Teaching Mathematical Vocabulary:

Is it Worth Teachers' Time?

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Abstract

Vocabulary has always been very important in communication and in mastering the concepts of mathematics. Most students are unaware that vocabulary is important and that they need to learn it, and teachers need to teach it. As the teacher of students in a geometry class research into teaching students vocabulary has been done to find ways to improve student's vocabulary and understanding of mathematics. Fifty students in a geometry class participated in playing vocabulary games, which were activities to improve the student vocabulary skills. The teacher spent a lot of time teaching and reinforcing vocabulary in her classroom and found out that it was worth the time.

Table of Contents

List of Tables

List of Figures

Teaching Mathematical Vocabulary: Is It Worth Teachers' Time?

Teachers often wonder why students get questions wrong. Maybe it is because they do not know the concept or it could be that they did not know the vocabulary. Lee and Hermer-Patrnode (2007) said that it is frequently because the students do not know the vocabulary word that is used in the question. Often the student understands the concept but not the specific vocabulary words connected with it.

All students have to take standardized tests throughout their education. All students in New York State take state assessment, starting in third grade students take a state assessment in Mathematics and English Language Arts every year until they get into ninth grade. If they are in high school they take the New York State Regents Exam, before they go to college they need to take the SAT's and the ACT's. It seems that more and more standardized tests are assessing students on vocabulary words rather than on concepts. On the New York State Regents test and the SAT if students do not know the vocabulary that the test uses the answers are impossible to figure out.

Even the New York State Standards stated that teachers need to make sure that their students can communicate mathematically. New York State Standard 3 stated (2005):

> Students will understand mathematics and become mathematically confident by communicating and reasoning mathematically, by applying mathematics in real-world settings, and by solving problems through the integrated study of number systems, geometry, algebra, data analysis, probability, and trigonometry. (p. 25)

In order to properly communicate and reason mathematically students need to use the language of mathematics. If students do not know the key vocabulary then they will not be able to use mathematical language.

This study will look into strategies that help students learn and retain vocabulary. The study will explore if these strategies help students better understand mathematical concepts. Finally, the study will examine if increased teacher instruction in vocabulary results in increased student achievement.

Literature Review

A teacher's job is to help students maximize their potential. One of the ways that a teacher teaches her students what they need to know is to analyze the standards and the new literature dealing with best practices pedagogy. Teachers then need to sift thought this information and decide what is best for their students. The teachers who use reflective practices on a regular basis will notice the emphasis on content literacy. Students need to be able to read, write and communicate in each of their content classes.

One of the most essential components of content literacy is vocabulary. There has been a great deal of research on vocabulary. Researchers have looked into why teachers should teach vocabulary, how vocabulary is best taught, and why some teachers are not teaching their students vocabulary. They also looked into how emphasis on mathematical vocabulary helps students, and what strategies benefit students who have different learning styles. This review of literature will explore each of these topics and ends with tips for teachers when implementing vocabulary into their classroom.

Why Teach Vocabulary

There seemed to be a consensus that teaching vocabulary is important. There is a strong connection between vocabulary knowledge and reading comprehension (Lucas & Goerss, 2007; Monroe & Orme, 2002; Vacca & Vacca, 2002). Nilsen and Nilsen (2003) said that "virtually everyone agrees that understanding the meaning of the words is crucial to reading, listening, writing, and speaking" (p. 31). These authors claimed that if students do not know the words they are reading then they will

never understand the meaning of what they are reading (Nilsen & Nilsen, 2003).

Monroe and Orme (2002) made a few good points on why teachers need to educate their students on vocabulary. They wrote that if students do not know word meanings then they will not be able to use higher level thinking. They also believed that language allows students to understand their world. If the students do not have the experience of learning the meaning of vocabulary then they will not grow to their full potential.

The existence of standardized tests is another reason that students need to know how to use vocabulary. Shanklin (2007) agreed with Nilson and Nilson (2003) that vocabulary skills are an integral part of standardized tests. Since teachers usually teach what is being tested, these researchers believe that vocabulary instruction should and will have more emphasis in today's classroom. Nilsen and Nilson (2003) also believed that students are at a disadvantage if they believe that every word has only one meaning. Students also need to know what the words have in common, as well as their differences.

How Vocabulary Different Depending on Class

All teachers know that home life affects students' ability to learn in school. What some teachers do not know is the impact this has on their vocabulary. Students' vocabulary is affected by what their parents' education and/or income. Studies have explained that parents with a higher educational level and/or are wealthier tend to play, read and care for their children. This causes these children to hear more and to learn more vocabulary (Hart, Risley, & Kirby, 1997).

Some of these studies also analyzed how many words children hear every day.

Hart, Risley and Kirby said that welfare families hear 616 words an hour. Whereas, the working class students hear 1251 words an hour, and the professional class hears 2152 words an hour. Hence, there is a huge difference in the amount of vocabulary children are exposed to based on socio-economic status. Most teachers have all three economic classes of students in their classrooms. The study also discovered what these students' cumulative vocabulary was at age three. They found that welfare students had 550 words, working class had 750 words, and the professional class had 1100 words. This study emphasized that teachers really need to concentrate on teaching vocabulary, so the students that come from a family on welfare has a fair chance compared to the students coming from a professional family. Teachers need to make sure they do not assume that their students know the vocabulary words (Hart, Risley, & Kirby, 1997; Stahl & Nagy, 2006).

Why Teachers are Holding Back

One reason that teachers do not focus on vocabulary is that it takes extra time. Richek (2006) said that "the pressing demands of today's ever-expanding curriculum and assessment both dramatically limit the time we can spend on teaching word meanings" (p. 19). Time on task is very precious and many teachers do not think that there is enough time to teach their current curriculum let alone teaching all the vocabulary that the students need. Some teachers do not think that is very productive to go into great detail with regards to the meaning of one word. However, the students will not just be learning one word. They will be learning about the process of how a word changes and grows (Nilsen & Nilsen, 2003; Richek, 2006; Stahl & Nagy, 2006).

Another reason that some teachers do not teach vocabulary is because they

were not trained to teach vocabulary. It was a common practice when they were in school to get a vocabulary list, look up the word, and then memorize the definition. Teachers recognize that this method does not result in retention. So teachers need to investigate how to teach vocabulary words effectively (Nilsen & Nilsen, 2003).

Difficulties in Teaching Vocabulary

One of the biggest reasons that teachers do not teach vocabulary is because it is an extremely difficult skill to teach. Stahl (2006) said that there are three obstacles in developing a large vocabulary. These consists of the number of words that children need to learn, the fact that English is a foreign language to some of the students even if they came from an English-speaking homes, and finally the fact that understanding a word is more than just memorizing the definition. Stahl (2006) said that the average student adds between two thousand and three thousand words in a year to their vocabulary, which computes to six to eight words a day (Ohanian, 2006; Stahl & Nagy, 2006).

The idea that words are very complicated makes teaching vocabulary very difficult. When a student looks in a dictionary under any specific word, there are at least two or three definitions for the word, and the definition usually depends on the context in which the word is used. Then to make it even harder when teachers use words in content areas, these words are more of a concept then just a single word (Monroe & Orme, 2002; Stahl & Nagy, 2006).

It is especially difficult to teach the vocabulary of mathematics content. The main reason is that there are limited opportunities to use the vocabulary. Monroe and Orme (2002) said that mathematical vocabulary is only used in a mathematics

classroom and that students most likely do not have background knowledge of these concepts. Monroe and Orme (2002) also said that "because teachers often neglect meaningful vocabulary instruction students are not likely to learn mathematical vocabulary in the classroom, either" (p. 140). This continues to supports that the teachers are responsible to teach the students the vocabulary (Lucas & Goerss, 2007; Monroe & Orme, 2002; Rubenstein & Thompson, 2002).

Mathematical Vocabulary

Vacca and Vacca (2002) believed "Vocabulary is as unique to a content area as fingerprints are to a human being" (p. 160). In the current society, it is very important for every individual to be confident in his or her mathematics' ability. Furner, Yahya, and Duffy (2005) said that "knowledge of mathematics is an important skill necessary to succeed in today's world" (p.16). To further support Furner and all it is clear that students need to understand vocabulary and complex concepts or they are not going to be able to complete complex tasks (Shields, Findlan, & Portman, 2005).

Mathematics' vocabulary is one of the hardest vocabularies to teach students. By the time students are in sixth grade they should know and understand forty-three terms and concepts from their previous years (Shields, Findlan, & Portman, 2005). Mathematics words are abstract and thus difficult to understand since many vocabulary words used in mathematics are used for more than one concept. An example is the word median; median can mean the line that is drawn from the vertex to the midpoint of the opposite side. However, median can also mean when data is put in numerical order and the middle data point is found. Both of these words do relate

to the middle, and teachers need to help their students make this connection (Rubenstein & Thompson, 2002).

Mathematics can seem like a strange foreign language to some students. It is not like any other language that students are accustomed to because math contains symbols, numbers, and figures in addition to vocabulary words. The vocabulary words that are used in mathematics are often not used in everyday life. So, usually the students are exposed to these words only in their mathematics class (Burns, 2006; Furner, Yahya, & Duffy, 2005; Shields, Findlan, & Portman, 2005). Burns (2006) was asked if mathematics should be taught as a second language. She replied that it is not comparable to a foreign language. Burns claimed this was because when students learn a foreign language they learn new words for concepts they already know. Whereas, in mathematics, the students are not learning new words for old concepts; they are instead learning new words for new concepts.

How Teaching Vocabulary Helps Math Students

Students need to master mathematic language if they are going to read, understand, and discuss mathematical ideas. Students benefit if teachers take the time and teach the language (Thompson & Rubenstein, 2000). Monroe and Orme (2002) said that "a key component in understanding mathematics is learning the vocabulary" (p. 140). As students learn and understand vocabulary their understanding of mathematical concepts increases. One of the goals for learning vocabulary is to have students able to independently problem solve. When the students learn the vocabulary and can problem solve correctly, they then will be able to apply the problem solving skills outside of their class (Shields, Findlan, & Portman, 2005).

Another positive aspect of teaching students vocabulary is that the students will have the ability to communicate in mathematics. This is very important on standardized tests (Nilsen & Nilsen, 2003). When students have to answer a question on a standardized test they have to understand the question. Usually the test makers have an extensive vocabulary and they use it. The tests makers sometimes unintentionally confuse the students. If the students also have a large vocabulary then they will not get confused about the words. The student has a fair chance of getting the question correct if he or she knows the concept and the vocabulary connected to it.

When mathematics teachers teach their students about vocabulary it does not only help in their own class, but it also supports cross curricular learning. Teaching vocabulary gives students many opportunities to learn how words are connected to other content areas. Most students believe that mathematics exists only in mathematics, English exists only in English, and social studies exists only in social studies. They do not realize that all these subjects intertwine (Shields, Findlan, & Portman, 2005; Vacca & Vacca, 2002).

Ineffective Strategies

Most students have had a class where their teachers told them that they needed to look up definitions for a list of words and then they would take a quiz or a test later in the week. This is a very ineffective strategy for teaching vocabulary. One reason is that the student takes the quiz on Friday and forgets the words on Saturday. Also, when the students look at the definition in the dictionary they only get a small idea of the word. In order to learn from a dictionary the students must know something about

the word (Daniels & Zemelman, 2004; Monroe & Orme, 2002; Shields, Findlan, & Portman, 2005).

Another ineffective strategy is the way some teachers and state mandated tests assess the students. Most vocabulary sections have the vocabulary word in four different sentences, all of which sound acceptable. This is ineffective because the students are spending three fourths of their time reading and looking at the wrong uses for the definitions. When the students read and reread these wrong answers, they begin to change their original correct knowledge about a word. (Nilsen & Nilsen, 2003).

It is ineffective to teach the students the wrong definitions for words. When students are in elementary school they often learn the incorrect use of words. For example, teachers will ask students to find a diamond in the room, instead of asking for a rhombus. Teachers use the term oval instead of an ellipse. Once students learn these words it is very hard to get them to use the proper terminology. Teachers need to always use vocabulary correctly so students will remember the words for many years to come (Tracy, 1994).

Memory devices can also be used ineffectively by teachers. Nilsen and Nilsen (2003) denounced memory devices; they said that these devices are based on puns. When the students use a memory device they are using the pun or riddle. They are not actually using what the word means. Therefore, the students are not actually learning the concept; they are only learning the pun (Nilsen & Nilsen, 2003).

Effective Strategies

There are four main principles in effective vocabulary instruction. The first

one is to use many different instructional strategies to teach the students. Teachers should not use just one method because some of the students many not be able to learn that way. The second way is to engage the student. When students are engaged they deepen their level of comprehension. The next principle is to make sure that teachers are giving students opportunities to interact with the vocabulary. Students should be able to communicate mathematically. They also need to see how the vocabulary is used in the questions. The last and most important principle is the help students connect the words to prior knowledge and to concepts (Shields, Findlan, & Portman, 2005). The most effective way to teach students mathematic vocabulary is to relate it to prior knowledge. If teachers connect the vocabulary to the concepts students already know, students will be more likely to remember the new information (Furner, Yahya, & Duffy, 2005; Lee & Hermer-Patnode, 2007;Shields, Findlan, & Portman, 2005). There are many strategies to help teachers effectively teach vocabulary.

Graphic Organizers

Graphic organizers are charts that organize words and concepts. They are usually set up the way the human brain logically organizes information (Monroe, 1998). Monroe said that "Graphic organizers have been found to be effective in helping students learn vocabulary in informational text" (p. 538).

Graphic organizers work best when they are student directed. If the graphic organizer is going to be completed by the whole class, the teacher can play the part of the facilitator. This means that the teacher should not be the leader. Another way the teacher can take herself out of being the center of learning is to form groups. Each

group can work on creating the graphic organizer (Allen, 1999; Daniels & Zemelman, 2004; Lucas & Goerss, 2007; Monroe, 1998; Vacca & Vacca, 2002).

When teachers instruct using graphic organizers, they have to keep in mind what they want students to achieve by creating the organizer. The students should understand that the vocabulary and the concepts on the organizer that they are creating should be connected to prior vocabulary words and concepts. Monroe (1998) said that "graphic organizers serve as retrieval cues for information; they also facilitate higher level thinking" (p. 538). There are many different designs of graphic organizers. Teachers should use the template that matches the concept that they are teaching.

Lucas and Goerss' (2007) study analyzed the effectiveness of composing graphic organizers as an instrument to review concepts ninth grade class. Lucas and Goerss asked eighteen teachers to choose words from a unit and asked students to create a post-graphic organizer for these words. Of the eighteen teachers that participated, seventeen said that they found the activity very useful. One teacher said that she did not think that vocabulary was that important until the students completed this exercise. When Lucas and Goerss interviewed a class of sixteen students, eleven of them found the activity very useful in understanding the vocabulary. Two said it was not helpful and the remaining three did not know if it was helpful or not. One positive outcome of this study was that the students knew the vocabulary better. Every person participated, which surprised Lucas and Goerss because the students were teenagers. This is important because and positive because if a student is engaged then they will retain the information. As a result of being engaged in the activity they

got a deeper understanding of the vocabulary.

Monroe and Omar (2002) said that graphic organizers have their limitations. To use graphic organizers the students need to have some background knowledge of a concept. Asking a student to create a graphic organizer if the student had never experienced the concept of imaginary numbers, would be pointless as the students would not even know where to start.

Games

If there is one strategy that all students love, it is playing games. Students are always asking if they can play a game and think that playing a game means that they do not have to learn that day. However, Shields, Findlan and Portman (2005) said that "vocabulary games engage students in repeated encounters with words. Interactive, visual and tactile experiences with words games provide the variety and repeated practice that result in vocabulary acquisition" (p. 38). There are a large number of games that the students will learn from as they have fun playing (Allen, 1999; Shields, Findlan, & Portman, 2005).

Most games that people play on game night can be modified to be used in a mathematics classroom. Charades and Pictionary are two examples. The teacher could create a word bank of mathematical vocabulary and play the game like the directions state (Allen, 1999; Shields, Findlan, & Portman, 2005).

Card games could also be used in mathematics classrooms. They are a good way to help students who are visual learners. Teachers could take games like Concentration, Old Maid, Rummy, or Go Fish and change them to mathematics vocabulary games. In Concentration, also known as memory, Go Fish and Old Maid

the teachers could use the mathematical symbol and the word and ask the students to match them correctly. With Rummy, the teacher could have students collect examples of all the same concept (Rubenstein & Thompson, 2002).

For both the board games and the card games, teachers could also keep adding words as the year goes on. This way students are not just getting the vocabulary that they are currently learning, but they will also be reinforcing past vocabulary words (Shields, Findlan, & Portman, 2005; Rubenstein & Thompson, 2002).

Fake-Out is another game that can be used in a classroom. In this game teachers would organize the students into groups. Teachers could group students by ability or by preference. Once the students are in their groups each group receives a different vocabulary words. The students are to look up the definition of the word and create a fake-out vocabulary card. This card has the word and has a list of possible choices. The point is to try and stump the other teams (Stahl & Nagy, 2006). There are positive and negative aspects about this game. The positive aspect is that the students are actually thinking about the vocabulary words. However, each group is only having an in-depth look at a few words.

In Bingo the students arrange 20 or 25 of their vocabulary words into a blank grid. Then the teacher reads definitions of the words. The definitions are on cards to make it easy for the teacher to be unbiased and to be able to check the answers. This game is very fun for the students and if they do not know the vocabulary, then they will not be able to win a prize (Stahl & Nagy, 2006).

Morphology

Morphology is the study of origins. It takes the words and splits them up into

parts which include root words, prefixes, and suffixes. If the students understand the Greek and Latin root words and the different prefixes and suffixes, then they will have the ability to enhance their vocabulary development in all content areas (Shields, Findlan, & Portman, 2005). Thompson and Rubenstein (2000) said that teaching the students the origin of words builds bridges between everyday language and mathematical language.

When teachers are familiar with the origin of a word, they should introduce the word and its origin. If the teacher is not familiar with the origin of the word, they should encourage students to look into the history of the word. It might seem like a waste of time to explain to students the different parts of a word. But once they know the different parts they might be able to figure out the meaning of the vocabulary words in the future (Shields, Findlan, & Portman, 2005; Thompson & Rubenstein, 2000; Rubenstein & Thompson, 2002; Kucan, Trathen, & Straits, 2007).

Writing Mathematics

There are many ways to use writing in a mathematics class. When students are writing in content area, they are communicating with the content language and they are also improving their depth of understanding ((Daniels & Zemelman, 2004).

Thompson and Rubenstein (2000) said that journal writing is one way to get students to communicate mathematically. They suggested that students keep a mathematics journal that the students could use to correct mathematical terms while writing and they can ask questions and get answers to the questions that they had that day in class (Thompson & Rubenstein, 2000).

According to Donna Hash (Kucan, Trathen, & Straits, 2007), a teacher with

15 years of experience, asks her students to write poems and songs and raps. Usually, she asks her students to work with a partner to create a poem related to a mathematics vocabulary word. One of her examples was about supplementary and complementary angles. The poem was about what they have in common and how they are different (Kucan, Trathen, & Straits, 2007).

Another way teachers can incorporate writing and vocabulary is when student are problem solving. When students are solving problems at home they should fold their paper in half. On the left of the paper they will solve the problem and on the right side they will explain in mathematical terms what they were thinking as they were solving the problem. Students will complain that it will take too long, but they will agree that it helps with their understanding (Thompson & Rubenstein, 2000).

Having students create mathematical cartoons will also deepen their understanding of mathematics. Making cartoons will help the students who struggle with written or verbal strategies. The visual and artistic prospects help students succeed in a different and new way. Teachers could also use this strategy as an assessment tool, to measure if students understand what the vocabulary word means (Thompson & Rubenstein, 2000).

An easy strategy is called a word wall or mathematical graffiti. These are papers or posters that have the word, the definition or a picture and how they are used. These should be made by the students and displayed for other students to from which to learn. Most of the time the word walls are very organized; whereas, the mathematical graffiti is more decorative and not in a particular order (Kucan, Trathen, & Straits, 2007; Rubenstein & Thompson, 2002).

Tips to Remember for Teaching Vocabulary

Researchers suggested that teachers should be enthusiastic about teaching new vocabulary. Shanklin (2007) said "Adolescents vocabulary learning is enhanced by teaching enthusiasm about language and word learning" (p 52). If teachers show their interest about words and learning what they mean, then the student will have the same interest. Teachers should show the students how to figure out what a word means and how to find what words have in common. Then the students will know what to do when they are stuck on a word (Shanklin, 2007).

A second suggestion for teachers or students was to read content area literature. Ohanian (2006) said "Children acquire vocabulary by reading and being read to" (p. 12). She also said that most vocabulary that students learn is through reading. Ohanian said that students learn ten times more efficiently when they experience new words in reading, rather than by direct instruction.

A third idea is to have students talk to each other using the vocabulary they are being taught. Nilsen and Nilsen (2003) said that "Language is a social phenomenon" (p. 31). This means that the students need to interact with others; they need to speak the words and they need to hear the words pronounced. Teachers should make sure that the students are using the correct vocabulary to help themselves learn the meaning of words.

Teachers should teach vocabulary but not stress vocabulary. Lee and Hermer-Patnode (2007) said that teachers need to be careful how much emphasis they put on vocabulary. They need to make sure that students do not think that learning the vocabulary is the same as learning mathematics. Vocabulary is only one part of

mathematics. It is an important part but only one part.

Also, teachers should be careful introducing new words. If there is a word that is being introduced for which the students have no prior knowledge, the teacher needs to be very precise. The teacher should make certain that the word is spoken, written, spelled and illustrated clearly. If a student incorrectly hears a new word or an incorrect definition for a word, it is very hard to undo what the mind has heard. Also, when the students use the vocabulary incorrectly the teacher should stop and restate the words so the vocabulary is used correctly (Lee & Hermer-Patnode, 2007) (Rubenstein & Thompson, 2002).

Use a variety of strategies is important. Burns (2006) said that "The National Reading Panel concluded that there is no one best method for teaching vocabulary. Rather, teachers need to use a variety of methods for the best results" (p. 41). Teachers need to make sure that they do not get in the habit of only using one strategy, because most students do not learn the same way (Burns, 2006; Lee & Hermer-Patnode, 2007).

Summary

It is obvious that vocabulary is the key to communication. Mathematical vocabulary is the secret to mathematical thinking and student success. Research leads us to believe that teachers should be focusing on vocabulary in content areas. There are also plenty of strategies for teachers to try to see what works for them and for their students. Teachers should start teaching students vocabulary at a young age. As the students continue in their schooling, teachers should keep reinforcing vocabulary as well as, teaching new vocabulary correctly. This process will insure that students

will become not only great at standardized tests but also in communicating in life.

Methodology

Designing lessons, choosing strategies, establishing the students, and collecting data were all incorporated to determine whether teaching student vocabulary improves their vocabulary. In order for students to understand mathematics vocabulary there were two methods that were researched in mathematics classrooms. Playing vocabulary games and writing mathematically help the students create a superior understanding of the vocabulary. These two strategies also give the teachers a chance to see what the students understood and what they need more practice on. This study will focus on whether or not focusing on vocabulary in a math classroom is worth a teacher's time.

Participants

In the suburbs of Western New York, there was a small all girls' private Catholic high school. This school had students from thirty four local public school districts. There were 646 students in grades seven thought twelve. One percent of the students were Native American, three percent Asian, three percent Hispanic or Latino, eight percent African American, and eighty five percent Caucasian. Within the 646 students the school had eight students that English was their second language, and there less were than 10% of the students on welfare. About four percents of the students were in need of extra assistance, they had either a 504 plan or an IEP.

These students were required to take and pass four years of Mathematics, three years of Science, four years of English and Language Arts, and four years of History classes. The student's classes were randomly grouped with students of all races, financial, and educational background. Many of the students come from high-

income families. These parents wanted their daughters to have a good catholic education. There were some of the parents that sacrificed to send their children to this school, and there were other students that were at the school by a sponsor.

There were 100 students in the Geometry class, who participated in the study about mathematics vocabulary. These students were a mix of freshman and sophomores. The freshmen were advance students taking a 10^{th} grade class in 9^{th} grade. The sophomores were taking the class that the state thinks they should be in as 10^{th} graders. Geometry is a New York State regent's class. The students had to take a standardized test called a regents' exam at the end of the school year. This class extended the topics geometry that the students learned in the previous year. They also were introduced to locus, circle and Euclidean proofs. The ability to produce a formal proof was developed.

In the attempt to reduce bias in the data results the 100 students are split into two different groups. There were two classes in each group. In each group there were the same number of freshman and the same number of sophomores. There were also the same numbers of minorities in each group, and there was a student that spoke English as a second language in each group. Since, the school was all girls the bias of girls versus boys was not an issue.

Procedure

Since, the participants were taking a geometry class, which main focus was learning how to write a formal proof. It is very important for the students to be able to express their ideas of geometry and their thought process. One of the main aspects of writing proofs is to know the vocabulary and the postulates. Vocabulary games gave

these students an extra exposure to the vocabulary that they needed to know. Journal writing also gave the students another chance to know if they really understand the vocabulary.

Every night the students had a journal topic to write about. A class discussion was used to introduce the journals to the class. The class discussed that even thought they were in a mathematics class they still needed to be able to write in class. They were told that the journals had to be writing in mathematics language. The students were informed that they were to respond to the question in two or three complete sentences. The students wrote their journal entry either at the top or the end of their homework. The teacher collected the homework and read and commented on the journal entries.

The one hundred students that participated were split into two groups. The control group, group B was taught by traditional teaching methods. The control group did all the same problems and proofs as group A, however, group A was taught using vocabulary games.

Finding time to play games in a regent level class was very difficult. In group A, the students played a vocabulary game every other day. The teacher decided that it would be best if she pick two or three games and played them over again. This would reduce the direction time in class. The teacher selected Bingo, Around the World, and Go Fish for her three games. After many days of planning the teacher had three games ready to go.

The teacher took the last fifteen minutes of class and played one of the three games with her students. When the class played Bingo the students had a Bingo

Board (see Appendix A), the night before they had to put in the vocabulary words. The teacher read off the definition of a vocabulary words from index cards and the students would make off the word that they thought matches the definition. When the first person thinks she had Bingo, she would get a prize. If there was time they would play another game.

When the class played Around the World, it was like elementary school students did when they were learning arithmetic. One student would go against the student next to them. The teacher would have cards of vocabulary words, and then they would make a noise to say they knew the definitions. If they got the definition correct then they would go to the next person. They continued this until the bell rang.

Go Fish was one of the games that took the most time to prepare. The teacher created 6 decks of cards. Within these cards half of them would be vocabulary words and the other half would be the definition. There are a couple of examples in Appendix B. The class would split up into groups of 4 or 5. They would then use the cards as if they were playing Go Fish. The winner of each table would get candy.

The purpose of choosing these three games was to give the students experience with the vocabulary in three different ways. In Bingo they heard the definition and had to know the vocabulary word, in Around the World they saw the word and had to come up with the definition, and in Go Fish they were matching the vocabulary word with the definition. Group A worked with these three games for three weeks.

Data Collection

One way that data was collected was through the journals. All students in

group A and group B participated in the journal writing. The teacher evaluated these journals on two objectives. The first objective was to see if the students understood the vocabulary that was being taught in class. The other objective was to determine if the students were communicating mathematically. During the few days of the students handing in their journal entries the teacher created a baseline for what the students understand and how well they were communicating mathematically. Then over the next few weeks they would be evaluated to see if their understanding and communication improved, remains the same, or decreased.

Vocabulary games were used in Group A to enhance the student understanding of mathematics and geometry. Both groups took the same quizzes, chapter tests and midterm. The students ended up taking two tests during the length of the research, one of these test was the midterm. The scores were compared to see what group performed better. The scores of Group A were also compared to the grades from past test to see if they improved, stayed the same, or decreased. The student's errors on writing proof were analyzed to see if they got the question wrong because they did not know the vocabulary or if it was another misconception.

Results

The students in Group A played vocabulary games for three weeks. These games consisted of Go Fish, Bingo, and Around the World. These students would play these games at the end of the period every other day. Most of the student in group A really enjoyed playing the vocabulary games. The students got really excited when the games were introduced. The students in group B were angry and upset that they did not get to play games in class. The teacher promised them that they would get to play games in the future.

One the first days that the games were introduced it took some time to get the students to focus and understand how to play. They were too excited to pay attention. But once the students calmed down and focused it went smoothly. The first few times playing each game the students were being very competitive, so that they would receive the prize which was candy. But after awhile the students started to help each other and it was more learning than competition. Once they started to help each other the students that won the prize were different, and sometime they were the students that really struggled in class.

In discussions that the teacher had with the students, she found that the students thought these games were very helpful. A lot of the students said that they liked the games because they were fun, and it did not feel like they were in a typical math classroom. There were a few student that told the teacher that they really thought they had a better understanding of vocabulary after they played the games a few times. Then there were a few students said that they had to study the vocabulary words at night so they knew them for class, and that is what really helped them with

learning the vocabulary.

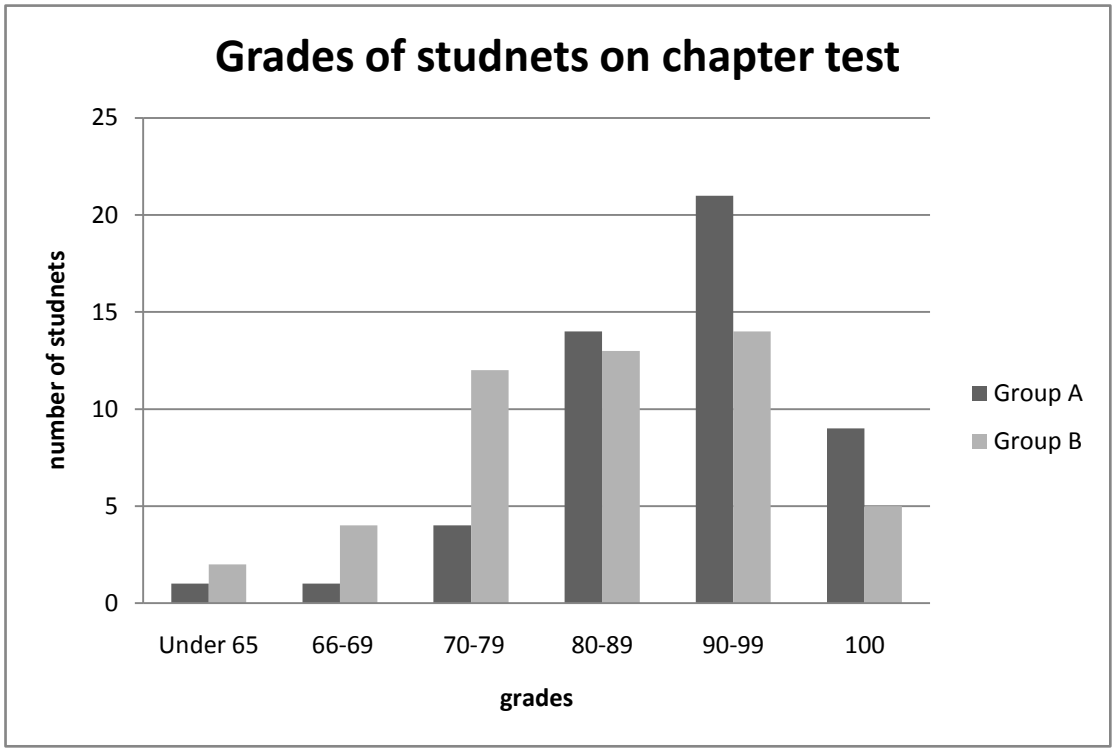
The students played these games for about two weeks. The teacher strived for every other day but sometimes they were played more often if there was time, when there was only two minutes left in class the students begged the teacher to play a short game, such as around the world. After the two weeks the students were tested on the chapter. The test can be found in Appendix C. This chapter was about proving triangles congruent and it focused on a lot of vocabulary. The vocabulary that the chapter focused on was altitude, median, and angle bisector. These were vocabulary words that geometry students get messed up on. In figure 1 is the results from that test. In group A, there where students that struggled with the test and did not get as high of a grade that the teacher would have anticipated. However, the overall average in group A was 90 percent and the overall average in group B was 84 percent. This means that group A outperformed group B.

When the teacher looked at individual papers and how they answered the questions; she found some differences in the student's mistakes. For question number four, the student really needed to know the difference in the meaning of median, altitude, and angle bisector. 93 percent of the student in group A got this question right, and only 89 percent of the students in group B got this question right. Another question that there were differences was in number seven, which the students had to do a two-column proof about a median and an altitude. The result for this question was similar to question four.

The teacher implemented these games into the review for the final. They would spend 75 percent of the class going over questions, and the last 25 percent of

Figure 1

Test results for chapter test



the class playing these games. The vocabulary list that was used was all the vocabulary for the first half of the year. There is a list of the vocabulary words in Appendix D. The teacher heard rumors that when the students from group A and B were studying at home they were playing games. The students were really focused on learning this vocabulary during the review days. The teacher observed that group A was using the vocabulary words when they were asking questions, where as group B was still giving examples, or asking for a question like the one in the book. After seven days of review, the students took their midterm.

The results of the midterm were similar to the chapter test. The student in group A had an average of 87 percent were the students in group B had an average of 80 percent. This meant that the average in group A outperformed group B by seven percent. The results can be found in figure two.

The teacher looked carefully at the students test to see if there were any differences. The midterm that was used can be found in Appendix E. There were a lot of questions that relayed on vocabulary. In table one, the researcher took each question that involved vocabulary and figured out the percentages that got it right from group A and group B. It is clear that the group A understood and could use the vocabulary on the midterm better than those students that were in group B. When the teacher looked at the students in group A that got part II and III questions wrong she noticed that students understood the vocabulary word, but made an algebraic mistake. Such as in question 24, most of the students in group A set up their equation to equal

Figure 2

Test Results for Midterm

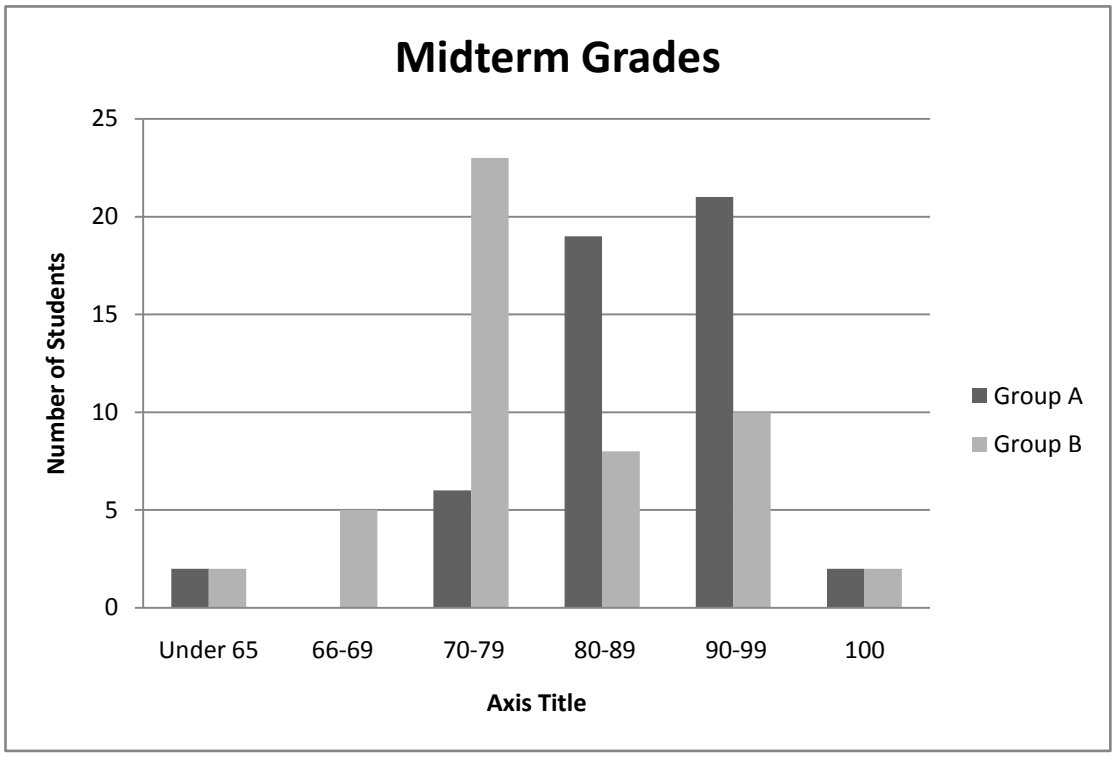


Table 1

Percentage of students to get question right in part one of the midterm

Question	Vocabulary word(s)	Group A	Group B
1	all types of triangles	92	88
4	Isosceles triangle theorem	71	55
5	isometry	88	84
6	equilateral, bisectors	83	79
7	Logically equivalent	54	50
8	indirect proof	96	66
9	congruent, complementary, supplementary, vertical	96	82
13	isosceles triangle, equilateral triangle	79	63
14	negation	100	100
15	perpendicular bisector	96	89
16	median, altitude, bisector	88	82
18	midpoint	96	95
19	perimeter, types of triangles	98	82
20	reflection	88	71
21	all properties	93	81
22	supplementary	96	89
23	acute angle, right triangle	96	85
24	triangle	94	79
25	transformations, rotation, reflection	88	84
26	converse, inverse, contrapostitive	83	78

degrees and then they would add wrong or divide wrong. Where as in group B, some students made an error with adding and dividing, but about half of the students that got the question wrong set their equation to 360 degrees. These students did not know that the angles of a triangle add up to be 180 degrees. Also, the students in group B did not know that a right triangle has a 90 degree angle. Whereas the student in group A knew that there was a 90 degree angle and set up the equation correctly, they just added two and four and got seven.

During the three and a half weeks that the students in group A were playing games, all the students in group A and group B were writing journals almost every day. Some of these questions were asked from question out of the book and other was questions that the teacher created. On the day before the students started to play the games, the students were asked do you think that vocabulary is important in math class. A variety of their answers can be found in table 2. After a few days of playing games the student were asked the same questions, the student answers for that question are in table 3. Group A seemed to think that vocabulary is more important after a few weeks of playing games. The day before the midterm the students were asked if they were happy with their understanding of vocabulary and if they thought it would help them on the midterm. Most of the students that were in group A felt that they had a good understand of the vocabulary that that it would help them on the midterm. The students that said that they did not feel good about their knowledge of the vocabulary did not do as well as the students that were happy about their ability. About a week after the midterm, the teacher had stopped playing the games to see what would happen. The teacher then asked the students to write down

Table 2

Students response to “Do you think that vocabulary is important in math class?” before games

Students	Students Response
Student A	No, because it’s math Why would I need to know vocabulary? It’s not English class!
Student B	No, Because I’ve always considered Math a subject consisting of numbers, not words for definitions.
Student C	I didn’t think vocabulary was very important in math class because I always associated math with numbers.
Student D	Yes, I thought it was important. If you know what certain vocabulary means, then you’ll be able to solve a problem that you couldn’t have otherwise. I thought it was important, but we didn’t need to use it very much or study it.
Student E	No because math is numbers and vocabulary is annoying and for English.
Student F	I think that knowing vocabulary for math class is very important, because without knowing what things mean, you won’t be able to solve the equation or get the right answer.
Student G	No, because you didn’t really use it in Algebra, it was more formulas and equations.
Student H	Absolutely not! I thought vocabulary is just for English class.

Table 3

Students response to “Do you think that vocabulary is important in math class?” before games

Students	Student Response
Student H	Yes, because in every problem there’s a vocabulary word. In order to finish the problem, you need to know the definition, especially on proofs. (Group A)
Student I	I think it is very important to know the vocabulary in this class because you have to know the definitions in order to do a lot of the proofs right. (Group A)
Student J	Yes, When it comes to solving geometric equations it is always helpful to know what type of object and angles and lines you are working with. (Group A)
Student K	Yes, I think it is important now in math. Without knowing it, it’d be impossible to finish some proofs.(Group A)
Student L	Yes, definitely! Proofs would be impossible without vocabulary. (Group B)
Student M	Yes, I do think vocabulary is important in math class now. (Group B)
Student N	Because it helps a lot with what we are doing in class including proofs. (Group B)
Student O	Most likely, but I dislike it a lot. (Group B)

what the definition of an altitude was. The students that were in group A seemed to retain the information better then the students in group B. 86 percent of the students in group A had the definition correct where only 72 percent of the students in group B had the definition correct. In table 4, are some of the responses that the student had for this question. It is clear that the students in group A are more confident and complete in their answers then the students in group B.

The teacher observed a lot of differences between group A and group B. It seemed that the students in group A communicated with the teacher and with each other more efficiently then the students in group B. The students in group A used correct vocabulary and complete definitions when they were talking. The students in group B only gave general idea as the definitions and often used the incorrect vocabulary word. The teacher or other classmates would correct them but it did not seem like the students really learned the correct definition.

Table 4

Student's response to "What is the definition of an 'altitude'?"

Students	Students Response
Student A	Altitude is a line segment that is drawn from a vertex, perpendicular to the opposite side. (Group A)
Student B	A line from the vertex of a triangle perpendicular to the opposite side. (Group A)
Student C	The altitude is perpendicular from the vertex of a triangle to the opposite base. (Group A)
Student D	Altitude is the height, and it is drawn perpendicularly to a figure's base. (Group A)
Student E	The base to the highest point of a triangle. (Group B)
Student F	Altitude is a line that cuts and angle. (Group B)
Student G	A line drawn from the vertex of a triangle to the base. (Group B)
Student H	A line segment of a triangle perpendicular to a base. (Group B)

Discussion

During the three weeks that the students were playing the vocabulary games, they did become more aware of the vocabulary words. Most of the students knew most if not all the vocabulary that was asked of them.

The research discussed that many teacher do not teach vocabulary because it is very time consuming. The teacher that had the students played games every other day agreed. It took many hours to create the flashcard for the bingo game and the around the world game. It even took longer to create the go fish game that the students played. That was just the teacher's personal time. The time that it took in class was also a lot of time. The teacher had to explain the games and it took time to play the games. The students in the game group usually got less instruction and class practice with problems then the group that did not play games. However, the group that played games still had higher averages. So, the teacher also agrees with the researchers that it takes time to teach and practice vocabulary but it seemed that it did help the students.

The test grades of the students also made the point that there are efficient and inefficient ways of teaching and practicing vocabulary. In group B the students were given all the vocabulary words and were told that they needed to know the definition by the time the test came around and they would need to know the vocabulary for all of the other chapters that they have done by the time they take the midterm. The students in that group that are proactive went and found all the definitions and studies the words. That was only about 10 percent of the student in that group. The rest of them put the list away and most likely did not look at it again. The students in group

A also got the list, but they also got the reinforcement of the vocabulary words because they played the vocabulary games. Some of the students in group A, said to the teacher that they have to study the definitions because they want to do well in the games. The students in group A learned and retained the vocabulary better then the student in group B. Therefore, it seems that playing the vocabulary games was a more efficient way of teaching vocabulary. The student also enjoyed playing the vocabulary games.

One of the researchers said that student learn better is they are engaged (Shields, Findlan, & Portman, 2005). Playing games are very engaged and the students that were playing were very engaged. They wanted to win; therefore they had to learn the words. Playing the vocabulary got them to communicate and interact with the vocabulary. When the students were playing games they were very engaged and they did end up learning the vocabulary, the test grade showed this.

The research said that there is a connection between vocabulary knowledge and reading comprehension (Lucas & Goerss, 2007; Monroe & Orme, 2002; Vacca & Vacca, 2002). The teacher agrees with this, she found that the students that played the vocabulary games answered the test questions better then the students that did not play the vocabulary games. The teacher suspects this is because the student in group B did not know what the questions were asking because they did not know the correct and complete definition of the vocabulary word or words in the question. The control group did between seven and eight percent lower on the test then the group that focused on learning and retaining vocabulary.

The idea of higher level thinking is every teacher's goal; the researchers said

that with the meaning of words they will not be able to use that higher level thinking. The high level thinking that the students in these classes were doing was geometric proofs. The students that learned the vocabulary by playing games could complete the proofs with more ease then those students in group B. When asked if they thought that vocabulary helps complete the proofs, the students said that if they had a better understanding of vocabulary it would make the proofs easier. The students in group A agreed that when their understanding of vocabulary increase the proofs seemed easier.

Another part of high level thinking is to get the students to think of school as a subject not just math, English, social studies and science. We want to mix them up and make sure that students do not think of math as just math or chemistry as just chemistry. When the teacher told her students that they were going to work on vocabulary, the student wined and said that vocabulary was for English class. They wanted to know why they had to learn vocabulary in math class. They soon found out that they do need vocabulary in math and it would help them with the problems. The teacher also had one student tell them that they used the idea of writing proofs when they wrote a paper in their history class. She had to write a paper and back up her ideas. She said that it reminded her of writing a proof because you always need to back up your statements.

The research said that mathematics vocabulary is very difficult to teach because the student only used the vocabulary in the mathematics classroom (Shields, Findlan, & Portman, 2005). This is true, in the fact that there are some words that are only directed to the mathematics content. But, the teacher had the students think about other words that were similar or words that had the same prefix, suffix or root

word. The students did find some connection between words in mathematics and words that they used in other classes. They also listened in other classes to see if they heard any words that sounded like the ones that they learned in math class. Along the same lines, the students found more than one word that meant a few different things. They learned that they had to see the vocabulary word in context to know which definition the word goes with.

Another hard part of teaching vocabulary is how many vocabulary words that the students need to know. In geometry there are about 160 words that a student needs to know at midterms. This is very hard for the students, especially if the student has not learned the actually word.

Some of the researchers said that there are four principles to teach vocabulary effectively. These principles are to use different strategies, engaging the students, interacting with the vocabulary, and to connect the new vocabulary to prior knowledge (Furner, Yahya, & Duffy, 2005; Lee & Hermer-Patnode, 2007;Shields, Findlan, & Portman, 2005). The teacher decided that she was going to play three different games with the students; this goes alone with the principles because she was using different types of games to give the students different ways to interact with the vocabulary. The games of course engaged the students; it was a surprise to the students and to the teachers when they realized how much the students got out of playing the games. The students really learned the vocabulary and retained it for a lot longer than the students in group B, which just got a list of the words. The third principle was to have the students use the vocabulary in class. The teacher found that this came with the students learning the vocabulary. Once the students learned the

vocabulary they started using it in their questions and their writing. The teacher notices that the student in group B used the vocabulary when prompted by the teacher but they were not as comfortable about using the vocabulary as group A. The last principle is that the teacher should relate the new information or vocabulary to the student's prior knowledge. The teacher made sure every time she introduced a new word, she would ask her students what they thought it was before she told them. This way they would look at the prefix, or suffix and make connections. The teacher seemed to think that these four principles made a lot of since, and decided that she thought they were very important for her students to learn vocabulary efficiently.

Conclusion

It appears that this research was successful in the geometry class. The student that were group A seemed to improve their understanding of the vocabulary. Communication between the students and the teacher was improved. However, more time would be needed to see if the vocabulary games really enhanced the student's mathematics skills.

A teacher's job is to prepare the student for their life and to make sure that they learn to their full potential. Teacher need to find ways to help the students reach their full potential. Teaching vocabulary seems to help to improve their success.

This research only looked at playing games in a mathematical classroom. The idea of vocabulary in other subject or the ideas of other effective strategies are left in the hands of future researchers. If things were done differently, the researcher would split the group up into four groups instead of two groups. Then they would play the games with one of the classes, but do other strategies with other classes. Such as use graphic organizers in one class and look at the development of vocabulary with the other class. This way the researchers would not only determine if teaching vocabulary is worth their time, but which way of teaching vocabulary helps the students the most.

This research indicates that teaching student's vocabulary is definitely worth the teacher's time. The students that had vocabulary reinforcement had higher averages than the students that did not get the reinforcement. The teacher also observed that those students seemed to be able to think more critically and communicate better.

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Appendix A

Bingo Board

Vocabulary Bingo

Appendix B

Example of Go Fish Cards

Altitude	A line segment (or its length) drawn from a vertex perpendicular to the line containing the opposite side.
Addition Postulate	If equal quantities are added to equal quantities then their sums are equal.

Appendix C

Chapter Test on Congruent Triangles

Appendix F

Vocabulary List for First Half of the Year

absolute value
Acute Angle
Acute Triangle
Additive Identity
Additive Inverse
Angle
Associative Property of Addition
Associative Property of Multiplication
Base Angles
Bases
betweeness
Bisector of a Line Segment
Bisector of an Angle
Closure Property of Addition
Closure Property of Multiplication
collinear set of points
Commutative Property of Addition
Commutative Property of Multiplication
Congruent Angles
Congruent Segments
Coordinate
Definition
Degree
distance from a point to a line
Distributive Property
Equiangular Triangle
Equilateral Triangle
Exterior of the Angle
Statement/Closed Sentence
Tree Diagram
Truth Table
Truth Value
Valid Argument
Addition Postulate
Axiom
Conjectures
Counterexample
Deductive Reasoning
Direct Proof
Division Postulate
Equivalence Relation
Generalization
Indirect Proof/Proof by Contradiction
Inductive Reasoning
Multiplication Postulate
Partition Postulate
Postulate
Powers Postulate
Reflexive Property of Equality
Roots Postulate
Substitution
Subtraction Postulate
Symmetric Property of Equality
Theorem
Transitive Property of Equality
Adjacent Angles

Geometry
Half-Line/Ray
Hypotenuse
Interior of the Angle
Isosceles Triangle
Legs
Line Segment
Line
Midpoint
Multiplication Property of Zero
Multiplicative Identity
Multiplicative Inverses
non-collinear set of points
Number Line
Obtuse Angle
Obtuse Triangle
Opposite Rays
Perpendicular Lines
Point
Polygon
Right Angle
Right Triangles
Scalene Triangle
Set
Straight Angle
Straight Line
the Distance from a Point to a Line
Triangle
Undefined Terms
Vertex Angle
Vertex
ASA Triangle Congruence
Complementary Angles
Congruent Polygons
Corresponding Angles
Corresponding Sides
Linear Pair of Angles
SAS triangle congruence
SSS Triangle Congruence
Supplementary Angles
Vertical angles
Altitude of a Triangle
Angle Bisector
Circumcenter
Concurrent
Corollary
Equidistant
Geometric Construction
Median of a Triangle
Perpendicular Bisector of a Line Segment
Abscissa
Axis of Symmetry
Composition of Transformations
Coordinate Plane
Dilation
Direct Isometry
Fixed Points
Function
Glide Reflection
Image
Isometry
Line Reflection

Biconditional
Compound Sentences
Conclusion
Conditional
Conjunction
Contrapositive
Converse
Disjunction
Domain
Exclusive
Hypothesis
Inclusive
Inverse
Law of Disjunctive
Laws of Detachment
Logic
Logical Equivalents
Mathematical Sentences
Negation
Open Sentences
Phrase
Premises
Solution Set/Truth Set:
Line Symmetry
Opposite Isometry
Ordered Pair
Ordinate
Orientation
Origin
Point Symmetry
Preimage
Quarter Turn
Range
Rotation Symmetry
Rotation
Transformation
Translation Symmetry
Translation
X-axis
Y-axis
Adjacent Interior Angele
Exterior Angles of a Polygon
Remote Interior Angles/Non-Adjacent
Transitive Property
Triangle Inequality Theorem
Trinchotomy Postulate

Appendix E

Geometry Midterm