both fluency and comprehension tested as to factors affecting word problem performance. With the
hierarchy of mathematical studies, it is no surprise that in middle and high school, more advanced reading and comprehension skills are necessary to successfully understand and solve mathematics word problems (Korpershoek, Kuyper & Van Der Werf, 2013; Kyttala & Bjorn, 2014; Pimperton & Nation, 2010). At the adolescent age, literacy skills affect learning in all core academic areas. Reading ability was found to be positively related to high school exam grades in math, physics and chemistry (Korpershoek, Kuyper & Van Der Werf, 2013). Real-life scenarios are incorporated in science just as much, if not more than in math courses. Word problems in science and math courses are tools for participating in modeling all kinds of situations in everyday life. The purpose of solving word problems at the secondary level is to train students to think critically, creatively and help deepen understanding of new concepts by applying them. It is debatable whether or not all math word problems students face will give them the presented experience, but it is known that secondary students are confronted with word problems on a daily basis in different disciplines and on standardized assessments; making the need for strategic problem solving essential.

Kyttala and Bjorn (2014) categorize unsuccessful problem solvers as those who simply select key numbers and key words from the text, and base their calculation process on these words and numbers regardless of the context and with really concentrating on the task. Using single words as hints is identified as a superficial strategy that leads to flawed solutions and outcomes. It is important to note that computational ability was not a major predictor of word problem performance (Bjork & Bowyer- Crane, 2013; Kyttala & Bjorn, 2013; Pimperton & Nation, 2010). Operating numbers procedurally may not correspond to understanding the relationships between numbers as conveyed through language in word problems. Recognizing what procedure to follow to solve a word problem is a challenge for many students. Ilany and
Margolin (2010), observed students trying to solve the following math problem with insufficient information: “Five dogs guard 125 sheep. How old is the shepherd” (p.140). Students went through trial and error of every operation (addition, subtraction, multiplication, and division), when in fact the problem had no mathematical solution because not enough information was given. Math students automatically assume that if a problem is given, there must be an answer. The shepherd question however has no mathematical language that would lead students to perform any operations but they did anyway. Ilany and Margolin conclude students must make a connection between the natural language and the mathematical language to construct meaning of the information in word problems. Assumption is not an effective, realistic problem solving strategy. One reason students resort to putting random information together is because they do not have an adequate problem solving technique; whether they were not taught one or simply do not know how to use it properly. In a study by Pape and Wang (2003) many students reported using organizational strategies to solve math word problems, but far fewer students actually showed evidence of strategy use; indicating that although students understand the importance of organizing given information in a word problem, they do not necessarily know how to do so independently. If and when students showed evidence of planning, transforming, and organizing information, students were more likely to choose a meaningful approach to solving the word problems (Pape & Wang, 2003). Learners must think about what is being asked and what information is given before diving into a solution. An example of a step-by-step strategy was developed and tested by Ilany and Margolin (2010) in response to the difficulties students have understanding text literally and mathematically. The model for problem solving has nine stages: reading the problem, understanding the linguistic situation, understanding the mathematical situation, matching the math situation to the linguistic situation, brainstorming ideas for a
solution, screening ideas, building a mathematical model, finding the solution and checking to see if the solution makes sense. Some literacy aspects within the nine stages would be self-regulation vocabulary knowledge and understanding the question being asked. Self-monitoring as also being asked of students in the reciprocal teaching group studied by Rilley, Parsons, and Bortolot (2009). During the clarification stage in the reciprocal teaching model students were asked to make a list of unfamiliar words they and state all of the facts they knew from the problem at hand. Both models of problem solving involve students going back to the text multiple times. Ilany and Margolin (2010) suggest having students read the question from the bottom up and from the top down to pinpoint where the meaning is in the text. Another similarity within the problem solving techniques is the modeling stage where students construct a representation of the mathematical principles relevant to the problem. Modeling mathematics could be drawing a diagram or a graph, or writing an equation. The most important piece of learners using the step-by-step strategies described is that both demonstrated impressive improvement in mathematical comprehension and ability to communicate correct solutions to math problems (Ilany & Margolin, 2010; Rilley, Parsons, & Bortolot, 2009).

Effective strategies for solving word problems do not have to be long and elaborate. Pape and Wang (2003) observed high achievement with word problems in students who reported using different strategies from different categories. Seeking information strategies were used the most among high achievers. This category is most directly related to literacy as it involves rereading to understand, using additional references, skimming, or searching definitions of unknown words. Another largely reported strategy used by high performers was seeking social assistance. Asking peers, teachers and parents for help directly relates to the social aspect of literacy learning. The third most used category of strategies was organizing and transforming
information to better understand the material. Included in organizing information would be re-representing information, writing an outline or creating a table of information, using models or manipulatives and dissecting the word problem. Within this category could be a thinking, visualizing approach studied by Abdullah, Halim, and Zakaria (2014) called VStops. The VStops approach consists of built in stopping points throughout the problem solving process where learners translate the words in the problem into visual representations. Abdullah, Halim and Zakara found that “the construction of visuals helped students connect with problem situations and facilitated students’ ability to communicate their understanding of that problem” (p. 171). Depending on how complex the word problem is, more than visualization and representation may essential to success. Pape and Wang (2003) found that students who used multiple strategies from more than one of these categories achieved at higher levels than students who used one strategy from one category. A commonality among all students involved in the study is that students were self-regulating and participating in active problem solving. Abdullah, Halim, and Zakaria (2014) assert that “students’ inability to self-regulate and be aware of their thinking processes causes problems during mathematical problem solving, especially with word problems” (p. 166). Students who cannot self-regulate are not able to have the internal dialogue to assemble relevant information in a problem into mathematical sentences, representations and appropriate procedures. Self-regulating understanding connects back to the studies that resulted in reading comprehension being a factor in word problem success because self-monitoring can influence reading comprehension.

When approaching word problems, students need to integrate multiple skills such as reading, comprehending and calculating. Strategies allow students to work back and forth
between literacy and computational skills are very useful. Evidently, mathematical word problems involve a level of comprehension first before reaching the work or calculation stage.

**Conclusion**

Even with the relationship between math and literacy existing and being well known, students in the United States remain stagnant in the field of mathematical literacy. Kelly et al. (2012) report that out of 64 counties, analyzed in an international student assessment, the United States ranked 35 for mathematical literacy and the U.S. average score for mathematical literacy was lower than the overall average of the countries participating in the assessment. Clearly there is still more work to be done with content area literacy by math educators in the United States. In general, some of our students are not prepared for facing mathematics after high school. According to the ACT (2005) 28% of college freshmen in the U.S. are enrolled in one or more remedial courses in reading or mathematics. The statistics presented suggest that schools are not preparing students well enough to perform in the mathematics field and face the challenges of mathematical literacy. Even though many teachers are implementing literacy strategies in math classrooms to mediate the struggle existing with math and literacy, more work and research needs to be done.

**Method**

**Context**

The research being conducted for this study took place in a public high school in upstate New York. According to the New York State (NYS) School Report Card enrollment data from 2012-2013, a total of 1,249 students attend the high school. The student population is approximately 76% White, 10% black or African American, 10% Hispanic or Latino, 3% Asian
or Native Hawaiian/Other Pacific Islander and 2% Multiracial. In addition, NYS School Report Card presents that 10% of students are considered Students with Disabilities and 23% are Economically Disadvantaged Students.

Within the high school, the research was performed in a geometry class of 20 students. 50% of the students in the class are male and 50% are female. All students except for two females are in grade 10. The two females are taking the geometry course a second time as eleventh graders, after having a failing grade (below a 65 average) for the course last year. Four students are multiracial and three of them have Hispanic or Latino listed as their identifying race. Two male students are Black or African American, and the remaining 14 students are white. One student in the class receives free or reduced lunch. Two students in the class have 504 plans with accommodations for diagnosed attention deficit disorder and one other student has a 504 plan to receive accommodations because he is deaf or hard of hearing. An FM system is used by the teacher and any other speakers during whole group instruction as one of the accommodations listed on the 504 plan for the student who is deaf/hard of hearing. Aside from specific demographics and academic needs, the personalities of students in the classroom vary. Some of the male students are friends and they like to socialize in the beginning and ending of the period. During instructional time, the strong male personalities like to participate and answer questions more often than the females. Students are seated in pairs and they do well communicating with their seat partner during work time. Each geometry period is 42 minutes long and this particular period begins in the middle of the school day, after lunch periods. There have not been any issues with attendance or behavior in the class. Nineteen students currently have a passing geometry grade.

Participants
I focused in depth on three particular students from the class of 20. Although three students were the foremost active participants in the study, five additional geometry students from the class were observed and their work was examined. Therefore, the five additional students were participants as well. The only difference is that only the primary three participants were interviewed. The three main participants were chosen based on math ability: high, average and low math abilities were represented through the participants. The three focal participants are all within the same socioeconomic status, and are part of the general education population. The three students differ in background, race and gender and math ability.

Nathan (a pseudonym) is an African American, 15-year-old male student in grade 10. He is taking all tenth grade level courses and has chosen to challenge himself with Advanced Placement (AP) European history. Nathan has perfect attendance for the 2015-2016 school year. He achieved at above average levels across the board in all ninth grade courses last year with final course averages ranging from 86 to 99 percent. He is one of the top math students in the geometry class and mathematics is considered to be one of Nathan’s best subjects. In grades three through eight, Nathan has consistently scored a three or four on the New York State Math Assessments and in ninth grade scored a 76 on the Regents Common Core Algebra 1 Exam, exiting the course with a 86% average overall. A similar pattern is seen in his scores for English Language Arts, consistently scoring a level three on all New York State ELA Assessments in grades three through eight and scoring a 76% on the local English post exam for grade nine. This data presents Nathan as a well-rounded student. Nathan enjoys school and is motivated by good grades. He participates in class and works well in groups with other students. Nathan usually understands new math concepts the first time something is taught to a whole group. He is good at remembering facts, vocabulary and mathematical procedures such as equation solving.
Nathan likes to get his work done quickly, which can sometimes cause him to make careless errors.

Courtney (a pseudonym) is a white, 15 year old female in grade 10. Courtney does not consider math to be one of her favorite or best subjects. Courtney is taking three advanced courses, AP European history, advanced English 10 and Chemistry which is considered an eleventh grade course. Although math is not one of Courtney’s advanced subjects, she still performs close to average in general education math courses. In her math career, Courtney scored at level two’s and three’s on the New York State Math Assessments in grades three through eight. Last year, Courtney scored a 68% on the Regents Common Core Algebra 1 Exam and exited the course with an 80% overall average. Courtney scored significantly higher on her ELA exams than the math exams. Last year she scored a 95% on the local advanced English nine exam and previously had all level three’s and four’s on the New York State ELA assessments for grades three through eight. Courtney is a nice student who has a lot of friends at school. She enjoys reading and being on the swim team. Courtney’s mother is a social studies teacher at the high school and frequently checks-in about Courtney’s progress in math because it is her weakest subject. It is evident that Courtney and her family value education and Courtney takes pride in getting good grades in social studies, English and science. For math, she sometimes settles for average grades and is does not seem to be concerned or motivated to achieve more. Courtney is sometimes distracted by her cell phone in class, but is generally focused and engaged in learning geometry. Courtney hopes that geometry will be more interesting and relevant to her than Algebra.

Megan (a pseudonym) is a white, 15 year old female in grade 10. Megan grew up in Indiana and moved to upstate New York at the beginning of her seventh grade year. Megan tries
hard in math and needs encouragement and reinforcement. She processes information slowly and often uses the full amount of time given to complete math tasks. Megan enjoys math class, and is interested in the subject. She asks questions when she does not understand and frequently comes in during study hall for extra help. Megan wants to do well in school, she is self-motivated and feels proud when she earns high grades. Having access to standardized tests from grade seven to present, Megan scored average on the grade seven New York State math exam, but then scored below average in grade eight and grade nine. Specifically, Megan scored a 65% on the Common Core Algebra I exam last year. This score is the scaled score given by NYS, not the raw score; as are the other scores listed for the students above. Megan scored lower on the NYS ELA assessments in grades seven and eight than the math assessments. A possible contribution to low performance could be learning a different state’s curriculum prior to grade seven. On the ninth grade local ELA exam Megan scored an 83, which is a significant difference from the grade 8 standardized state test. Megan tries not to get discouraged by low scores and attempts to use it as motivation to better next time. She was thankful to have passed the math exam with a 65 to fulfill a graduation requirement and avoid having to take it over again.

Although she strives for excellence and mastery, Megan realizes that the Common Core exams are tough for her and she needs to maintain a focused effort to pass these high stakes tests.

**Researcher Stance**

I am currently a graduate student at St. John Fisher College and a tenured high school math teacher in upstate New York. I am working toward a Master’s of Science in Literacy Education, and adolescent literacy certification for grades five through grade twelve. I hold a Bachelor’s degree in Mathematics, which I earned at Hartwick College in Oneonta, New York. My current New York State teaching certification is in Mathematics Education, grades seven
through twelve. As the researcher for this study, I was an active participant observer, meaning that I observed and recorded the outcomes of my own teaching practice while actively engaging in teaching math concepts and strategies (Mills, 2014). Since I teaching math content, it was seamless to incorporate strategies and activities into my own instruction. This action research project did not feel random or awkward for the observer or the participants because I have been the student’s original math teacher from the start of the school year. As the participants math teacher, I already observe what the students do on a daily basis, and for my research I was observing more closely and documenting what I observed as much as possible. Mills acknowledges that “as an active participant observer of our own teaching practices, however, we may be so fully immersed in what we are doing that we don’t have time to record our observations in a systematic way during the school day” (p. 75). To combat this issue, I made sure to record any mental notes as soon as the work period began. I also circulated the room and took notes during the work period, observing participants as they applied the taught strategies or participated in the directed activity.

**Method**

For this study, I collected only qualitative data to determine how literacy activities help students learn geometry content and solve geometry problems. Three separate activities were implemented during whole group instruction. I modeled two of the strategies as a mini-lesson and students were asked to apply the strategy on their own during the work period. Directions for the third activity were explained, but it was more student-centered and no model was provided. Each strategy was designed to address one of the following three literacy areas: reading comprehension, vocabulary, and written responses. As methods of data collection, I observed participants, interviewed the three students of different math abilities, and collected
their work. A total of three observations and three meetings took place. Although I instructed all twenty students at the same time, I closely observed the student participants as they learned the strategy for the first time, and as they are used the strategy independently during class time. During instruction, I looked for who was engaging in the strategy or activity and who was not. I also observed the general responses from students as I explained each strategy and activity and provided examples. I asked questions to myself such as, are students listening, and attentive to the strategy being taught, or are they going ahead to the next problem? etc. In addition to observing all participants, I meet with the three individual students as soon as possible after the implementation of each strategy and activity to gain their perspective.

The first strategy I taught to the geometry students was designed as a reading comprehension strategy for math word problems. The strategy consisted of six guiding questions that students answered during and after reading the geometry word problem (see appendix A). In terms of literacy instruction, the strategy can be considered an active reading strategy. The students were directed to answer the questions before solving the math problem, as a way for students to check their own comprehension of the word problem.

The second part of my research was on a vocabulary activity (see appendix B). The activity was done as a starting activity for the second introductory lesson on angles. Students were asked to use their prior knowledge to develop a mathematical definition for new angle vocabulary terms. Using the prefix or the root of the word to help write a definition was suggested and modeled as a vocabulary strategy. For example, a “linear pair” of angles are two angles on a line. This makes sense because the root word of linear is line and pair means a set of two. Another strategy that was suggested to help students define geometry terms was drawing a diagram. For some terms, the parts of the word will not be enough, so students were instructed
to draw a diagram first and then describe what the angle relationship looks like in order to write the definition. Students were exposed to some of the diagrams the day prior to this activity and in the beginning of the school year. The terms students defined in this activity are the foundational angle concepts that students will need to know moving forward in the course to solve problems and write proofs.

The third way literacy was incorporated into a geometry lesson was through a group revision/writing activity (see appendix C). One essential skill geometry students are learning is how to explain their reasoning. The writing activity was developed in order to help students elaborate their own written explanations. Students were asked to work together to discuss and compare two inadequate written responses. Groups naturally started to revise each written response and then based on their discussion made a list of do’s and don’ts for how to explain mathematical reasoning. The revising/writing activity was done twice for different geometry questions so students were able to see that each explanation will be different depending on the math used to solve the problem.

Quality and Credibility of Research

Qualitative research is becoming increasingly popular and important in the field of Education. Many teachers utilize the outcomes of research as implications for instruction and to inform further teaching practices. Using research to inform instruction is one of the crucial reasons why research studies must be validated and considered trustworthy. Mills (2014) suggests that qualitative researchers address four characteristics as identified by Guba (1981) to ensure trustworthiness of a study: credibility, transferability, dependability, and confirmability. When these four components are thoroughly thought out by the researcher the criteria for quality and creditability is likely to be met.
The credibility of a study is referred to by Mills (2014) as “the ability to take into account the complexities that present themselves and to deal with patterns that are not easily explained” (p. 115). In accordance, credibility for my study will be ensured in multiple ways. First, as a fifth year math teacher in the school district in which the study took place, I had been immersed in the setting for a prolonged amount of time as suggested by Guba (1981) to overcome biases and perceptions. Arguably the most effective way to ensure credibility was done through triangulation of data collection. Mills (2014) suggests to compare a variety of data sources and different methods with one another to cross-check data and thus maintain credibility. To demonstrate triangulation, I used three different methods of data collection.

Transferability was also addressed in the study through my ability to identify with the context and setting of the study. Mills (2014) explains transferability as the qualitative researchers’ belief that the study is bound to a specific context and setting and that the goal of their work is to develop context-relevant statements. To facilitate transferability, I collected and presented descriptive data and clearly explained the context in which the study took place so others can compare if this type of research will fit into a different context.

Dependability of data is another piece of criteria to be met. Dependability, as cited by Mills 2014, refers to the strength and stability of the data being collected. By overlapping methods of data collection, dependability was addressed. Specifically, student work was collected in accompaniment with interviews as a way to validate and fill in information that students either did not verbally express in an interview and vice versa.

Lastly, the forth characteristic of quality, creditable research is confirmability. Mills (2014) describes confirmability as the “neutrality or objectively of the data that has been
collected” (p. 116). Practicing triangulation is one way to ensure confirmability, which was implemented in my data collection process. Also, student participants have a history of different levels of achievement in math. Including students with varying math abilities was another way to make the data more objective; as opposed to only using high achieving students and consequently having subjective, skewed data.

Informed Consent and Protecting the Rights of the Participants

I presented and introduced the research to my sixth period class as a whole group. Prior to conducting any research I asked for parent permission of each adolescent in the geometry class. I also asked for assent from students themselves. Each parent and student received a permission form, which clearly stated the purpose of the study and the request of participation from the student. Eight out of 20 students were given permission and gave their own assent to be involved in the study. After receiving the permission forms back, I was able to continue with the research. I also met individually with the three focal students to further explain what their role was going to be. Parents and students were informed that participant names will not be used to guarantee confidentiality.

Data Collection

As discussed briefly before, three forms of data was collected during and after each strategy or activity was implemented. The first form of data collected were observation field notes. I took notes while students were introduced to the strategy or activity and while students were involved in independent or group practice. Since I was teaching the strategy myself, short notes were taken simultaneously with direct instruction and more specific notes were taken during the work period when I was able to circulate around the classroom. All notes were revisited directly after the period of implementation to add on to and reflect on.
Shortly after a strategy was taught, I met individually with the three identified students for interviews. Each interview was be recorded and transcribed. A total of nine interviews took place throughout the course of the data collection process. The interviews were brief, lasting only five to six minutes long. During each interview, students were asked the same series of questions (see appendix D). After the first strategy I asked the same questions but further asked students to compare and contrast the strategies and activities. I inquired about which strategies they would like use again and which one worked best for their learning style.

To cross check what students say in the interviews, their work was collected and used as the third form of data. All worksheets used were teacher made and created around the instruction of the literacy strategy or activity as it was utilized to teach math content and problems. Guiding questions for students were be typed into the worksheets and student responses were hand written into the same sheets to be analyzed. Student work has allowed me to see if the students were implementing the strategy correctly and if it helped lead the students to the correct math process or understanding. Sometimes students may think they understand something, but their has revealed some misconceptions they were not aware of at the time of the interviews. The artifacts collected sometimes validated a student’s interview responses and other times provided the researcher with a different perspective of student understanding.

Data Analysis

All data collected was analyzed in an attempt to answer the research question: How can utilizing literacy strategies and activities in math class help math students understand geometry content and problems? The data collected from this action research included field notes, student interviews, and student work samples. To begin data analysis, I first read through the field notes that I took while observing students engage in each activity. During a second read of the notes, I
specifically looked for any notes that answered my research question. I re-wrote the important notes I found on a separate pieces of paper to compare and group with what I found in other forms of data. Next, I read through each transcribed interview several times. I looked for what students found helpful, what they didn’t find helpful and if there were any commonalities or differences among the three leveled student responses. Each individual interview was coded and then codes were compared across interviews for the three students. The important information was written on separate pages. Having interviewed students of different achievement levels, some responses to interview questions differed and some responses were consistent. Although student work samples were not scored, I was able to compare the work from several students, look for literacy practices used and also analyze the math processes. Student work from the three main participants was scanned, clipped and included as part of my findings to provided additional insight. After all three data types were gone through, I was able to take the separate pages of data, slide them on the table into three columns. Data was grouped based on patterns and meaning. I kept grouping and re-grouping until the data was organized into clear themes.

Findings and Discussion

Literacy is an essential aspect to the success of students in content areas courses. The purpose of this study was to find out how literacy activities and strategies help high school math students. The qualitative data presented in this section is based on three reoccurring themes that emerged with implementing literacy strategies and activities in math. Each theme was developed analyzing observations, student responses to interview questions and student work, which will all be presented below. The themes include: helpfulness of literacy strategies and activities differs for high and low achieving math students, other strategies used, and the importance of content area vocabulary. The findings suggest that the helpfulness of literacy strategies is different for
students of different abilities in mathematics. Student participants identified additional strategies to be helpful when solving math problems, aside from the ones used in this study. Lastly, geometry vocabulary appeared to be essential to know in almost every activity and students pointed that out in every interview.

**Helpfulness of Literacy Strategies and Activities Differs for High and Low Achieving Students**

A clear difference was discovered in the helpfulness of literacy strategies and activities between the high achieving students and the low achieving students. The difference was shown through the actions and engagement level of students during the implementation of each strategy or activity, and also shown explicitly what each interviewed student identified as helpful or not. Strategy effectiveness was also apparent based on student understanding or lack of understanding shown through their work. During the reading comprehension strategy for word problems, above average math students demonstrated a high level of understanding of the text in the word problems by answering the guiding questions elaborately and correctly. Nathan, (pseudonym) a high level student, understood the purpose of the guiding questions strategy, but did not feel all of the questions were necessary.

He stated:

I thought it was trying to help us decipher the problem in case someone does not understand. Only parts of it were helpful for me- what are you trying to find out? And, the ideas for solving process. I would only use these two parts of the strategy again, thinking them my head, but probably not write it down. The other guiding questions I just knew because I’ve been doing word problems for years. (Student Interview, 2015).
Nathan along with other high level math students are able to identify the math specific vocabulary in a problem, and intuitively apply their prior knowledge with new knowledge to solve the problem. Nathan’s general reading comprehension was never tested, however his ability to answer all guiding questions correctly shows that he is able to comprehend complex math text independently. Bjork and Bowyer-Crane (2012) found that mathematical word problems involve a first state of comprehension; even with children as young as six or seven years of age. Comprehending word problems is a skill that students begin to develop in elementary school. Math students have been taught and guided towards critical thinking throughout schooling. A student who can process information quickly and are metacognitively aware of what they are reading, are more successful with math word problems. As Nathan said in the interview “I’ve been doing word problems for years.” During the lesson he and another top student asked if they needed to answer the guiding questions, or if they could just go directly to the solution (Field Notes, 2015). The guiding questions were not a good use of Nathan’s time, because he is able to monitor his own understanding. He knows when he does not understand is able to resort to another strategy such as re-reading, looking in notes, or asking peers and teachers. During the work period, students were given the choice to write out the guiding questions or not. Nathan chose not to, and he was able to answer further word problems correctly by mentally thinking about the guiding questions as he mentioned in the interview. Written out comprehension questions were not an influential factor in helping Nathan answer area and perimeter word problems correctly. Self-regulated learners, such as Nathan, are activate participants in their own learning who have control of their own cognitive and metacognitive processes, (Pape & Wang, 2002). Self-regulation enables students to be in control in problem solving process. Strong math students are self-regulators who can implement modeled strategies
independently and monitoring their own progress along the way. Thus monitoring one’s reading comprehension of a math problem is an internal, independent practice for self-regulated learners.

In contrast, average and low achieving math students found the comprehension strategy to be more helpful. Courtney, (pseudonym) an average math student, identified guiding questions 1: What is this question about? 4: What information do you know? and, 5: What are you trying to find? to be the most important because they helped her “think of every step before starting” (Student Interviews, 2015). Courtney and other average math students find it beneficial to plan and organize the content before jumping into the solution- she described this strategy as a similar process to outlining or planning an essay for ELA. Making connections and knowing what process to apply does not come instinctively, as it does for the top math students.

Appropriate planning helped Courtney choose the correct math procedures for each word problem. In a similar study on strategy use in math by Pape and Wang (2002) students who reported setting goals and planning for academic tasks and of organizing and transforming academic information were related to whether students chose a meaningful approach to solving mathematics word problems. Courtney also mentioned how the “guiding comprehension questions force you to carefully read the word problem” (Student Interviews, 2015). Reading carefully was evident during the work period, by observing all students going back to the text multiple times in order to fill in each guiding question. The strategy was designed to help students fully understand the word problem solving thought process. Megan, (pseudonym) a low achieving math student said the guiding questions made her more confident in being able to set up the problem: “I think I would have been able to set it up without the questions, but I wouldn’t have been as confident if I did it right or not” (Student Interviews, 2015). Guiding comprehension questions led below-average math students through the problem solving process.
and can help students choose appropriate math processes for word problems. When comprehension is not monitored, Kayttala and Bjorn (2014) found that weak math students who lack confidence in their problem solving abilities and will often choose superficial strategies such as selecting certain key numbers from the problem and performing mathematical operations based on simple math words such as *more or less*. Insufficient planning and comprehension often leads to flawed solutions and outcomes. The authors also suggest another potential reason for superficial performance is task-avoidance, which is often linked to math anxiety. Kayttala and Bjorn assert that word problems are often considered difficult which is why it is probable that students with math anxiety feel distress when confronting word problems. Students that experience low self-assurance and anxiety tend to avoid math problems by rushing through tasks, without applying prior knowledge, or critical thinking. The guiding comprehension questions forced Megan and other weak math students to slow down, think about the problem and be more confident. The answers to comprehension questions served as the evidence for students to understand why they chose a certain operation or why they wrote a certain equation. However, math students would need to be answering the guiding questions correctly in order for the strategy to be helpful. For low-level math participants in this study, prior knowledge was the missing link to reading comprehension of geometry word problems. See Figure 1 on the next page, the student correctly identified that the word problem was about building a fence. Then, in later questions, interpreted fencing to mean area of a space and planned to use multiplication to solve. When in fact, fencing would require perimeter, which is addition. The misunderstanding present in this student work could be a result of lack of real world background knowledge.
The student work shown here is contradictory to the interview with the student, in which the student explained that the strategy was helpful in making them feel confident in their understanding of the questions. Although the student expressed confidence in their procedure, the procedure was still incorrect due to misunderstands of mathematical concepts. The misunderstandings suggest that there are some gaps in learning and prior knowledge around area.

Figure 1. Student work sample of guiding questions for a word problem about the perimeter of a rectangular garden.
and perimeter of rectangles. Pimperton and Nation offer another explanation for unsuccessful problem solving as follows: “poor comprehends’ difficulties are not restricted to the domain of literacy, but rather that underlying impairments can selectively affect performance in those areas of mathematics which load particularly high on verbal ability, semantic processing, and linguistic comprehension abilities” (p. 265). A strong prior knowledge base is an essential piece in being able to interpret word meaning and thus successfully answer word problems. Weak math students would have benefited more from explicit pre-teaching and review of the concepts area and perimeter prior to engaging in word problems. As the teacher, I assumed that all 10th grade students would have the knowledge base about area and perimeter, but that was not the case. We reviewed the actual algebraic solving process in days previous to the word problems, but not how to set it up.

All three focal participants found the vocabulary activity (see appendix B) to be beneficial in understanding new geometry concepts. In this activity, students filled in a three-column chart with given vocabulary terms, their own definitions and a visual representation. There were no specific directions on which column to fill in first. Some students started with drawings, while other students attempted writing the definitions first. All students were very engaged in the activity during the lesson. Students were asking questions and wanted to make sure they knew each definition and how to draw each diagram. During student interviews, each primary participant identified different aspects of the activity that were helpful to them individually and also explained different reasons for why the vocabulary activity was helpful. Nathan realized the importance of knowing exact definitions in geometry. He highlighted the most helpful part of this activity to be developing new knowledge that he had not known before (Student Interviews, 2015). Nathan is genuinely interested in math and with math being his top
subject, Nathan is always eager to learn more. In geometry, vocabulary instruction gives students the chance to acquire new knowledge. Students are then able to apply the knowledge obtained, resulting in a useful, meaningful learning experience, which is reflected through student achievement in mathematics problem solving (Abdullah, Halim & Zakaria, 2014). Another student, Courtney, saw this activity as a way to connect prior knowledge with new knowledge. She recognized that we had learned some of the vocabulary terms before and transferred what she already knew to help her come up with new definitions. Adams (2010) who studied math teachers implementing literacy strategies would agree with Courtney and would classify the vocabulary activity as a strategy to support students in making observations, identifying patterns and relationships, clarifying thinking, and constructing new meaning. Courtney described using two known words to come up with the drawing and definition of a new concept in Figure 2 below. Courtney spoke about the vocabulary words themselves saying, “we didn’t know all of them, like the angle bisector. I just drew the angle and then I knew bisect was middle, so it made me think of two things I knew and put it together” (Student Interview, 2015). From her description in the interview, I believe Courtney saw this activity as way to practice developing meaning of unfamiliar math words. During the activity, she was able to come up with her complex definitions either based on words she already knew the meaning of, or on what the diagram looked like.

Figure 2. Vocabulary chart student work sample. (It reads: the middle of an angle separates the angle into two congruent parts.)
For the low achieving student, Megan, (who is low in both math and ELA) found this activity as way to “help remember the words more” (Student Interviews, 2015). In this way, Adams (2010) would say literacy enhanced learning by focusing on and practicing procedures, increasing awareness of procedures and providing additional opportunities to rehearse material to be learned. Megan was more interested in the product of the activity, and using it as a study tool, rather than developing the skill of figuring out word meanings. Adams (2010) does not say one use of literacy in math is better than the other – “both types of learning (conceptual and procedural) can benefit students, each affords a different benefit” (p. 387). If a student like Megan just doesn’t remember, there might not be any conceptual understanding or literacy strategy to fall back to figure out the word meaning. Weak math students also struggle to choose meaningful approaches to solving multi-step problems. Some students do not know where to start, and others will complete the first step and not realize there is more to the problem or don’t know what to do next. When observing Megan working independently on word problems, she stalled at one point. I asked her what she was thinking and she said “I forgot why I was doing this” (Field Notes, 2015). Weak math students try to memorize problem solving processes, rather than understanding the concept and transferring the concept to many different problems. For example, in relationship to Figure 1, Meagan said she chose multiplication because that’s what the example was like (Student Interviews, 2015). Therefore, revealing that she did not have the conceptual understanding of the area of a rectangle and was purely copying a previous problem. Thus further demonstrating that the comprehension guiding questions will only work if students have the correct mathematically understanding beforehand.
Having compared student interview responses, field notes and student work, the way each student finds literacy helpful in math depends on the individual, including their overall ability, confidence and achievement in mathematics. Korhonen, Linanmaki and Aunio (2012) found at the end of high school, the content of mathematics includes considerable number of mathematical concepts. Students with low performance in both math and literacy are likely to struggle with learning these concepts. Using literacy strategies in math can help some of the struggling students, but this study found that some explicit pre-teaching may be necessary in order for a comprehension strategy to be successful for math word problems. Above average math students do not find reading comprehension strategies helpful in math because as research from Abdullah, Halim and Zakaria (2013) suggest, strong math students are aware of their own thinking and have been able to master the problem solving process because of their ability to think metacognitively with exposure and practice. Average and weak math students find strategies to be the most helpful, but the strategy needs to be coupled with correct math understandings. Abdullah, Halim and Zakaria (2013) identify to overcome the disconnect with math word problems, students need to develop and grow the habits and tendencies that will give meaning to the problems, and allow them to interpret problems carefully.

**Use of Other Strategies to Solve Math Problems**

During student interviews, the primary participants were asked if they use other strategies on their own to help understand geometry concepts and solve problems. A commonality was found in additional strategies students used. All participants were observed drawing diagrams to assist with the word problems in the first lesson of this research project (Field Notes, 2015). Students were drawing visuals to help them make meaning of the situation. Nathan said “I drew a rectangle to represent the soccer field, because it let me know where to put the numbers and
variables. A drawing is good so when you go to organize the equation you can easily find what you need” (Student Interview, 2015). The second part of Nathan’s response shows that he uses visual representations as a way to plan the problem solving process. In general, I found that if math students know what the situation looks like first, then they can make more sense of the words. Ilany and Margolin (2010) had similar findings when implementing problem solving process with math students. The author’s research showed that building a mathematical model is an essential piece of bridging the gap between mathematics and linguistics. Modeling a mathematical situation visually can help students link the math to the language in the problem. Observing Nathan during the vocabulary activity, it was noted that he drew all the diagrams first, then went on to the definitions. Figure 3, below, is an example of Nathans work from the vocabulary activity. Drawing a visual first helped him make a connection to the geometry words he needed to develop the definition.

<table>
<thead>
<tr>
<th>Terms</th>
<th>Definition</th>
<th>Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Angles</td>
<td><strong>The angles formed when two lines intersect.</strong> <em>(Always congruent)</em></td>
<td><img src="image" alt="Diagram" /></td>
</tr>
</tbody>
</table>

*Figure 3. Vocabulary chart student work sample. It reads: the angles formed when two lines intersect. *opposite each other (always congruent)*

Courtney unconsciously used visuals in a similar way to Nathan. When asked what additional strategies she uses for word problems, Courtney said “I draw a picture when it says something about a shape, is that even a strategy?” Courtney many other math students automatically draw pictures to visualize the situations, but they do not necessarily recognize that as strategy. Students sometimes do not realize that problem solving strategies can be simple and efficient. Using a strategy does not always mean a big elaborate graphic organizer etc. Simply drawing a
visual, organizing the relevant information in a table or list, re-reading the text and/or unpacking the question are all simple, yet vital strategies to help math students make meaning of written text and vocabulary words. Pape and Wang (2003) assert that each of these strategies: using objects, organizing information, re-reading the question and underlining important facts, represent important behaviors needed to develop a situational or mental model for the problem. In the specific case of area and perimeter word problems, a model (diagram) was specifically helpful in the second problem, see figure 4 below. The problem said fencing would only be needed for three sides because the back of the house will serve as a boundary for one of the sides. In this example of student work, Courtney read the problem clearly and was able to identify what the situation was about: a three-sided fence. Then in guiding question 3, she wrote, “add all sides,” which in this case is not entirely correct. It seems that her understanding of perimeter misled her to adding in an extra amount, 2x. The work sample shows a diagram, but it was noted that she did not originally have the diagram drawn for her first attempt at the problem (Field Notes, 2015). During the work period when I checked in with Courtney, I prompted her to check the setup of her equation. At that point, she re-read the problem, drew a diagram and then crossed out the length of one of the longer sides in her equation to accurately reflect the situation at hand. In this case, drawing a diagram and re-reading were two strategies Courtney used to fix her error.
When asked about this in an interview, Courtney said “I needed the diagram to remind me what to add up. When I didn’t have it the first time, I only thought of perimeter and forgot about the three sides” (Student Interviews, 2015). Ilany and Margolin (2010) experienced similar results with a student solving a math word problem. In the data presented from their study, a student did not know what math operation to apply, so they decided to draw a picture, which helped the student decide that her original idea of subtraction did not make sense. Drawing the situation out before solving enables students to figure out the mathematical relationship based on the visual. Even high achieving math students might not make meaning from words alone.

Making a visual representation is especially helpful for weaker math students. A diagram or graph can at least give a student something to start with and build on. Megan, resorted to a visual for the explanation writing activity (see appendix C). After reading the math problem, which asked: are the lines parallel perpendicular or neither, Megan graphed the line segments first before she read the responses and wrote her own (Field Notes, 2015). Although Megan’s response was solely based on the graph (and did not include the concept of slope) she was able to
describe what the relationship between the line segments looked like. To have a complete, correct response, Megan would have needed to provide mathematical reasoning by discussing the slope of each line. However, she was still able to demonstrate the basic understanding of parallel and perpendicular lines by interpreting the visual. During the interview following the activity, Megan said “I didn’t remember what the slope was supposed to be, so I just graphed the points and based my answer off what it looked like.” Without a visual, Megan may not have been able to provide any reasonable explanation at all because she did not know the slope formula. However, creating a visual representation of the situation helped her approach question and provide an answer that made sense. In a study specifically about using built in visualization stopping points, researchers Abdullah, Lilia and Zakaria (2014) back up the data presented in this study by saying “the construction of representation in the form of visualization can help students connect with a problem situation and facilitate students’ ability to communicate their understanding of that problem” (p. 171). Many students struggle to know where to begin a word problem, however, the data presented has shown that a diagram can lead students in the right direction.

**Importance of Content Area Vocabulary**

During and after each literacy strategy or activity implemented, all student participants mentioned the importance of knowing geometry vocabulary. Courtney recognized that “in geometry, you have to know what specific words mean in the problem because the words lead you to know how to solve it” (Student Interviews, 2015). As part of the reading comprehension strategy, a guiding question prompted students to identify all of the math vocabulary words in the
word problem. Nathan shared how he thought this particular question was unnecessary, while identifying that coming up with ideas for solving process was the most important question. As a follow up question, I asked Nathan student how he came up with multiplying the expressions as the problem solving process, he then said “because it says ‘area’” (Student Interviews, 2015). Contradictory to the first response, Nathan identified a specific vocabulary word that led him to set up the correct equation for the solution. When asked to revisit the importance of the guiding question on vocabulary, Nathan said, “I know which words are important and I know what they mean. I don’t really think I need to be asked about them” (Student Interviews, 2015). Strong math students, like Nathan, intuitively use content area vocabulary words as clues for solving math problems. Apply vocabulary knowledge to problems situations becomes intuitive after much practice and after students explicitly learn it as a strategy for problems solving; taught by myself as a math teacher. Vocabulary knowledge is an early predictor of numeracy performance, and mathematical reasoning ability even with students as young as five years old (Pimerton & Nation 2010; Purpura, Hume, Lonigan & Sims, 2011). By describing how he came up with multiplication, Nathan proved that he understood the importance of vocabulary for solving word problems.

With the writing activity (see appendix C) all students participating in the study identify using geometry vocabulary as one of the most important aspects of a good written explanation. Students were able to revise the inadequate responses on the worksheet to reflect understanding of a geometry concept or theorem learned in class. The main way responses were enhanced was by students adding in geometry related vocabulary words (Field Notes, 2015). Students replaced words such as “they” and “it” with the appropriate terms, such as “line segments” and “slope.” Using correct geometry related vocabulary was a necessary part of this activity, in order to link
the pre-written explanations to the correct geometry concept. Statts and Batteen (2009) explain that throughout consistent interaction, students may develop habits of speech for communicative tasks. Using math vocabulary regularly in the classroom and providing opportunities for students to discuss, read, revise, and write mathematical explanations will foster a communicatively oriented classroom with consistent math specific vocabulary use. Figure 5 below shows an example of a student communicating using mathematical vocabulary and symbols. Instead of just using numbers as an explanation, Nathan was able to associate the numbers with the appropriate concept – congruent corresponding angles. The response given in figure 5 would not be true without the appropriate vocabulary that matched the picture. Nor would the response be true without identifying the congruence of the angles, which Nathan did by using the symbol ≅.

Figure 5. Writing activity student work sample. (It reads: The lines p & r are parallel because the corresponding angles are congruent. 108° = 108°)

The last instance where the participants stressed the importance of vocabulary was during the vocabulary definitions activity. Students were able to use the vocabulary words to draw geometric diagrams of angles. I previously mentioned how diagrams led students to the definitions, well, in some cases, the vocabulary words lead students to draw the diagrams. For example the term “linear pair.” Students were observed being able to draw a linear pair of angles by first drawing a line, which they recognized as the root word of linear and next understanding that pair means two – thus two angles on a line (Field Notes, 2015). Content area vocabulary
will assist students in visualizing which, as previously mentioned, is a helpful strategy used by geometry students to solve word problems and learn geometric relationships. Similarly, Bruun, Diaz and Dykes (2015) found that math teachers learned how important explicitly teaching math vocabulary was because students developed conceptual understandings of the vocabulary. These researchers also found that visual strategies were helpful to students when comprehending problems using math vocabulary.

**Implications and Conclusions**

The above findings and data gathered through field notes, student interviews and student work imply that math teachers should not force the use of literacy strategies and activities in math lessons. Instead, math teachers should integrate literacy in math lessons when appropriate and necessary for learners. Students should be offered many strategies as optional supplemental tools. One of the most important strategies being the use visual representations.

The first implication would be for math teachers to continue embedding literacy into math instruction. Adams (2010) and Carter and Dean (2006) found that teachers know the importance of content area literacy and inherently instruct students in reading strategies, vocabulary instruction, and the use of language (spoken or written) to deepen student understanding of mathematical concepts and relationships. Math teachers do not have to force the use of literacy strategies into lessons. If literacy feels random and separate from the math lesson, then students will not see a clear connection to their learning. The last strategy implemented in this research project on writing explanations was not planned to fit with a specific geometry lesson and stood alone as its own activity due to limitations on time frame of data collection and length of teaching periods, (42 minutes per day). The disconnection of the activity caused student participants to think they were doing the activity more for me, the
researcher, than for themselves and their own learning. However, taking risks and trying new strategies while teaching math is encouraged, as long as they are purposeful and planned.

In addition, every math teacher, especially geometry teachers, should make drawing diagrams an essential practice in their classrooms. Math teachers can model how to draw and use appropriate diagrams to communicate their thinking as a way to encourage the use of this approach to solve problems and represent math terms. Rilley, Parsons and Bortolot (2009) explain that accurately visualizing the problem will lead to better comprehension and more successful outcomes. Visualization skills should be practiced in the math classroom to further develop students’ strategic thinking and comprehension of math problems.

The timing of this research project did not coincide with the New York State, Common Core Geometry exam, so questions still remain on the effectiveness of literacy strategies to help prepare for and perform on the assessment. Additional research should be in types of content area literacy strategies to use in math. Only three were implemented in this study, and all three were teacher created. What else are math teachers doing with their students to help improve mathematical literacy skills and encourage high achievement in the math classroom? It would be informative to look across grade levels for consistencies and/or inconsistencies in literacy use in math.

This action research project was designed to investigate how math students find literacy strategies and activities helpful in understanding geometry concepts and problems. A small group of geometry students participated in literacy activities in a geometry classroom. Three different literacy activities were implemented on the following literacy aspects, reading comprehension word problems, vocabulary, and written explanations. Students were observed in the classroom while using literacy in geometry, their work was analyzed, and three students of
different abilities were interviewed after each activity. Within the data collected, some reoccurring themes emerged and these themes revealed that the effectiveness of literacy strategies and activities in math differs for students of varying math ability. Strong math students are able to self-monitor their comprehension of a word problem, as well as instinctively transfer literacy skills such as re-reading or using vocabulary, and thus do not find explicitly taught literacy strategies in math to be helpful. Weaker math students need even more support than just literacy strategies and activities to understand geometry concepts. The literacy strategies and activities were the most helpful when used as a supplement for understanding concepts with average level math students. Furthermore, visualization and drawing a diagram was identified to be the most helpful strategy used by all students to solve word problems and understand vocabulary. Although the use of literacy strategies is helpful for some students, weak math students will need more explicit re-teaching of math concepts and procedures to be successful.

A result of implementing three literacy activities in a high school geometry course is that the helpfulness of literacy strategies differs for high and low achieving math students. Specifically, answering the guiding questions for word problems proved helpful for some students but not for others. Strong math students demonstrate the cognitive habits and tendencies that will help them make meaning of the problems and interpret the problems carefully, thus making the guiding questions unnecessary. In contrast, average performing and weaker math students who struggle to self-monitor and plan out the problem solving process benefited from the guiding comprehension questions. In agreement, Abdullah, Halim, and Zakaria (2013) found that students who are not aware of their own thinking process have trouble with mathematical problem solving, especially with word problems. In addition to having less
cognitive awareness, some of the weaker participants failed to connect the given information to the correct mathematical concept. Weak math students need more than just a literacy strategy to help accomplish a word problem, implying that math teachers may need to re-teach concepts and help students access specific prior knowledge before approaching word problems. A lesson on solving word problems would be most successful if differentiated based on ability and readiness.

High achieving and average level math students can be given a reference sheet with an example and some guiding questions to help students start the problem solving and planning process. The low group of students would work with the teacher where direct instruction is given and verbal and written promoting is used throughout the solving process, with the intention of leading students to become more independent thinkers. Further research is needed to fully examine math students’ cognitive problem solving process and more specific ways to develop the process.

To overcome some of the difficulty with making meaning from word problems or content area vocabulary words, all student participants found making visual representations to be the most helpful strategy. Visual modeling of a problem situation or a specific geometry vocabulary word can help students connect the situation with prior knowledge and connect to the appropriate mathematical concept or procedure needed to solve the problem or understand the definition of new vocabulary. Most importantly, construing a visual representation will help spark the meaning making process and facilitate students’ ability to communicate their understanding of a problem or new concept. Pyke (2003) and Abdullah, Halim, and Zakaria (2013) both presented similar results that showed math students’ use of diagrams to demonstrate their ideas contributed to the cognitive processes involved in the problem solving.

In summary, the research presented examined how literacy strategies and activities help geometry students understand math problems and new concepts. The results varied depending
on the ability of the student who was using each strategy and participating in each activity. The data led the research to believe there is more than literacy involved in being a successful math student, including prior knowledge, ability to visually represent a situation and independent thinking strategies. Essentially, math teachers need to balance lessons with conceptual understanding and procedural mathematical fluency. Using differentiated content area literacy strategies and activities is a suggested way to teach math concepts, specifically new mathematical vocabulary.
References


Appendix A

Geometry NOTES

Strategy 1 – Reading Comprehension of Geometry Word Problems

*Answer the guiding questions before setting up your solution. These questions are meant to have you think about the problem before diving into the calculations.*

Guiding Questions:

1. What is this problem about?

2. What are the math vocabulary words in this problem?

3. What *prior knowledge* can you bring in to help?

4. What information do you know?

5. What are we trying to find out?

6. Ideas for solving process:

1. A school is building a rectangular soccer field that has an area of 6000 square yards. The length of the soccer field must be 40 yards longer than its width. Determine the dimensions of the soccer field, in yards.
Carlos wants to fence in his rectangular vegetable garden at the back of his house to keep out the deer. He needs to fence only three sides because the back of the house will serve as one side. He wants the side parallel to the house to be twice the length of the two adjoining sides. If Carlos uses 12 ft. of fencing, what are the dimensions of the enclosure?

Guiding Questions:

1. What is this problem about?

2. What are the math vocabulary words in this problem?

3. What prior knowledge can you bring in to help?

4. What information do you know?

5. What are we trying to find out?

6. Ideas for solving process:
Appendix B

Geometry - Vocabulary Strategy

Developing vocabulary knowledge is essential to understand Geometry! Write your own definition for the following vocabulary terms. Drawing a diagram may also help if you do recognize the concept by just the words alone.

<table>
<thead>
<tr>
<th>Terms</th>
<th>Definition</th>
<th>Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Angles</td>
<td></td>
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<tr>
<td>Linear Pair</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angle Bisector</td>
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<td></td>
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<tr>
<td>Supplementary Angles</td>
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</tr>
<tr>
<td>Complementary Angles</td>
<td></td>
<td></td>
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<tr>
<td>Angles around a Point</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corresponding Angles</td>
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<td></td>
</tr>
</tbody>
</table>
Appendix C

Geometry Writing Activity

Review the following written responses with your group. Revise response A and B together. How can you enhance each response to make the explanations stronger? Based on your discussion, come up with some “dos” and “don’ts” when writing math explanations. At the end, write your own response.

1. \( \overline{AB} \) and \( \overline{DE} \) have the following endpoints: \( A(-7, 4) \) and \( B(-1, 6) \) and \( D(5, 4) \) and \( E(-7, 1) \). Use the slope formula to determine if the two line segments are parallel, perpendicular or neither. Explain your response in complete sentences.

Student Work:

\[
\begin{align*}
  m_{\overline{AB}} &= \frac{6-4}{-1-(-7)} = \frac{2}{6} = \frac{1}{3} \\
  m_{\overline{DE}} &= \frac{1-4}{-7-5} = \frac{-3}{-12} = \frac{1}{4}
\end{align*}
\]

Response A: They are neither because the line segments have \( \frac{1}{3} \) and \( \frac{1}{4} \) as the slope.

Response B: The slopes are not parallel because \( \frac{1}{3} \neq \frac{1}{4} \) and the slopes are not perpendicular because the numbers are not flipped or opposite.

<table>
<thead>
<tr>
<th>Do’s</th>
<th>Don’ts</th>
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<tr>
<td></td>
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My Response: